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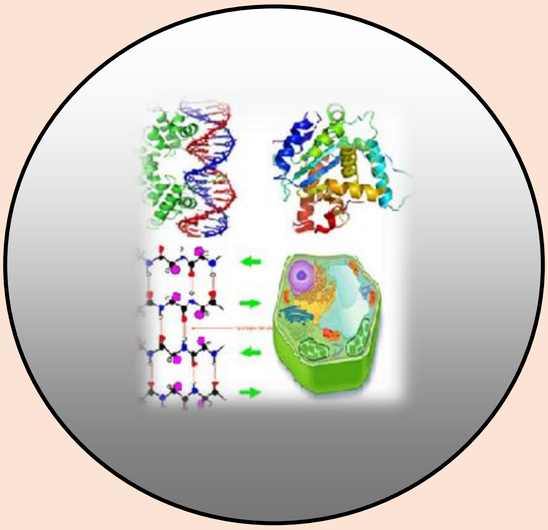

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REVIEW ARTICLE

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# Principles of Soil Classification: A Review

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## ABSTRACT

***Soil classification is the separation of soil into classes or groups each having similar characteristics and potentially similar behavior. A classification for engineering purposes should be based mainly on mechanical properties, e.g. permeability, stiffness, strength. In fact Soil classification deals with the systematic categorization of soils based on distinguishing characteristics as well as criteria that dictate choices in use. In soil survey, as practiced in the United States, soil classification usually means criteria based on soil morphology in addition to characteristics developed during soil formation. Criteria are designed to guide choices in land use and soil management.***
***Keywords: Soil classification, Soil series, Soil management and Mechanical properties.***

## INTRODUCTION

Soil series as established by the National Cooperative Soil Survey of the United States Department of Agriculture (USDA) Natural Resources Conservation Service are a level of classification in the USDA Soil Taxonomy classification system hierarchy. The actual object of classification is the so-called soil individual, or pedon (Johnson William 1963). Soil series consist of pedons that are grouped together because of their similar pedogenesis, soil chemistry, and physical properties. More specifically, each series consists of pedons having soil horizons that are similar in soil color, soil texture, soil structure, soil pH, consistence, mineral and chemical composition, and arrangement in the soil profile (Soil Survey Staff 1993). These result in soils which perform similarly for land use purposes. The soil series concept was originally introduced in 1903 (Simonson Roy, 1968, Simonson Roy, 1952). Soil series were originally intended to consist of groups of soils which were thought to be the same in origin but different in texture. Soils were thought to be alike in origin if they were derived from the same kind of rocks or if they were derived in sediments derived from the same kind of rocks and deposited at the same time. A soil series name generally is derived from a town or landmark in or near the area where the soil series was first recognized (Kellogg Charles, 1949). For example, the Haugan Series was first identified near Haugan, Montana. The distribution of a given series is not necessarily restricted to the boundaries of only one county or state—for example, the Hagerstown Series (National Cooperative Soil Survey, 2010) was first described near Hagerstown, Maryland, but has also been found as far away as Tennessee and Kentucky.

**Relationship to soil mapping**

Depending on the context, a soil series may be defined as either a *taxonomic unit* or a *mapping unit*. A taxonomic unit is a category belonging to a specific level of a classification system. It is a conceptual entity that describes the "central nucleus" or essential characteristics of a class.

On the other hand, a mapping unit delineates areas of soil in the landscape (i.e. adjacent pedons or polypedons) that possess similar characteristics. The characteristics of a soil series (taxonomic unit) may or may not overlap either fully or partially with the characteristics of pedons within a given mapping unit. Mapping units consist of one or more components. Each component represents polypedons that belong to a particular soil series. The name of a map unit is usually named after the dominant component within the mapping unit. For example, the dominant component of the mapping unit *LhE—Lily sandy loam, 15 to 35 percent slopes, very stony* in the Greenbrier County, West Virginia soil survey is the Lily series, which comprises 80% of the mapping unit. The remaining 20% of the mapping unit consists of the Dekalb series, Berks series, and "soils that have stones covering less of the surface" than the Lily series.

