A System of Soil Classification

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THIS paper describes a field and laboratory investigation on soil behavior in bases, subgrade and embankments as a part of a study by the State Highway Department of Georgia and the development of a soil-rating chart applicable to those soils found in the state. The classification developed has aided the department in securing a better understanding of soil behavior and in the design of roadway sections.

● SEVERAL years ago it became quite evident that the system of rating subgrade and embankment soils which was being used by the State Highway Department of Georgia was not satisfactory. Where the system was applied on a number of projects it was found that some soils, rated by the system to need subgrade treatment, stood up exceptionally well under the construction equipment and had served satisfactorily as subgrade under old pavements. At the same time, other soils which had been rated under the same system as requiring no treatment were actually requiring treatment to get the construction equipment through (Fig. 1 and Fig. 2).

Therefore, with these facts before us the department set about to study the problem of soil characteristics and design with the idea of correcting the rating system and developing the best knowledge it could in an attempt to avert in the future some of the failures we were having.

The studies were conducted in the field on projects which had been constructed a number of years and consisted of driving over hundreds of miles of old pavements and studying the actual behavior of the soils when used in the various components of the roadbed—how the soil had acted a number of years when used in embankments, subgrades and bases. Notes were made as to whether or not the soils had acted satisfactorily or whether they had failed, the condition under which they had failed, i.e., whether due to wet roadbed conditions or otherwise and the soils were visually examined and studied and large samples taken for further laboratory study.

It was particularly noted, after several failures of subgrade had been examined, that those soils which had failed appeared to have much less body than the better-acting soils. Further field observations appeared to bring out that the excellent-acting soils were much denser than those which had failed. These observations set us to comparing soil mixtures with pavement mixtures, for instance, portland-cement concrete. It is well known that a concrete mixture full of honeycomb or voids is not nearly as as strong and durable one with a low-void content. From this the idea was conceived that possibly the difference in behavior of soils was due mainly to the difference in voids. Therefore, it was concluded to study the soils from this angle. Since field studies showed that soils usually served somewhere near maximum density as determined by AASHO test method T 99-49, when originally compacted to this density, tests were conducted on the samples to determine the void content at maximum density. In almost every case studied in northern Georgia, it was found that the improper-acting subgrade materials contained over 40 percent voids, while those of the better-acting subgrade soils contained less than 40 percent voids, and the excellent ones contained less than 30 percent voids. To express these results conversely, based on a 2.65 specific gravity, it was found that those soils with over 40 percent voids had a maximum density at optimum moisture of less than 100 lb. per cu. ft., those soils with less than 40 percent voids had a maximum density of more than 100 pcf. and those of less than 30 percent voids had a maximum density over 116 pcf. It was further found that the excellent acting soils where used as subgrades were also the soils generally used as bases for surface treatment.

Therefore, from these studies it was concluded that the very light fluffy, disintegrated rocks and highly micaceous soils which had been observed in north and central Georgia

Figure 1. Soil which by old rating system would require treatment. LL = 54, PI = 17; minus No. 200 = 62 percent; total volume change, 8 percent; maximum density, 95 lb. per cu. ft.

Figure 2. Soil which by old rating system would not require treatment. Nonplastic; minus No. 200, 35 percent; total volume change, 16 percent; maximum density, 79 lb. per cu. ft.

were examples of poor soils because of the high void content and lack of body. They failed to contain, after thorough compaction, sufficient solid material per unit volume to support the loads imposed upon them, i.e., these soils contain more than 40 percent of their volume as air, or air and water, depending upon the condition, neither of which will support highway vehicles very well.

