ture is one of the major determinants of soil permeability and also affects the ease of soil excavation. For example, the fragipans of Canfield soils, which have a weak, platy structure, are very dense, very hard when dry, and more difficult to excavate than horizons above and below. The C horizons of Geeburg soils are also compact, but the high clay content of Geeburg soils causes them to be sticky and difficult to grade when they are moist or wet. In both soils, the blocky structure of the upper B horizon results in easy excavation.

Soil pH and Exchangeable Cations

These properties are important in preparing specifications for concrete, and they also influence the proper use of lime or other chemicals for stabilization of soils as subgrade. Again, as a result of the same kind and degree of soil weathering in similar parent material, given horizons of soil series have a narrow range in these properties.

SUMMARY

Soil series are the lowest category in Soil Taxonomy, having a narrower range in both properties and performance than any of the five higher categories. Soil series occupy unique landscape positions and have narrow ranges in important site and environmental conditions that are considered soil properties in pedology but not in soil mechanics.

Confined in their ranges by the limits of the higher categories, soil series represent the product of a specific kind and degree of soil weathering. Of particular importance is a limited and specifically defined range in composition (especially in mineralogy and particle size) that relegates the occurrence of soil series to a specific kind, or very similar kinds, of parent material. Knowledge of the soil series thus identifies, within narrow ranges, not only the parent material but also the grain-size distribution, composition, and chemical properties of each horizon, the thickness and structure of each, and the seasonal soil temperature and wetness at the site.

Soil series provide a structure for organizing knowledge about soils and a basis for predicting the performance of soils in highway construction and for other engineering uses. Identifying soil series is helpful in planning the testing programs required for highway design.

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Publication of this paper sponsored by Committee on Exploration and Classification of Earth Materials.

Application of Soil Taxonomy in Engineering

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Transferral of soil information among the disciplines concerned with soil is important. One of the traditional sources of basic soils information for engineering uses at the reconnaissance level has been the pedological maps and soil surveys prepared by the Soil Conservation Service. The new Soil Taxonomy incorporated by the Soil Conservation Service and other, cooperating agencies into all recent pedological mapping and reports contains key formative elements as building blocks for constructing soil classifications. Engineers may obtain useful information concerning soils on a regional basis by becoming familiar with the new Soil Taxonomy. Individual soil profiles are classified and the formative elements give clues

to general climatic conditions and more specific information on such criteria as soil moisture, texture, and soil particle mineralogy. Examples are given of information that can be inferred with accuracy, and limitations are stressed at category levels above the soil series. Soil series will remain the basic unit for engineering interpretations of soil surveys because of their familiarity and the availability of extensive quantitative data.

There are many related disciplines that concern themselves with the unconsolidated material at and below the surface of the earth. Soil scientists, geologists, and geotechnical engineers each study, define, classify, and utilize soil for their own purposes, and much of the resulting information is transferred from one discipline to another. It is necessary, therefore, for each discipline to keep informed about recent developments in the others.

In 1960 a revised descriptive taxonomy popularly known as the 7th Approximation was published by the Soil Conservation Service of the U.S. Department of Agriculture (1). The taxonomy has had many growing pains through the years and is just now beginning to become known to the engineering profession. Johnson and McClelland, in a paper in this Record, have explained the history and philosophy of Soil Taxonomy.

Reactions to the new Soil Taxonomy have ranged from a humorous introduction by Handy (2) to a less than enthusiastic reception of the nomenclature by Hunt (3). The question seems to be, What are soil scientists attempting to do by introducing a new taxonomy, and why is it of any importance to geotechnical and other engineers? The system classifies soils as naturally occurring bodies in their natural setting and introduces quantitative values as well as qualitative determinations, thus, in part, satisfying the engineer's quest for numbers. It also enables one to become familiar with basic concepts of soil properties over large areas. Of course the engineer is mostly interested in small sites; as the classification narrows, more detailed information becomes available. However, for reasons explained later in this paper, it appears that the soil series will still provide the most data to engineers for some time to come.

The Soil Taxonomy system, built on diagnostic soil horizons, has been detailed by Bartelli in a paper in this Record. These diagnostic horizons are specific combinations of physical and chemical properties that define a central concept. Most of the distinguishing characteristics of the system are based on the presence or absence of the specific diagnostic horizons or on their existence in specified portions of the soil profile.