**WHAT ARE SOIL SERIES?**

- They constitute the most detailed hierarchical category in a soil classification system.
- They are practically independent from the classification system to which they refer (Boulaine, 1980)
- Each soil series represents a specific soil class with a unique set of physical, chemical and mineralogical characteristics It is the most homogenous category in taxonomy.

**WHAT ARE SOIL SERIES FOR?**

They constitute an essential vehicle for transferring soil information and knowledge from one place (where it was obtained) to another (where there are similar soils).

**QWHICH SOILS FORM PART OF A SOIL SERIES ?**

The soils of a particular series

- have similar observable properties;
- have similar reactions with regard to their use and management;
- have similar horizons in their layout and characteristics; are homogenous and have developed from a particular original material
- exhibit properties that vary within a narrowly defined range. The surface horizon and soil features such as slope, stoniness, the extent of erosion and topographical position may all vary, but these features are associated with significant differences in the classes and the layout of the horizons.

**HOW CAN WE DIFFERENTIATE BETWEEN SOIL SERIES?**

The following criteria are generally used to differentiate between soil series, with more specific details being established for each country and geographical region:

- classes, thicknesses and the layout of the soil horizons;
- soil structure, colour, texture, reaction, consistency, calcium carbonate and soluble salt content, organic matter, coarse elements and mineral composition.

Significant differences in any of these properties may serve as the basis for identifying different series. It is very rare for differences to be based on only one of these characteristics because due to their relationship with soil formation processes more than one of them tends to vary at a given time

A series is perfectly characterized by

- its position in the landscape, slope and material of origin;
- its morphological aspect: its sequence of horizons, structure, colour, coarse elements, and depth, etc.;
- its functional aspect: its temperature regime, drainage class, permeability, etc.;
- its mineralogy: the nature of its clay and other minerals;
- its analytical aspect: its particle size and distribution, reaction, cation exchange capacity (CIC), iron content, organic carbon content, calcium carbonate, etc.;
- the permitted range of variation for each of its characteristics.

**HOW ARE SOIL SERIES DENOMINATED ?**

A soil series normally bears the name of the area where it was first recognized, which is a place at which the soil in question is well represented in the surrounding area.

Soil series should therefore be described for each territory and should have locally appropriate names. At meetings and in scientific works, it is habitual to use higher hierarchical levels.

**CORRELATION OF SOILS**

Each series should be described in a detailed way, following a standardized format applied by the different survey teams. This definition is dynamic, because it can be improved with time; as knowledge of the soil increases, it is possible to improve the definition of a given series.

In order to avoid duplications, the Department of Agriculture of the USA (USDA) created the figure of soils correlator, with three important functions:

- to check that each candidate for recognition as a new series really is such and that it has been described according to the established standard
- to keep a single, constantly up-dated, soil series record;
- to check that the limits established for map units coincide with those of earlier maps.

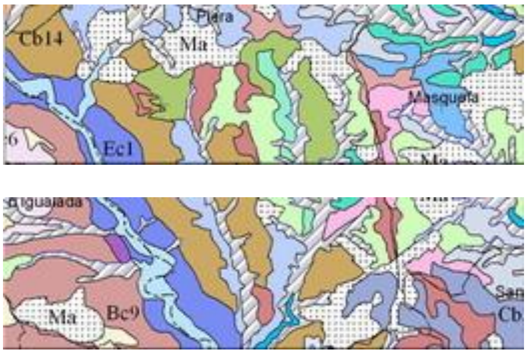


**Figure 1. The limits of the map units used for these two maps concur due to a supervising correlation that was carried out by the map correlator (J. A. Martínez-Casasnovas).**

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Who hasn't seen a young child eagerly digging in the ground, collecting rocks of all shapes and sizes to stuff in a pocket – and otherwise visually examining each grain of sand, clump of soil or piece of rock as if it was a precious gem ? Fast forward 20-some years to the same person, still visually examining every grain of sand, clump of soil or piece of rock, but now as a civil or geotechnical engineer with a trained eye. He or she also has a bigger purpose: testing and classifying those natural earth materials for their potential use in highway, infrastructure and other construction projects.