As the field studies were carried further into

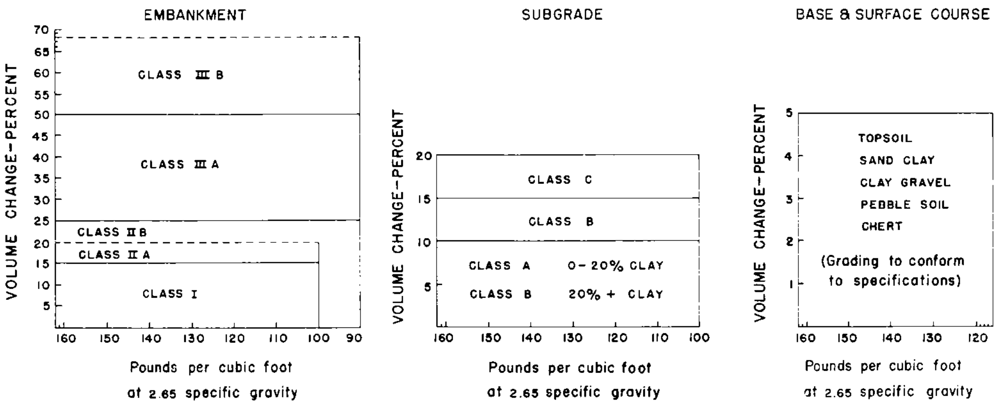

Figure 3. Rating chart for embankment, subgrade and base and surface courses developed and used by Georgia.

the southern part of the state, it was found in many instances that the density or void content fell within the limitations for the better-acting soils of north Georgia, but the soil had failed under service. With the same idea of density or void content in mind, it was thought that the density of the soils must at some stage during service become less than shown at optimum moisture and maximum density. Therefore, a study was conducted on the components of the soil mixture. Knowing that the mixture consisted of gravel, sand, silt and clay and that the first three held closely to their original volume through any change of temperature or moisture to which they might be subjected, studies were conducted on the clay fractions. It was found that certain clays, upon becoming wet, swelled a considerable amount, in some instances as much as 110 percent of their original dry volume. This swelling broke the complete soil structure down to such an extent that the voids were higher than in the better acting soils, resulting in a density that showed failures under service in north Georgia.

From this phase of the study it was concluded that it would be necessary to set some limitation on the volume change whereby a soil upon becoming wet under normal field service would not change volume to the extent of expanding the soil mixture below the density required to support the loads.

Upon arriving at the two above conclusions, additional samples were taken under both good and bad conditions over the state and the void contents at optimum moisture were determined together with the total volume change of a compacted specimen from complete dryness to complete saturation and the results of these tests were plotted and the results carefully studied. Based upon the conclusions an Embankment, Subgrade, Base and Surface Course Rating Chart (see Fig. 3) was developed and is now included in all sets of plans when pertinent to the type of construction.

EMBANKMENT MATERIALS

Embankment materials are separated into eight different classifications, five based upon maximum density and total volume change and three upon other characteristics.

1. Soils with a maximum density of at least 100 pcf. and a total volume change of not more than 15 percent generally require no treatment, except for construction of sand-bituminous road mix and lime-rock.

2. Soils with a maximum density of at least 100 pcf. and a total volume change of between 15 percent and 20 percent, generally need 6 inches of treatment, except in case of bituminous-concrete base or portland-cement-concrete base or pavement when grading shows more than 70 percent retained on the No. 200 sieve, and portland-cement and bituminous stabilization construction.

3. Soils with a maximum density of between 90 pcf. and 100 pcf. and a total volume change of not more than 25 percent, and soils with a maximum density of more than 100 pcf. and a total volume change of between 20 percent and 25 percent, generally need 6 inches of treatment.

4. Soils with a maximum density of at

least 90 pcf. and a total volume change of between 25 percent and 50 percent generally need 12 inches of treatment.

5. Soils with a maximum density of less than 90 pcf. and a total volume change of more than 50 percent are generally wasted or placed in outer areas of embankments. In special cases this soil may be used in bottom of embankments to a height of not over 10 feet when the density is more than 90 pcf. and the volume change is less than 70 percent. Generally needs 18 inches of treatment.

6. The other three classifications are (a) peat and muck soils which are entirely removed by excavation or blasting ahead of embankment construction; (b) laminated soils which generally require treatment depending upon the density and volume change; and (c) solid rock which is generally topped with 12 inches of subgrade-treatment material.

SUBGRADE MATERIALS

Subgrade soils follow somewhat the same arrangement but all must have a maximum density of at least 100 pcf.