PAST USE OF SOIL SURVEY DATA

The practice of preparing engineering soils maps from soil survey information has been common since the close of World War II. Soil surveys have been used in conjunction with air-photo interpretation, geologic mapping, and groundwater investigations to provide basic data for the deductive reasoning processes that lead to the engineering soil map at the reconnaissance level. Many states have been using soil surveys for these purposes for many years. Some states, such as Illinois (4) and South Dakota (5), now incorporate statistical evaluations of engineering data of soil series in their work.

In New York State, Bennett and McAlpin (6) pioneered engineering soil mapping. Refinements of these early efforts (7) used soil surveys to a greater extent for basic soils data, and the other data sources became supportive. As in most work using soil surveys, the basic information block was the soil series. The soil series was converted to a landform-depositional process map unit based on geologic origin and type of parent material. In time, as soil scientists refined their discipline, the number of soil series multiplied. Arnold (8) indicates that the explosion of soil series information made it difficult for any one individual to become knowledgeable about the hundreds of soil series except by constantly using them in routine work. But that makes it difficult to extrapolate knowledge into areas where no familiar soil series exist.

APPLICATION OF SOIL TAXONOMY FOR ENGINEERING DATA

A basic knowledge of a few key words can provide the engineer with soils information on a regional basis. For example, the soils of New York State are geologically young, the result of glacial and postglacial deposits in a temperate, humid climate. All soils in New York are classified into 5 orders, excluding the Histosols or organic soils. These include only 10 suborders and 17 great groups. The following table gives the higher classification of the mineral soils of New York State.

Order	Suborder	Great Group
Entisols	Aquents	Fluvaquents
		Psammaquents
	Orthents	Udorthents
	Psamments	Udipsamments
		Aquipsamments
Inceptisols	Aquepts	Fragiaquepts
		Haplaquepts
		Humaquepts
	Ochrepts	Dystrochrepts
		Eutrochrepts
		Fragiochrepts
Mollisols	Aquolls	Haplaquolls
Spodosols	Aquods	Fragiaquods
		Sideraquods
	Orthods	Fragiorthods
		Haplorthods
Alfisols	Aqualfs	Ochraqualfs
	Udalfs	Hapludalfs

Knowing only information up to the great group level, the engineer with no knowledge of New York soils would recognize their geological youthfulness. The formative elements ent and ept would indicate little or minimum change in the parent material on which the soil profiles are produced. The engineer would also recognize those soils that have characteristics associated with seasonal wetness (Aquents, Aquepts, Aquolls, Aquods, and Aqualfs). The formative element ud, as in Udalf or Udorthent, indicates that the soil is a well-drained soil of the humid, temperate climates, as contrasted to the Uoralfs of colder areas or the Ustalfs of drier areas. It is this type of information that allows the engineer easily to become familiar with soils at a regional level. Buol, in a paper in this Record, has explained how soil moisture and temperature regimes are used in Soil Taxonomy.

At the next level of the system, the subgroup, a modifying work is added to the classification. The great group level identifies soils that satisfy a central concept or set of criteria. The subgroup modifier identifies a feature or features that fall outside of this central concept. One example of this that is of interest to the engineer is lithic, which denotes a rock contact within the control section.

As the classification becomes more specific more engineering information is revealed that, in turn, enables inferences and predictions to be made intelligently. Handy and Fenton, in a paper in this Record, explain in detail the information used at the family level of classification, including textural properties, mineralogy of clays and coarser particles, and other criteria.

Most engineering properties of soils are the result of moisture and texture relations. Particle-size distribution, mineralogy of the soil particles, and moisture content are among the most basic information needs of the geotechnical engineer. From these parameters many behavior characteristics of soils may be intelligently estimated. Such basic soil properties as suitability for cross-country trafficability, shrink-swell characteristics, and plasticity may be determined. It is quite obvious that a soil classified (at the family level) as sandy, siliceous; as coarse loamy over sand; or as sandy-skeletal, mixed will behave much differently from the soil classified as very fine, illitic.