**The Role of Geotechnical Engineering in Highway & Infrastructure Construction**

Geotechnical engineers are civil engineers who specialize in rock and soil and developing foundations in road or bridge construction, mining and similar industries – and the path to a new road construction project starts with them.

**Soil Classification: Foundation and Pavement Design Starts Here**

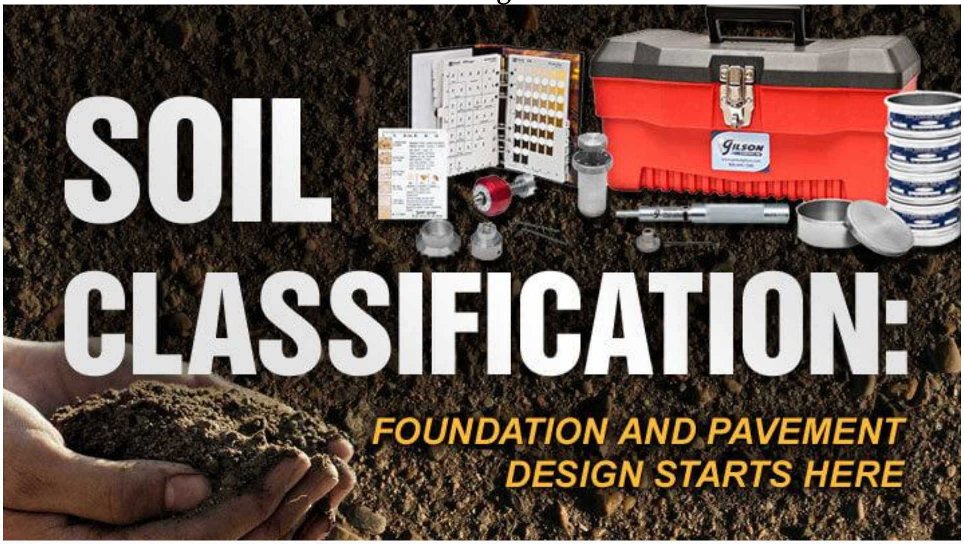


**Figure 2. Soil classification book.**

**Visual Classification: the First Look**

Before any construction design is approved, geotechnical engineers take samples of, visually examine, and analyze soil and rock materials to determine composition and suitability for proposed use, as well as engineering properties that include:

- Shrink/swell
- Permeability
- Consolidation
- Shear strength

**Figure 3. Soil profil classification study.**

They are looking at grain size, structure and composition of materials ranging from soft clay to intact rock – and all other soils in between. With further field and lab testing, the soil's ability to stand up to structural foundation or paving loads will be determined. One good resource to use during a visual inspection or field testing is a Geotechnical Gauge, which is convenient to carry and contains information on:

- Coarse-grained soils
- Fine-grained soils
- Gravel and gravelly soils (clean and with fines)
- Sand and sandy soils (clean and with fines)
- Silts and clays
- Highly organic soils