1. Class A subgrade soils which are generally satisfactory for sand-bitumin road-mix construction; lime-rock construction; macadam, sand-asphalt and soil-base and surface construction; and bituminous-concrete base or portland-cement-concrete base or pavement when grading shows more than 70 percent retained on the No. 200 sieve, must have a total volume change of not more than 10 percent and in addition must have a clay content of not more than 20 percent.

2. Class B subgrade soils may have a total volume change up to 15 percent and includes those soils which have a total volume change of less than 10 percent but a clay content of more than 20 percent. These soils are generally satisfactory for macadam, sand-asphalt, and soil-base and surface construction; bituminous-concrete base or portland-cement-concrete base or pavement when the grading shows more than 70 percent retained on the No. 200 sieve; and portland-cement and bituminous stabilization construction.

3. Class C subgrade soils are those with a volume change of between 15 percent and 20 percent and are generally satisfactory for bituminous-concrete or portland-cement-concrete base or pavement when grading shows more than 70 percent retained on the No. 200 sieve, and portland-cement and bituminous stabilization construction.

Base and surface courses must conform to specific gradation requirements for the various types of material and in addition must show a total volume change of not more than 5 percent and a maximum density of not less than 116 pcf.

The grading requirements are included to select soils with reasonably hard, durable particles and to provide a field control to secure repetition.

Where subgrade treatment is required selective grading is normally employed in an attempt to take full advantage of the soils encountered during construction.

Where satisfactory soils are not available by this method, selected subgrade treatment material is borrowed from local material pits economically available to the project. To insure that imported material is worth the price required for the extra cost of material and haul, special requirements generally are established for this material. For example, a soil with 98-pcf. density and a total volume change of 16 percent would normally be unsatisfactory as subgrade under soil bases, and it would be uneconomical to replace this material with a soil with a density of only 102 pcf. and a total volume change of 14 or 15 percent. The specification for imported subgrade treatment material generally sets up the maximum particle size permitted, the quantity of material retained on the No. 10, No. 60 and No. 200 sieves and a total volume change of not more than 10 percent. This requirement assures that the material will conform to the minimum requirements set up in our specifications for the various types of local base-course materials, yet it does not require the stringent grading controls normally used for these materials.

DEVELOPMENT OF TEST

After the limitations had been established, it became necessary to develop a relatively rapid and inexpensive test to determine the volume change caused by the absorption, adsorption and loss of water. The maximum density could be determined by the method already established in AASHO test method T 99-49. Therefore, it was felt that if a test could be developed which would use some of this equipment the cost and availability would be in line. To this end a mold 4 inches in diameter and 1 inch high was made which would permit the use of the mold extension and rammer normally used to determine maximum density. Further, if the soil could be placed in the mold in one layer using the same number of blows prescribed for the maximum density determination it would insure a specimen compacted as desired. In addition to this basic equipment, it was necessary to develop a measuring stand for the specimen which was to be dried and another stand for the specimen to be immersed in water. The other piece of new apparatus necessary was a dial plate, so called because it would hold a dial micrometer in such a manner that it would fit precisely on legs of the two stands, enabling changes in volume to be measured to 0.001 inch.

PROCEDURE FOR DETERMINING VOLUME CHANGE

The soil to be tested is first sieved over a No. 10 sieve and air-dried to a slightly damp condition. A 2.2 lb. sample is then mixed thoroughly and sufficient water added to bring the total moisture content to the optimum as determined by AASHO designation T 99-49.

After incorporating the water into the soil the mixture is divided into two equal parts and compacted into two 4-inch-by-1-inch-diameter molds (with the extensions attached) by the application of 25 blows from the tamper dropped from a height of 12 inches above the soil. During compacting the mold rests on a uniform, rigid foundation weighing 250 lb., or a foundation of equivalent rigidity.

The blows must be uniformly distributed over the surface of the soil being compacted. The extensions are removed and the compacted soil carefully trimmed even with the top of the mold by means of a steel straightedge.

