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16. ABSTRACT

Numerous soil classification systems have been proposed and used by various groups of highway engineers. One of the earliest, and perhaps the most generally used, is the United States Bureau of Public Roads system of subgrade soil constants, described in "Public Roads" Vol. 12, Nos. 4, 5, 7 and 8 in 1931. This system has been in use by various agencies since that time, and a few years ago it was improved by introducing additional sub-types to the original soils groups.

During the past two decades a number of other engineering soil classification schemes have been proposed and put into use by various agencies; examples of these classification systems are those developed by the Texas Highway Department, the Civil Aeronautics Administration, the United States Engineering Department, and the United States Bureau of Reclamation. The engineering soil classification system which is perhaps most generally accepted at the present time is the "Unified Classification," which is a modification of the Casagrande or CAA classification system.

In view of the number and variety of soil classification systems it is not surprising that the average highway engineer is unfamiliar with the pedological classifications, and is perhaps reluctant to adopt or make use of another and different system, particularly one which was originally developed primarily for agricultural use. Although the various classification systems give consideration to several soil properties, most of the systems are based primarily on grain size distribution and Atterberg limits. One great difference between the pedological classification and practically all of the engineering classification systems is that the former considers the in situ soil, its origin and environment, whereas other systems are based almost entirely on inspection and laboratory tests of a soil sample regardless of its environment in place.

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PEDOLOGICAL AND ENGINEERING CLASSIFICATIONS

presented at

Third Annual Technical Work Planning Conference of Forest Service Soil Scientists

by

A. W. Root*

Numerous soil classification systems have been proposed and used by various groups of highway engineers. One of the earliest, and perhaps the most generally used, is the United States Bureau of Public Roads system of subgrade soil constants, described in "Public Roads" Vol. 12, Nos. 4, 5, 7 and 8 in 1931. This system has been in use by various agencies since that time, and a few years ago it was improved by introducing additional sub-types to the original soils groups.

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In view of the number and variety of soil classification systems it is not surprising that the average highway engineer is unfamiliar with the pedological classifications, and is perhaps reluctant to adopt or make use of another and different system, particularly one which was originally developed primarily for agricultural use. Although the various classification systems give consideration to several soil properties, most of the systems are based primarily on grain size distribution and Atterberg limits. One great difference between the pedological classification and practically all of the engineering classification systems is that the former considers the in situ soil, its origin and environment, whereas other systems are based almost entirely on inspection and laboratory tests of a soil sample regardless of its environment in place.

A number of excellent papers have been published on the use of pedological soil maps for engineering purposes, including papers by L. D. Hicks, J. R. Bissett, Geoffry B. Bodman and many others. These authors have probably had wider experience with the use of agricultural soil maps for engineering purposes than the writer, since the California Division of Highways has made only limited use of the pedological reports. However, just as the average highway engineer is unfamiliar with pedological classifications, soil scientists are probably not cognizant of the type of soils information required in highway design and construction. It seems appropriate, therefore, to discuss the type of soil data used by the highway engineer, and then to consider how much of this information is available from pedological reports.

Much of this discussion will refer to conditions and practices pertaining to highways of the California Division of Highways, with which the writer is most familiar. Although conditions may be greatly different in other regions, and other agencies may be performing soil surveys in some other manner, the same basic soil information is probably required by numerous agencies engaged in engineering work.

Perhaps mention should be made of some of the reasons why the California Division of Highways has made such limited use of pedological maps. Until recent years soil map coverage of the State was fragmentary, and much of the mapping had been done prior to 1915. Highway Research Board Bulletin No. 22, dated 1949, listed 92 soil maps, of which only about 30 were given a United States Department of Agriculture rating of 1, and 18 of the earlier ones had a U.S.D.A. Rating 2. The soil mapping of the State is still far from complete, but the recent maps are superior in every respect; since they are prepared on an airphoto base the topography and soil distribution are more accurate; the scale is generally larger, and the mapping is more detailed.

