Particle Size and Mineralogy in Soil Taxonomy

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Particle size and mineralogical composition are fundamental criteria for grouping series into families of mineral soils. The compositional data are averaged over a discrete thickness of soil, usually the upper 0.25 to 1 m (10 to 40 in), referred to as the control section. Averaging the data through a control section and relying on compositional rather than genetic factors for soil classification both significantly improve the applicability of Soil Taxonomy for use by engineers. Several suggestions are made for further increasing its usefulness, including (a) distinguishing at the family level certain problem soils such as loess, perhaps by including density as a criterion; (b) emphasizing the depth and kind of bedrock when the rock is deeper than the present depth cutoff at 0.5 m (20 in); and (c) recognizing the dominant clay mineral when the clay content is less than the present cutoff at 35 percent.

This paper concerns compositional aspects of the new system of taxonomy for mineral soils. Soil composition, of course, has a high degree of relevance in civil engineering. Categories in the new Soil Taxonomy, from highest to lowest level, and populations currently recognized in each category are as follows:

Category	Population	Category	Population
Order	10	Subgroup	970
Suborder	47	Family	4 500 (U.S.)
Great group	185	Series	10 500 (U.S.)

Particle size and mineralogical characteristics of soils are fundamental for distinguishing families of mineral soils within subgroups. As pointed out in Soil Taxonomy (1), families and the lower category, series, serve purposes that are largely pragmatic. The pragmatism of the soil series lies in its use as an important component of the basic mapping unit appearing on published soil survey maps. But soil series are named for localities and thus are not very descriptive. A series name such as San Saba or Houston Black, for example, may convey little to anyone who has not experienced or excavated or built on or gotten stuck in these Texas pearls (2). The soil order Vertisol, or inverted soil, tells much more and implies a certain instability for volume change. Figure 1 shows such a severely expansive soil, the result of vertical mixing by soil sloughing into shrinkage cracks. In Figure 2, an example is shown of the slickensides that often characterize the individual ped faces of Vertisols and that indicate severe shearing disturbances as a result of expansion pressures.

A suborder name such as Ustert may say something about the climate, in this case seasonally hot. Further down in the classification a great group name such as Pellustert may indicate color, in this case black or gray, in what were previously referred to as Black Cotton soils, Rendzina soils, and Grumusols. Note that the name Pellustert designates the order (Vertisol), suborder (Ustert), and great group (Pellustert). The particle-size class, clayey, has the advantage of being both directly descriptive and in English, and the mineralogy class, montmorillonitic, flags the real problems. The latter terms will occur within descriptions of individual series, but they are essentially family descriptors.

Family differentiae for mineral soils are listed in Soil Taxonomy as follows: particle-size classes, mineralogy classes, calcareous and reaction classes, soil temperature classes, soil depth classes, soil slope classes, soil consistence classes, classes of coatings (of sands), and classes of cracks. That is, classes defined on the basis of variations in these properties are used to distinguish families of mineral soils within a particular subgroup.

It may be noted that the new Soil Taxonomy is modeled from biological classification and uses some of the same words. There is an important distinction between soil and biological classifications: In biological systems, evolution occurs along discrete stems so that intergrades ordinarily do not occur above the genera level, whereas soils evolve in response to climatic and other factors that are not discrete. Soils, therefore, suffer intergrades at every classification level. This is recognized by defining intergrade subgroups that are still within a group but show intergrading tendencies to a different group, suborder, or order.

TEXTURAL CLASSES

Texture Versus Particle Size

Soil Taxonomy defines particle size as the entire particle-size distribution of a soil, whereas texture refers only to the fraction finer than 2 mm. Most engineers are familiar with the use of textural triangles to define textural terms such as silt loam and loam and probably realize the arbitrary nature of the subdivisions. The parent diagram [Figure 3(a)], still a commonly used chart in engineering, was originally devised in the 1930s by the predecessor of the U.S. Department of Agriculture, the U.S. Bureau of Chemistry and Soils. In the 1940s the triangle was changed [Figure 3(b)] to reflect a change in the definition of clay size from <0.005 to <0.002 mm. The revised chart, the one currently used by U.S. soil scientists, is more complicated, partly because it attempts to maintain the same class names for the same soils but introduces two additional classes, loamy sand and silt. In this system silt, like clay, may refer to either a particular range in particle sizes or to a textural class that combines several particle-size ranges. In the textural triangle proposed in the new Soil Taxonomy to differentiate soils at the family level, that ambiguity is avoided by changing clay to clayey and silt to silty [Figure 3(c)]. Furthermore, the new version has 7 classes instead of the previously defined 10 or 12, which many acknowledge as desirable. The new textural class boundaries also relate more closely to engineering classifications by having fewer subdivisions based on variability of sand contents.