Specimen 1, mold and base plate, is placed in a tank and the water level raised to within ½ inch of the top of the mold. The micrometer-dial support is placed on the dial plate

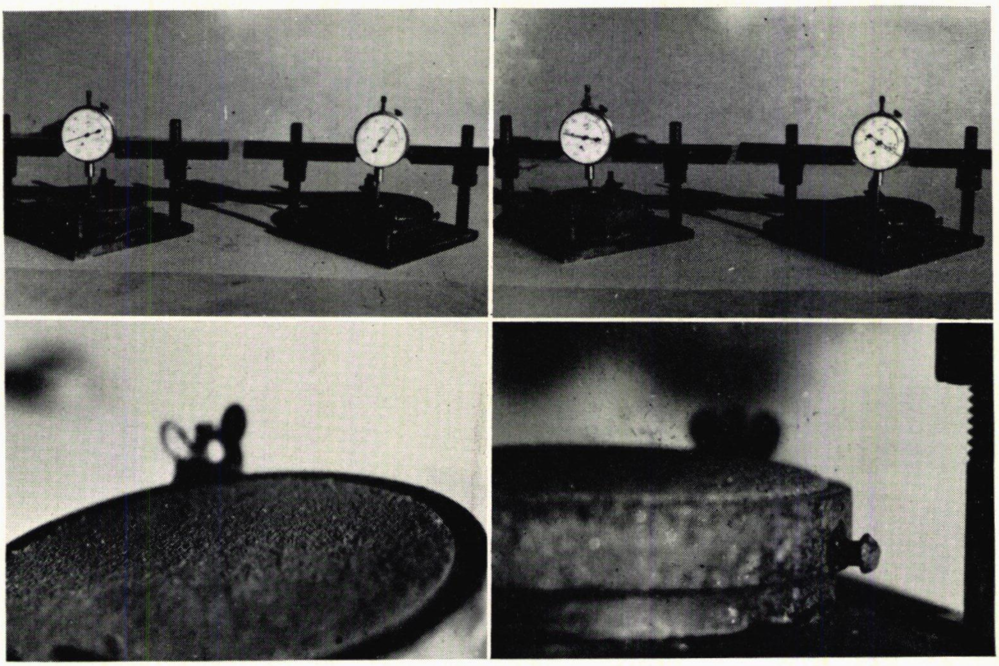

Figure 4. Swell test: Upper left, before being placed in water; upper right, after 24 hours in pan of water; lower left, close-up of satisfactory subgrade soil (shown in Figure 1); and lower right, close-up of unsatisfactory subgrade soil (shown in Figure 2).

legs, the micrometer reading taken and recorded as the original dial reading. The specimen is allowed to remain in the tank for 48 hours and the micrometer dial and support again placed on the dial-plate legs and a second measurement (final dial reading) made (see Fig. 4).

The micrometer dial and support are placed on the short dial plate legs of Specimen 2 and the micrometer reading is recorded as the original dial reading for thickness. The dial and dial support are removed and the sample air-dried (retained in the mold) for a period of 12 hours. The specimen is then dried to a constant weight in an oven at 110 C. (230 F.). After drying, the dial and support are again placed on the short dial plate legs and the micrometer reading recorded as the final dial reading for thickness. The dried specimen is then removed from the mold and placed with its diameter perpendicular to the base plate of the shrinkage-pat-measuring stand in such a manner that the dial stem rests on the top edge of the specimen after the dial and support are placed on the long legs of the measuring stand. The reading is recorded and the specimen rotated 90 deg. and the micrometer reading again recorded. The specimen is rotated until four readings have been obtained. The average of the four readings is calculated and recorded as the final diameter reading.

The volume change is then calculated from the following formula:

Total volume change

$$= \left(\frac{V_2 - V_1}{V_1} + \frac{V_3 - V_4}{V_3}\right) \times 100$$

Where:

V_1 = Original volume of Specimen 1
V_2 = Final volume of Specimen 1
V_3 = Original volume of Specimen 2
V_4 = Final volume of Specimen 2

CONCLUSION

Since soils are considered to fail through shear and since it has been determined that shear is directly influenced by density, the choosing of a soil mixture with a high density when compacted (and which will retain that density in service) results in one with a high resistance to shear and consequently one of high stability.

It is realized the limitations as now set up are not the complete and final answer to soil classifications, but to date the limitations appear to give excellent results when used on the soils encountered in Georgia.