Before discussing specific applications of pedological maps to highway engineering, the purpose and nature of the highway soil survey will be briefly described. Two cases should be considered; (1) advance or reconnaissance soil surveys to evaluate soil or terrain conditions which might affect or control the location or route adoption of a new highway, and (2) complete soil surveys for design purposes, made after the alignment and profile of a highway have been tentatively or definitely established. The nature of the soil survey and the type of information needed are not the same for the two cases, and pedological soil maps are not equally useful for the two types of soil survey.

On present day highway location, especially for expressways and freeway, the general location of the route is rather closely controlled by factors other than soil conditions, and only drastic terrain or soil conditions will have any major influence. Some of the factors which are carefully studied and seriously considered in deciding on the location of highways are: (1) known or active landslides which would be crossed or might affect the road; (2) potential landslides or areas where cut slopes might be unstable or induce landslides; (3) unstable areas which would not support the required embankments or structures (4) deep deposits of soils subject to settlement or subsidence, either when subjected to embankment loading, or due to saturation or flooding. Many other factors or conditions would affect the cost of construction and maintenance, and might influence the location of the highway, especially the less important roads with light traffic. However, the four conditions mentioned above are generally the ones which more often actually determine the tenability of a proposed highway location.

On the other hand much more comprehensive and detailed soils data are required for the design of a highway project. In addition to the factors mentioned above the bearing value or supporting power of the various soils on the project must be determined in order to design the structural section, i.e. the thickness and type of surfacing, base and subbase. The character of the material in cut areas must be determined for proper design of cut slopes. Ground water conditions should be known, both for design of subdrainage systems and for use in design of stable cut slopes. Knowledge of the susceptibility to erosion of the various formations will be useful in designing surface drainage as well as for deciding on types of planting or other erosion control measures. Information on the pH of the soils and the alkali contents will be of use in design of culverts and structures, and for estimating the life of various types of pipes and culverts. Expansive properties of the soils are important, especially if rigid pavement is proposed; excessive volume change due to fluctuation in moisture content may result in distortion of and damage to the pavement. In-place density and degree of compaction must be known in order to estimate shrinkage or swell from excavation to embankment, for computing earthwork quantities. In a few areas in California, in the higher mountains, frost susceptibility must be considered. This is, of course, of more concern in regions where deep frost penetration is normal in large areas. And obviously the location, quantity and character of available construction materials should be determined, and the design should be based on the most economical use of available materials for such purposes as subbase, base, mineral aggregate and other construction materials.

It is evident from the above comments that a vast amount of soils information is required in the design of a major highway project, and all sources of information should be utilized to obtain the most reliable and comprehensive data with the minimum expenditure of time and effort. Depending upon the character of the terrain, types of soil and other conditions the following procedures may be employed:

a. Air photo analysis
b. Correlation of soil data from pedological maps
c. Geological mapping
d. Geophysical exploration
e. Test borings for obtaining undisturbed samples for laboratory testing
f. Ground water observations in test borings and if necessary installation of piezometers
g. Borings to obtain representative samples for tests on which to base the structural design

Preparation of the soil profile and materials report on California Highway projects always includes the last named operation, i.e., obtaining samples for laboratory tests of typical soils encountered in roadway excavation and also the location and testing of available local sources of aggregate.

On heavy construction through difficult terrain all of the above mentioned methods may be employed during the design of the project.

The purpose of some of these soil investigations and the nature of the testing performed may be of interest to the soil scientist who may be concerned with soil properties affecting the use of land for agricultural or forestry purposes rather than for highway construction. Geological mapping, obtaining of undisturbed cores and determination of ground water conditions are means of securing information necessary for design of cut slopes and prevention or control of landslides. The principles of soil mechanics are applied in designing embankments over areas of weak or compressible soil; such analyses require laboratory tests of undisturbed samples of the soils involved, often to depths of 50 ft. to 100 ft. The character of the surface soil is of minor importance, and in rough terrain involving heavy grading, exploration to depths of 100 ft. is common, and borings have been made to depths as great as 400 ft. in the investigation of proposed cut areas.

