COMPACTION OF EMBANKMENTS, SUBGRADE TREATMENTS AND SOIL STABILIZATION[1]

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The American Association of State Highway Officials has set up a standard method which describes in detail the steps necessary to obtain the moisture density relationship for soils

This method has been adopted by a large number of State highway departments without variation, as standard for determination of the weight per cubic foot for soil in place in embankments Kansas and California report departures from this procedure Kansas uses an 18-in drop of the standard hammer and requires that the soil be placed in the mold in four lifts instead of three when the plasticity index of the soil exceeds 25.

California compacts the soil sample under a static load of 2000 lb per sq. in or uses a mold $2\frac{7}{8}$ in in diameter and a sample thickness of approximately 10 in The compaction hammer weighs 10 lb and is dropped 20 times on each of five layers of soil The California report indicates that a moisture-density curve was not plotted, but that the proper quantity of moisture was determined by the appearance of the soil.

The purpose of the tests for finding the optimum moisture content and maximum density is to determine the characteristics of the soil which will be productive of the least settlement or volume change in the embankment after it is in place After the moisture density relation has been found and a conclusion has been reached as to the optimum moisture and maximum density, the soil materials must be placed accordingly Construction procedures for the accomplishment of this vary but little throughout the United States.

When the addition of water is necessary, it is accomplished by irrigating borrow pits, or by sprinkling the soil on the fill by means of pipe lines and hose-nozzle connections, or by tank wagons and sprinklers. If the soil is moistened after delivery it is necessary to mix it by means of blades, harrows, discs, etc. The reports indicate that tank wagons and sprinklers are used most widely because more uniform moisture distribution can be obtained, especially in heavy soils

Roller equipment does not seem to vary much There is a general trend toward heavier equipment and lower moisture content to accomplish the desired results Most specifications provide for the use of both smooth face and tamping rollers The latter type are used in the majority of the work. The minimum pressure per square inch under the feet of tamping rollers varies from 50 lb , specified by the California Division of Highways to 270 lb , specified by the Bureau of Reclamation The Bureau of Reclamation reports special rollers which will furnish compacting pressures from 270 to 675 lb per sq in. The use of such rollers may bring about higher densities at lower optimum moisture contents which are indicated by increasing the number of blows of the hammer in the compaction test

The Reclamation Service also reports that very little increase in density is obtained in average soils by more than 12 trips of the roller regardless of the weight It follows, therefore, that if

[1] A digest of the reports presented at the Eighteenth Annual Meeting (1938) of the Highway Research Board The complete reports will be found in Part II, Vol 18, Proceedings, Highway Research Board

the same or higher densities are to be obtained at lower moisture contents, the weight of the rolling equipment must be increased

After the soil has been rolled in place, it is necessary to check the density and moisture content. The Proctor needle is useful in checking these values If the Proctor needle is used it is necessary to plot a penetration resistance moisture curve at the time the data for the compaction curve is obtained The moisture content is then obtained by compacting two layers of the soil taken from the fill in the mold and obtaining the resistance to penetration Comparison of the readings taken in the field with values from laboratory curves indicates the moisture content The needle may also be used to check the density of the soil in place The sand method, which consists of removing a quantity of soil from the fill with a posthole augur, weighing the soil carefully and finding the volume of the soil removed by filling the hole with dry sand of known weight per cubic foot, is most commonly used to check the density of compacted earth

The results of many compaction tests made in Ohio and Kansas indicate that all curves have characteristic shape. The sandy soils, having the higher weights per cubic foot, have steep slopes and the maximum compaction is obtained with relatively low moisture contents The clay soils on the other hand give curves with much flatter slopes and have relatively high moisture contents at maximum densities Ohio has found it of practical value to compile all of the compaction data obtained in the State during each construction season and to plot a series of compaction curves from the data so obtained. The maximum dry weight per cubic foot values are divided into intervals of 5 lb , all samples in each 5-lb. interval are averaged and one curve drawn from these averages to represent all curves for the interval