Texture Versus Plasticity

The textural and engineering soil classification systems are not directly translatable because the latter are not based purely on texture (grain size) but also use plasticity data and thus reflect clay mineralogy. Furthermore, it is unlikely that a precise translation between textural and engineering classifications will ever be made because their purposes differ. Engineering classifications are directed toward variations in soil behavior relevant to engineering, and textural classifications are more concerned with scientific description. Although attempts to adapt an engineering classification to a textural triangle

[Figure 4(a)] must include gradational boundaries, such an adaptation is valuable for showing approximate interrelationships: The clays or clayey soils used in Figure 3 are usually A-7, the silty soils A-4, the sandy soils A-3, and so on. On this basis, the Soil Taxonomy textural triangle shown in Figure 3(c) correlates much better with engineering classes than the earlier textural triangles.

A more accurate presentation of engineering classes in the triangular form can be made by substituting the plasticity index for percentage of clay and liquid limit for percentage of silt [Figure 4(b) and (c)]. The resulting diagrams are comparable to one another and somewhat comparable to the previous textural triangles, except that in the American Association of State Highway Officials (AASHO) and Unified Soil Classification systems the percentage of sand is ignored below 65 and 50 percent (on a gravel-free basis) respectively. Note that different size boundaries are used to define the gravel fraction.

Texture as a Criterion in Soil Taxonomy

The textural terms in Figure 3(c) present a further compromise with the common engineering definition of the sand-silt break at the No. 200 (0.074-mm) sieve because here the soil scientists' very fine sand (0.100 to 0.050 mm) is treated as silt for family groupings of silty soils or as sand for groupings of sandy soils. The use of particle size to define soil families is direct and graphic: Clayey means soils averaging 35 percent or more clay, fine means soils with 35 to 60 percent clay, very fine means soils with 60 percent or more clay, and so on.

Figure 1. Vertisol.

Figure 2. Slickensides in a Vertisol.

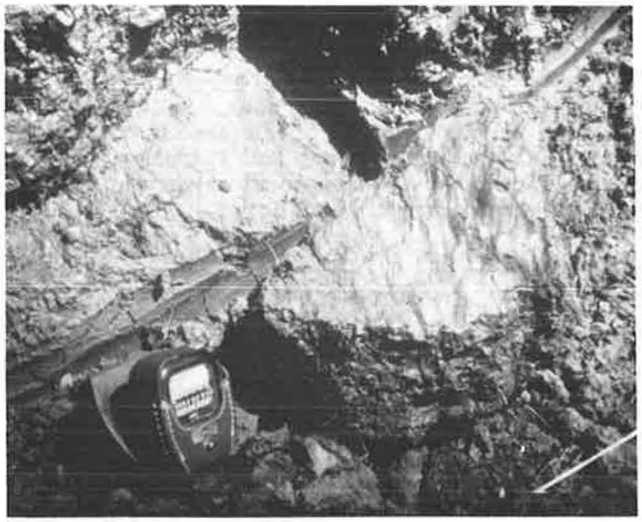
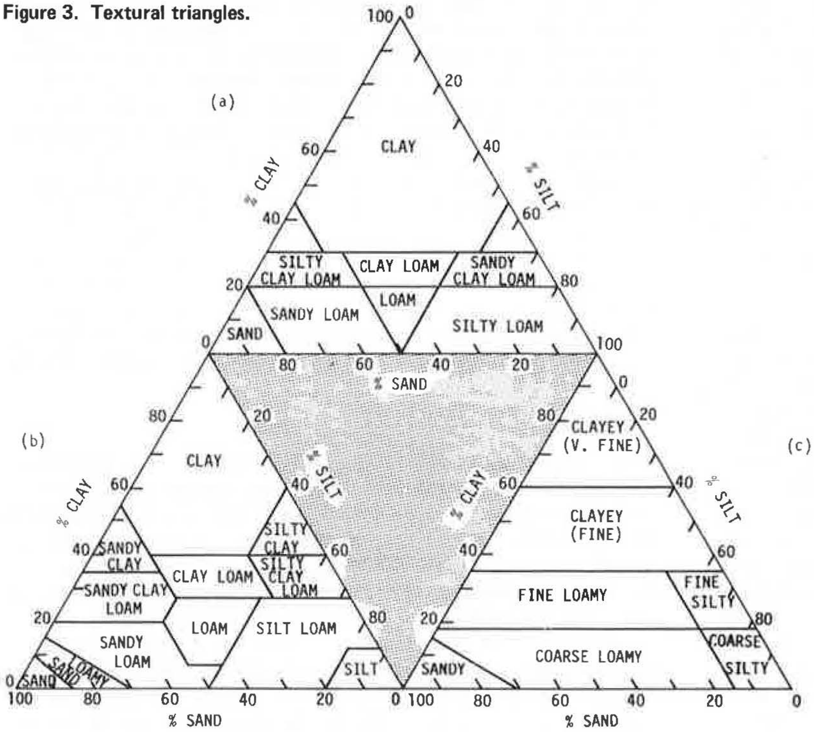