Features such as frost potential may be inferred from the texture, moisture, and temperature parameters found at the family level. Coarse silty, fine silty, and fine loamy soils fall into the optimum permeability-capillarity range for frost susceptibility. Soil strength is a feature not easily estimated from the information at the family level and will be discussed further. However, in the fine and very fine textural classes, the mineralogy of the clay is an important feature in qualitatively determining strengths and behavior. It is important if the soil scientist can identify the clay minerals, and a large volume of X-ray data identifying the kind of clay minerals by horizon of soil series now exists.

LIMITATIONS OF SOIL TAXONOMY FOR ENGINEERING APPLICATIONS

All classification systems regarding soils and soil properties are limited when they are used for something other than that for which they were designed. Orvedal (9) points out that the problem with Soil Taxonomy for geotechnical engineers is the same as that with previous pedological classification systems, namely, the relatively shallow depth [usually 1 m (3.3 ft) but sometimes deeper] on which Soil Taxonomy is built. Users of soil surveys for engineering purposes have long recognized this shortcoming but nevertheless have extrapolated this information to deduce deeper soil characteristics. Because soil surveys are usually made for large areas, many borings to determine the deeper materials within the area cannot be expected.

Parent material as such is not a soil property in Soil Taxonomy. One problem encountered in working with levels of the taxonomy above the soil series is that without going to the soil series description it is often impossible to determine the parent material on which the soil has developed from the information contained even at the family level. For example, several soil series, given in the table below, are classified as Mollic Haplaquepts but are formed on various parent materials that have widely differing engineering properties.

Soil Series	Parent Material	Soil Series	Parent Material
Alden	Glacial till	Lamson	Glacio-lacustrine fine sand
Atherton	Glacio-fluvial sand and gravel	Fonda	Glacio-lacustrine silt and clay

Even at the family level, different parent materials give rise to the same classification. The following table gives variations of the parent material, Glossoboric Hapludalf, for various soil series.

Soil Series	Parent Material
Cayuga	Glacio-lacustrine over glacial till
Riga and Lairdsville	Frost-fractured material and glacial till over soft shale bedrock
Hudson and Schoharie	Glacio-lacustrine silt and clay

Although all five soil series in this example are classified at the subgroup level as Glossoboric Hapludalfs and at the family level as fine, illitic, mesic, one is formed on a glacio-lacustrine veneer over glacial till; two are formed on frost-fractured material mixed with glacial till moderately deep over soft, weathered shale bedrock; and two are formed on layered glacio-lacustrine silt and clay deposits. Engineering properties such as bearing capacity and consolidation characteristics of the deeper material vary greatly among soils in the same family.

Perhaps the easiest limitation to overcome is the nomenclature. The most useful terms have been explained by Philipson, Arnold, and Sangrey (10). As pointed out by Pheasant (11), the entire system need not be known to be of value in determining soil characteristics at a general level. The formative elements can be learned in a relatively short time.

ENGINEERING INFORMATION FROM SOIL SERIES

McCormack and Flach, in a paper in this Record, explain why the soil series has been retained in Soil Taxonomy. As early as 1963 Orvedal (9) stated that most data collected for engineering purposes have been collected at the series level. This is even more true today, especially in those states where there exist cooperative testing programs between the Soil Conservation Service and the state highway or transportation agency. Many qualitative data are given in the soil series description that complement and enhance the information available from both higher levels of soil classification and detailed quantitative data. These qualitative data include depth to contrasting material, drainage class, parent material, and landforms. Flooding, ponding, permeability characteristics, and internal structure are important characteristics of soil series.

As indicated earlier, the geologic relation and the origin of the parent material on which the soil-forming factors of time, climate, and biologic activities have been working are especially important. For example, the internal fabric or structure described for a series provides valuable engineering information relating to relative permeability. The descriptions also usually go beyond the thickness of the control section.

The soil series has long been familiar to geotechnical engineers interested in soil mapping. It will undoubtedly remain the basic information source.

CONCLUSIONS

Soil Taxonomy information can be a valuable extension of tried and proven methods for preparing engineering soil maps and interpretations. Much valuable information exists in the system and is reflected in the descriptive nomenclature by key formative elements. As in any classification scheme, the limitations of both the system and the nomenclature must be recognized. Members of the various disciplines concerned with soil should acquire a working knowledge of Soil Taxonomy so that information can be shared and the new taxonomy can be made more meaningful for all.

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Publication of this paper sponsored by Committee on Exploration and Classification of Earth Materials.