The result is a series of curves which may be used during the early stages of construction where it has not been possible to obtain samples for the preparation of compaction curves The proper curve for use with the type of soil in question is chosen by the correlation of the penetration resistance, the weight per cubic foot and the moisture content. The method is offered as a temporary measure until complete data can be obtained from samples taken from the embankment soils

Recognition is made of poor foundation conditions and while this cannot be corrected by compaction of the fill, provision is made for conditioning the layer upon which the fill is started It is required that the surface be scarified and recompacted to maximum density before the placing of the embankment is started

Since most of the projects on which the compaction methods described above have been used have been in service only a short time, information indicating the success of the procedure in reducing the settlement or detrimental volume change of embankments is not available However, the California Highway Department reports that very little settlement has occurred on projects built in 1929 under controlled conditions

The compaction of embankments is tied very closely to the preparation of subgrades since the objective of both operations is to provide a foundation for pavements which will have maximum bearing capacity and will be subject to minimum changes due to the action of the elements The selection of nonexpansive soils for use in the finished subgrade is the simplest and perhaps the most effective subgrade treatment Such soils are usually located in the soils survey which should be made a part of the plans on every highway project

If nonexpansive soils are not available on the project, it becomes necessary to

change the characteristics of the existing soil or to replace it with nonexpansive materials from borrow pits, screening piles, or other available waste materials

The characteristics of the soil may be changed by mixing the existing soil with granular material or other admixtures such as portland cement Since the soils to be treated in most instances are heavy expansive clays, difficult to break down, without considerable expense, to sizes which will mix with sand or cement, the procedure is not used very extensively

When granular or other nonexpansive material is used the depth of treatment must be designated California arrives at the depth of granular material necessary by means of swell and bearing tests on available materials The maximum total depth of acceptable subgrade material and surfacing is 18 in

New Hampshire reports that as much as 4 ft of granular material is used in some locations Other States report depths of treatment from 9 to 12 in

Nebraska, Texas, and California report that the compaction of soil to maximum density at optimum moisture content is a satisfactory subgrade treatment provided the moisture can be retained Texas and California advocate the protection of subgrades with impervious coverings to retain the moisture Texas places a bituminous membrane from shoulder slope to shoulder slope at the bottom of the pavement and covers it with a light covering of sand California uses the same procedure except that the bituminous membrane is covered with 9 to 12 in of nonexpansive material when available Results reported by Kansas indicate that the use of a membrane or other protective treatment is not necessary to retain the moisture in the soil after it has been compacted to maximum density Texas reports excessive shrinkage and subsequent swell on heavy clay subgrades which were placed when the soil moisture was equal to or greater than the field moisture equivalent at the time of the concreting and when no effort was made to increase the density of the soil

Texas, California and Nebraska report that pervious materials used as base courses should be carried to the shoulder slope in order to prevent the trapping of water under the pavement In other words the use of the trench method of construction should be avoided

Stabilization of base and surface courses is divided into four main divisions as follows

1 Soil Stabilized Aggregate Mixtures
2 Soil Stabilized Aggregate Mixtures plus Chemical Admixtures
3 Soil-Bituminous Mixtures
4 Soil-Cement Mixtures

The specifications for materials for soil stabilized aggregate mixtures for base and surface courses have been standardized through the efforts of State highway departments and the Bureau of Public Roads Such specifications include the gradation from the maximum size to the material passing the No 200 sieve, the liquid limit and plasticity index and have been adopted as standard by the American Association of State Highway Officials These specifications are intended for use with materials of average characteristics Notable exceptions are such materials as topsoil, pebble soil, sand-clay, etc , which occur in the southeastern section of the United States, especially in the States of Alabama, Georgia, North Carolina, and South Carolina Georgia reports the use of all these materials under a grading specification without regard to plasticity requirements North Carolina, on the other hand, has set up specifications which require lower plasticity indexes than those specified in the American Association of State Highway Officials specifications The most significant trend in the materials specifications for

base courses is the lowering of the plasticity index requirements and the narrowing of the range used. For example, Missouri is of the opinion that a maximum plasticity index of 4 is satisfactory and Indiana specifies 1 5 to 4 5 for gravel or 0 to 3 for limestone