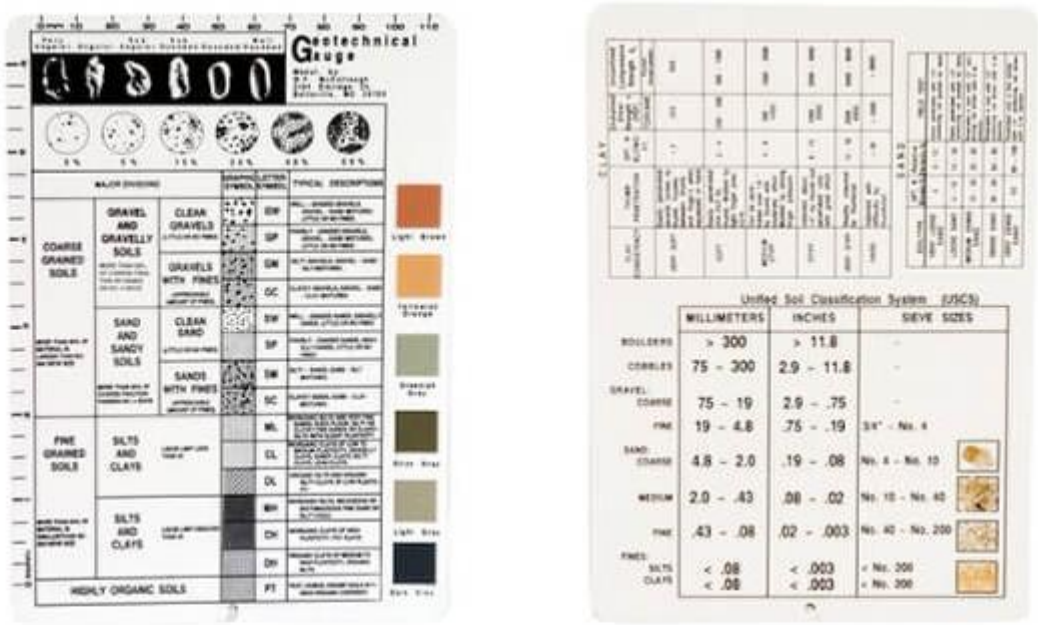


**Figure 4. Total classification series.**

The Geotechnical Gauge also indicates how to do thumb testing penetration in clays ranging from very soft to hard, with information on field testing sand types ranging from very loose to very dense. Other useful tools in the field technician's kit for soils classification include Pocket Penetro meters and Shear Vanes for estimates of unconfined shear strength, color charts to assist classification, and field sieves to confirm grain sizes.

**Laboratory Soil Classifications**

With further testing, strength, particle size and composition of the soil, how it responds to moisture and its plasticity, as well as organic content, are all examined. Most importantly, the testing will determine if sub-surface conditions meet all the requirements for the proposed construction.

Different classification systems in wide use today include:

- The Unified Soil Classification System (USCS), which describes four major classes of soils as coarse-grained, fine-grained, organic soils and peat, then into subgroups with unique characteristics.
- American Society for Testing Materials, ASTM D-3282 - 15,*Standard Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes,* and ASTM D-2487, *Standard Practice for Classification of Soils for Engineering Purposes.* These practices classify soils by group indexes, based on grain size and plasticity characteristics.
- American Association of State Highway and Transportation Officials, AASHTO M-145, *Standard Specification for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes* uses practices similar to the ASTM methods.

AASHTO soil classifications encompass seven basic soil groups – A-1 through A-7, with A-1 through A-3 being sands and gravels, and A-4 through A-7, silts and clays. An additional group, A-8, is defined as unusable peat. This AASHTO chart compares grain size classifications of different methods to ASTM E11 sieve sizes.

Comparatively, ASTM classifies earth materials used in highway construction in seven groups too, through laboratory determination of "particle-size distribution, liquid limit and plasticity index." Additional information on the seven groups is available within the ASTM D-3282 - 15 standard referenced above.

Moisture content, particle size, plasticity index and other properties can vary widely among soil types and directly impact characteristics such as bearing capacity, stability and drainage. Appropriate testing calls for careful consideration in selecting tests and testing equipment. Fine-grained, plastic soils are defined by liquid and plastic limits (Atterberg) and hydrometer tests to profile their particle size beyond the lower range of sieves. Sand and gravel samples call for different sample preparation, larger sieves and usually, larger samples. Measurements for strength, stability, or permeability often use different standard test methods for different soil types.