Regarding the testing of native soils for highway purposes, the California Division of Highways design is based on Resistance R-value test which is made with the Hveem stabilometer. Several of the western states use this test method; others determine the bearing value or load supporting capacity of the soil by the CBR (California Bearing Ratio) test, the triaxial compression test, or the cone penetration test. In California the

R-value test is applied to aggregates for subbase and base, as well as to the basement soil, often referred to as "subgrade." In California the "Sand Equivalent" test has largely replaced the Plasticity Index as a test method for indicating the amount and character of clay or objectionable fines in soils and aggregates.

The above discussion may appear irrelevant in a paper on "Pedological and Engineering Classifications." However, it is believed that the usefulness and limitations of pedological maps can be best evaluated if there is an understanding of the type of soils information required or being used in the design of highways. This leads to question which is of interest both to highway engineers and to the soil scientists and administrators of the Soil Conservation Service: How can the highway engineer utilize the soils information available from pedological maps and what correlation is there between the pedological classifications and engineering classifications of soils?

The current Soil Conservation Service soil surveys, such as those now in progress in California, include data on engineering properties of soils not furnished in most of the available Department of Agriculture Soil Survey publications. Few of these new improved soil surveys have been published and none in California; there will be no widespread coverage for many years, and hence the following discussion will refer principally to the generally available Soil Surveys which do not contain the specific information on engineering properties of the soils.

The importance and usefulness of engineering soil classifications have, in the writer's opinion, been somewhat exaggerated. It is true that some rational system for description of soils is convenient and desirable. However, it should be recognized that all of these engineering classification systems, whether based on visual inspection or classified by laboratory tests for grain size and Atterberg limits, are qualitative rather than quantitative. The classification systems are useful for logging boreholes or test pits, and may provide information for preliminary estimates. They are probably of greatest value for determining the nature and scope of the program of sampling and testing required to obtain adequate information on the engineering properties of the soils for design purposes.

It should be recognized, however, that laboratory tests of representative samples of the soil in question are necessary for quantitative determination of such engineering properties as shear strength, volume change, permeability, compressibility and resilience. In this respect the engineering and pedological classification systems are similar, a fact that is not generally recognized by engineers. Regardless of which classification system is used, laboratory testing is required to determine specific engineering soil properties for design of any important highway or structure. Soil classification by either system can greatly extend the qualitative information beyond the point at which sampling and testing has been performed, thus permitting a reduction in the amount of detailed soil sampling and testing.

When interpreting agricultural soil survey maps for engineering purposes it should be recognized that the agricultural soil surveys are surficial, and extend generally to depths of only three to six feet. Furthermore, the soil surveys were made primarily for agricultural or forestry purposes. Nevertheless, proper interpretation of the agricultural soil surveys will yield useful information for highway purposes, and may greatly reduce the work required for preparing a highway soil survey. Although the pedological soil survey is surficial, valuable information is included on the parent materials, which can be utilized by the highway engineer. The agricultural soil surveys are unique in that the same classifications and nomenclature are used nationwide; this is true of no other system of soil classification. The Bureau of Chemistry and Soils textural classification happens to be the same as that in use by the California Division of Highways. Regardless of the system in use by a particular agency, the textural classification used in the agricultural soil surveys provides the necessary information on grain size distribution for the soils so classified.

The textural classification applies only to a soil "type," that is, the soil in the "A" horizon. Texture of the soil in the entire corresponding series is not given in the pedological classification, but information on the engineering properties of the soil series may frequently be obtained from detailed highway soil surveys at other locations where soils of the same series have been tested.