The construction methods in this type of stabilized road consist of proportioning and mixing the materials, spreading, wetting and compacting The mixing of the materials is accomplished by the road-mix method and by means of traveling or stationary plants The compaction is done with smooth face or multiple tire rollers and is checked by some modification of the standard compaction tests.

For control of materials most States depend upon the sieve analysis and a wash test made in the field Pennsylvania has developed apparatus which consists of a metal hydrometer and soil container, scales and pans by means of which the material passing the No 270 sieve can be determined accurately enough in the field for control purposes

The use of chemical admixtures is divided into three parts as based on the method of application of the salt,—(1) Dust control, (2) surface consolidation, (3) integral mixtures The dust control consists of the surface application of calcium chloride to the surface and results in surface consolidation if the materials in the road surface are suitable The integral mixture of salt and calcium chloride with aggregates properly graded and with plasticity indexes the same as those required for soil-aggregate mixtures without admixture brings about the retention of moisture in the base course or road surface The Canadian representatives reported that the use of sodium or calcium chloride results in increased resistance to frost action It is reported that the surfaces are so toughened that roads which have previously been closed due to frost boils have been kept open through the entire year after treatment It was also reported that the use of chemicals has resulted in increased density in the compacted material

A report was made by the Calcium Chloride Association of a field device for checking the stability of base courses and subgrades.

Tars, emulsions, asphalts are used in the stabilization of soils without the addition of granular materials However, due to the large amount of bituminous materials necessary to use with raw soils it is usually customary to add granular material retained on the 200 mesh sieve as a matter of economy. The gradation of such granular material is not important and it can often be obtained from waste piles or other local sources.

The procedures for determination of the quantity of bituminous materials vary with the different types or kinds. Most of the methods include some type of modified Hubbard-Field stability test or some other shear testing device In all of the methods the test pieces are molded under pressure. In all of the methods the samples are subjected to water curing of some type

Absorption by capillarity alone, total immersion in water, and the immersion of the test pieces to half their depth in water are used to determine absorption. One of these methods or a combination of two of them are used by several manufacturers of materials.

The minimum absorption and maximum shear values are used for setting the percentage of bitumen All tests are made on the soil mortar fraction passing the No 10 sieve.

The Koppers Company has developed a plastigraph which shows promise as a method for determining the percentage of bitumen in tar-soil mixtures. The machine records automatically the

stability or workability of water-tar soil mixes

The grades of tar or asphalt for use in soil mixtures have not been definitely decided. The tar industry reports that the heaviest tar possible to mix seems to give the best results.

Bituminous materials, soil and water are mixed during construction by road-mix methods, traveling plants and stationary plants The trend is toward traveling or stationary plant mixes due to the ease of control of proportioning and mixing and to the ease of handling material on the road

Drying, spreading and rolling the mixed materials are accomplished by means of blades, tamping and smooth face or multiple tire rollers

The density of the compacted materials is usually checked by the standard compaction test used in the compaction of embankments Moisture-density curves are plotted from test data obtained prior to construction using the soil-bitumen mixture and varying percentages of water It is a simple matter to compact the completed mixture in the mold and check the density

The drying requirements for tar and emulsified asphalts soil mixtures were reported as decidedly different The tar industry advocates the retention of moisture and specifies a seal coat immediately after completion of rolling so as to avoid loss of moisture during compaction by traffic The emulsified asphalt users, on the other hand, have found that the moisture content of the mixture should be reduced to a minimum by traffic before the surface is sealed

In conclusion, it is evident that test procedures for determination of bitumen and moisture contents should be checked against field conditions and an effort made toward standardization and simplification