Gilson has an extensive video library with useful short videos on soil testing and related products – as well as numerous other topics. In addition, we have a reference guide on what Atterberg Limits are, the significance of the tests for determining the liquid, plastic and shrinkage limits of soils, and basic equipment needed.

**Other Considerations and Resources**

While there are ASTM and AASHTO standards for subsurface soil testing and pavement design, don't overlook regulations from your state department of transportation. The Federal Highway Administration lists all state DOT's.

State DOT websites may also include programs and workshops on related topics such as visual classification of soil and rock strata, how-to manuals, guides and more.

Other resources include:

- ASTM Geotechnical Engineering Standards – a comprehensive list
- Federal Highway Administration Geotechnical Aspects of Pavements Reference Manual
- Unified Soil Classification System Training (a PowerPoint Presentation of USDA NRCS)

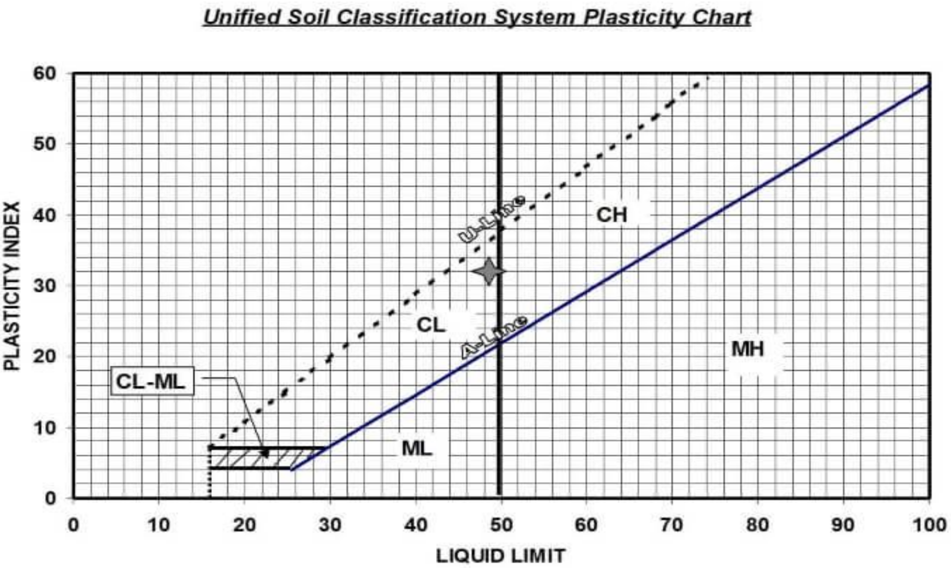


**Figure 5. Plasticity andix for soil classification.**

**The Base of It All**

Testing soil and rock for efficacy in any given construction project is not a new practice. One of the first geotechnical engineering classification systems for highway construction has been around since 1929, developed by Karl von Terzaghi (1883-1963). Terzaghi was considered one of the greatest minds in the field, a pioneer in geotechnical engineering, and the "father of soil mechanics."

In addition to his role in developing the civil engineering science of soil mechanics as it continues to be known today, he is credited for Terzaghi's Principle: *Total Stress = Effective Stress = Pore Water Pressure*. He is also recognized for his theories of consolidation, bearing capacity, and stability.

Terzaghi was one of a trio of visionaries in soil testing, forever connected by their work in testing and classification of soil. Also ahead of his time was Albert Atterberg (1846-1916), whose name goes down in history for developing the Atterberg Limits tests; he also developed a soil classification system in 1900. Rounding out the trio was Arthur Casagrande (1902-1981) who worked with Terzaghi for 25 years in soil mechanics and soil testing apparatus. Casagrande was integral to developing the USCS – and refining the Atterberg Limits test, first known as the liquid and plastic test – and incorporating it into the USCS.

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