MATERIAL ANALYSIS – EARTH AS A BUILDING MATERIAL

ABSTRACT

Soils are the result of a long process of deterioration of the original parent rock. Depending on the chemical composition of the parent rock, the environmental conditions, and the physio-chemical process affecting the parent rock over centuries, soil can be formed in an infinite variety of compositions, and possess an endless variety of properties, such as: adhesion, cohesion, compactibility, bulk density, porosity, plasticity, capillarity and linear and volumetric shrinkage, among others.

Soils also are made up of a number of substances including gases, liquids and solids. Among their gaseous constituents are nitrogen, oxygen and carbon dioxide. They fill the voids in soil and come from the outside environment. The main liquid constituent is water, but soluble substances are also found dissolved in this water, present as organic materials (such as sugars) or mineral compounds (such as dissociated salts).

While the solid components in soil are largely mineral constituents, organic elements from plant and animal life are also present in soil. The mineral constituents are the result of the deterioration of the parent rock, as either fragments of the parent rock or as minerals making up these rocks. Mineral constituents make up the greatest part of soil. Houben and Guillaud (1989) subdivide them into two distinguishable groups: *unweathered* minerals (pebbles, gravels, sands and clays) and *weathered* minerals (silts and clays, ‹2μm, 10^{-6}m, 0.002 mm).

Weathered minerals are typed and classified by their capacity for cation exchange upon contact with water. Due to their sticky appearance and their binding function, weathered minerals were originally called colloids, derived from the French *colle* (glue). They are, however, mostly composed of clay minerals and therefore geologists refer to weathered minerals as clayey fractions rather than colloidal fractions. Clays are fine-grained minerals with particle diameters of ‹2μm (10^{-6}m, 0.002 mm)[1]. They are also called phyllite because they have a flat, sheet-like grain shape.

These sheets are composed by silica or alumina/magnesia-based hexagonal layers arranged in hundreds of stacks of columns with different distances between them (7, 10 and 14 Å). The natural binding force of clay minerals is the strength that keeps earthen materials together. This strength originates from the electrostatic forces between the clay layers which are not electrically neutral. The water contained in the soils is the bonding agent. Water is loaded with positive ions, or cations, thus balancing the negative charge of the clay sheets and shaping the soil as a building material. These clay sheets exhibit different structures that also determine a clay's swelling properties. This is how clays are classified into groups. Three main types make up the most frequently encountered clays: Kaolinites, Illites and Montmorillonites. These types all react differently to the addition or the subtraction of water by normal evaporation and therefore have an effect on the binding properties of the earthen materials.

The identification of the clay type is therefore crucial for the material modeling, expected behavior, and future deterioration. To be more precise, the distribution of clay particles

[1] This definition of a clay mineral was given in the nineteenth century to materials beyond the resolution of the optical microscope. Thus the designation *clay minerals* came into use for submicroscopic and crystalline material. However, it should be remembered that not all mineral grains in nature in the < 2 μm range are of the same mineral type. Non-clay minerals, such as quartz, carbonates, and metal oxides, most often can form 10%–20% or more of a clay-size assemblage in nature. Velde (1999)

determines the soil's texture, plasticity, compactibility, and cohesion as a building material. A soil's texture reflects the particle size distribution (organic, gravely, sandy, silty, clayey); plasticity indicates its ability to submit to deformation without elastic failure, as characterized by cracking or disintegration; compactibility is a soil's ability to be compacted, characterizing its porosity and reaction to water; and cohesion defines a soil's capacity for the grains to remain together under tensile and compressive stress.

As defined by Teutonico"… soils consist of an assemblage of discrete particles of various shapes and sizes. The types and relative proportions of these particles give the soil a particular behavior"[2]. Unaltered soils can be used for construction, but they can also be modified to achieve desired working properties and increase their performance as a building material. This can be achieved by manipulating soil particles or adding other materials to the original composition. Additives can be organic or inorganic and will mostly impact the stability of the material (densification, reinforcement, cementation, linkage, impermeability, and hydrophobicity).