Plasticity is not reported and cannot be accurately estimated from the present pedological classifications. An experienced soils engineer can probably make rough estimates based on the textural classification and descriptions of other properties for a given soil type.

The Soil Surveys furnish specific information on the pH of the soils and report the presence of alkalies and salts. The engineer needs this information for selecting the type of cement in concrete and for designing culverts which will have adequate resistance to corrosion. Although additional testing may be necessary the Soil Surveys give an indication where troublesome soils may be encountered.

Where frost susceptible soils must be detected and guarded against the pedological maps may indicate the presence and areal extent of such soils, especially if correlated with tests and service records of soils of the same series.

The bearing value or R-value of a soil may be roughly estimated for the A-horizon where textural description is given in the Soil Survey. Since this would be applicable only to the surface soil and would not relate to soils at any appreciable depth, it is believed that only very fragmentary data on this engineering property can be derived from the pedological classifications. The maps would be of greatest value where a correlation had been established for the engineering properties of soil in a given series at other locations.

The currently available agricultural maps do not furnish any information on the in-place density or relative compaction of the various soil types or series. The Soil Surveys now in progress, which will incorporate a chapter on the engineering properties of the soils, will report the in-place density as well as the relative compaction. These data can be used by the highway engineer for estimating earthwork swell and shrinkage factors, at least for soil at the relatively shallow depths at which these tests will be made.

The pedological maps show the location of peat beds and peaty soil. Even though the depth of the peat beds may not be reported in the Soil Survey, the highway engineer is warned of the presence and areal extent of the peat land, and can make whatever exploration is warranted to ascertain the thickness and exact character of the peat layers.

In addition to the specific soil classifications given in the Soil Survey reports and maps, the reports also include general information useful to the highway engineer. For example, the Soil Surveys discuss such features as drainage, irrigation, topography, erosion, vegetative cover, and other conditions of interest to the engineer.

The usefulness of the pedological maps will depend largely on the degree of uniformity of engineering properties of soils in a given soil series. That is, can it be assumed that if the engineering properties of a soil series at some location are known, the same soil series at some other geolographical location will have approximately the same engineering properties? Several agencies report reasonable correlation and make use of the Soil Surveys for projecting engineering soil data from known areas to other regions where the same soil series occur. The writer has had no first-hand experience in establishing such correlations. In any event, as has previously been mentioned, the data thus obtained should not be considered quantitative, and should be verified by at least a nominal amount of sampling and testing in the area being investigated.

The title of this paper is somewhat of a misnomer, as most of the discussion pertains to the engineering use of agricultural Soil Survey Reports, rather than being restricted to pedological and engineering classifications. It is hoped that these comments and the discussions which may be evoked will lead to better utilization of the pedological maps by engineers, a matter which is of interest both to the highway engineers and the Soil Conservation Service scientists who perform and administer the Soil Surveys.

It is the writer's opinion that the Class 1, and to a lesser degree the Class 2, Soil Surveys can be of considerable value to the highway engineer, but their usefulness will be greatly enhanced by the chapter on the engineering properties of soils which will be included in some of the Soil Survey Reports now being prepared. The agricultural maps will probably be of greatest value to those counties and agencies which do not have the laboratories or materials departments for making comprehensive soil surveys, and for use on less important roads where detailed soil studies are not economically feasible.

Moreover, the agricultural soil surveys are made primarily for agricultural and forestry purposes and cannot be expected to include complete and detailed engineering analysis of soils. Most efficient utilization of the pedological maps will be achieved by accumulating correlative data for relating the pedological classifications to the engineering properties of the soils. These data can be compiled for various projects involving a given soil series or for a selected area. Some states and counties have prepared engineering soil maps based on the Soil Survey maps, by correlating the pedological classifications with test data and performance records within the area being mapped. It is believed that more thorough and general understanding of the pedological maps by the engineers will enable them to use the Soil Survey Reports more intelligently, with a resulting reduction in engineering expenditures.