OBJECTIVES

As a result of this session, the participant should be able to:
- Understand the composition of earth as a building material
- Become familiar with earthen components by analyzing earthen samples
- Become familiar with different soil classification systems

CONTENT

Field exercise:

A simple field exercise will introduce the study of earth as a building material. The field exercise will be to define, describe (verbally and graphically), and document the different components found in different soils samples. The students will devise a classification system based only on their observations.

- The class will be divided in different groups and each group will receive approximately 2.5 kilograms of well-sorted soil in a plastic basin
- Each group is to carefully observe their sample and separate the different constituents
- Each group will propose a classification system to the class
- Together, the class will come up with a common classification system

Figure 3.1.1
Students from PAT course sorting soil components
PAT course, 1999 © J. Paul Getty Trust

Figure 3.1.2
Students presenting their soil visual classification
PAT course, 1999 © J. Paul Getty Trust

[2] Teutonico, Jeanne Marie. ARC A laboratory manual for architectural conservators. ICCROM: Rome, 1988, pp. 73.

Classroom Lecture:

The classroom lecture will introduce the subject and discuss the results of the field exercise. The instructor will give a general overview of the different soil classifications systems used in different countries and how applicable these systems are for the conservation field.

In support of the objectives of this section, the instructor will present:

- Introduction
    1. Congratulate students' participation with the field exercise and discuss the outcome and/or conclusions based on their classification systems
    2. Establish a relationship between this session and both the previous and upcoming sessions

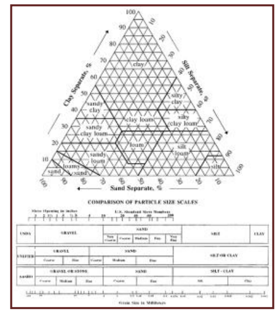
- Purposes for soil classification systems
    1. Ask the students why it is important to recognize the different components of an earthen sample
        a. Identify the differences between the components found by each group during the exercise
        b. Ask the students to brainstorm about the potential roles of each component
        c. Jointly define the importance of each earthen component
    2. Geotechnical classification system
        a. AASHTO—American Association of State Highway and Transportation Officials
        b. USCS—Unified soils classification systems
        c. Symbols
        d. Simple classification system
    3. Pedagogical classification system
        a. French Soil Reference System
        b. Food and Agricultural Organization (FAO)
        c. Specific types of soils
        d. Others
    4. Available information:
        a. Data bases and services
    5. Discuss the soil classification systems already developed and how the objectives of each of them make the components varied.

REFERENCES
💻 = Available online

Soil classification systems:

Geotechnical Engineers classify soils according to their engineering properties as they relate to use for foundation support or building material. Modern engineering classification systems are designed to allow an easy transition from field observations to basic predictions of soil engineering properties and behaviors. The most common engineering classification system for soils in North America is the **Unified Soil Classification System (USCS)**.
💻 http://www.naturalresources.nsw.gov.au/care/soil/soil_pubs/soil_tests/pdfs/usc.pdf

The AASHTO Soil Classification System was developed by the **American Association of State Highway and Transportation Officials (AASHTO)**, and is used as a guide for the classification of soils and soil-aggregate mixtures for highway construction purposes. The classification system was first developed in 1929, but has since been revised several times.



Natural system approaches to soil classification, such as the **French Soil Reference System** (Référentiel pédologique français) are based on presumed soil genesis. Systems have developed, such as one by the **United States Department of Agriculture (USDA)** which uses taxonomic criteria involving soil morphology and laboratory tests to inform and refine hierarchical classes.

ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Taxonomy/tax.pdf
Soil texture triangle showing the USDA classification system based on grain size

The Food and Agriculture Organization of the United Nations (FAO) developed a supra-national classification, also called the World Soil Classification, which offers useful generalizations about soils pedogenesis in relation to the interactions with the main soil-forming factors. It was first published in form of the UNESCO Soil Map of the World (1974). In 1998 this system was replaced by the **World Reference Base for Soil Resources.**
http://www.fao.org/ag/agl/agll/wrb/default.stm

Bibliography

📖 = Essential reading material

Identification and Characterization

Citations in this section deal with the identification and characterization of the discrete components of earthen structures. This section is divided into three subsections: Mineralogy, Clay Science and, Soil Science.

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