Figure 3. Textural triangles.



Particle-size classes for family groupings are as follows (1):

1. Fragmental: Particles are stones, cobbles, gravel, and very coarse sand, with too little fine earth to fill interstices larger than 1 mm.
2. Sandy-skeletal: Particles coarser than 2 mm are 35 percent or more by volume, with enough fine earth to fill interstices larger than 1 mm; the fraction finer than 2 mm is that defined for the sandy particle-size class.
3. Loamy-skeletal: Coarse fragments are 35 percent or more by volume with enough fine earth to fill interstices larger than 1 mm; the fraction finer than 2 mm is that defined for the loamy particle-size class.
4. Clayey-skeletal: Coarse fragments are 35 percent or more by volume, with enough fine earth to fill interstices larger than 1 mm; the fraction finer than 2 mm is that defined for the clayey particle-size class.
5. Sandy: The texture of the fine earth includes sands and loamy sands, exclusive of loamy very fine sand and very fine sand textures; coarse fragments are less than 35 percent by volume.
6. Loamy: The texture of the fine earth includes loamy very fine sand, very fine sand, and finer textures with less than 35 percent clay; coarse fragments are less than 35 percent by volume. Table 1 gives data for four loamy particle sizes.
7. Clayey: The fine earth contains 35 percent or more clay by weight and coarse fragments are less than 35 percent by volume. Clayey includes (a) fine, a clayey particle size that has 35 to 60 percent clay in the fine-earth fraction; and (b) very fine, a clayey particle size that has 60 percent or more clay in the fine-earth fraction.

In three cases particle-size names are replaced by other modifiers.

1. Psamments and Psammaquents are by definition sandy soils; a particle-size class name is redundant.
2. No size class is used for soils containing appreciable amounts of amorphous gels, such as Andepts and Andic subgroups.
3. Particle-size class names are not used if the organic content is high and particle size has little bearing on chemical and physical properties.

In the second and third cases given above, the following terms may substitute for particle-size class names, reflect both particle size and clay mineralogy, and substitute for both (1):

1. Cindery: More than 60 percent (by weight) is volcanic ash, cinders, and pumice and 35 percent or more (by volume) is 2 mm or larger (weight percentages are estimated from grain counts, and a count of one or two dominant size fractions of conventional mechanical analysis is usually sufficient for the placement of the soil).
2. Ashy and ashy-skeletal: Ashy is 60 percent or more (by weight) volcanic ash, cinders, and pumice and less than 35 percent (by volume) is 2 mm or larger. Ashy-skeletal is 35 percent or more coarse fragments (by volume), and fine earth is ashy.
3. Medial and medial-skeletal: Medial is less than 60 percent (by weight) volcanic ash, cinders, and pumice in the fine earth; less than 35 percent (by volume) is 2 mm or larger; and the fine-earth fraction is not thixotropic. Medial is dominated by amorphous material. Medial-skeletal is 35 percent or more coarse fragments (by volume), and the fine-earth fraction is medial.
4. Thixotropic and thixotropic-skeletal: Thixotropic is less than 35 percent (by volume) 2 mm or larger, and the fine-earth fraction is thixotropic. Thixotropic-skeletal is 35 percent or more coarse fragments (by volume), and the fine-earth fraction is thixotropic.

Particle-size classes in vertical sequences within a profile that differ significantly in pore-size distribution, so that movement and retention of water are seriously affected, are recognized as strongly contrasting particle-size classes. The transition zone between two contrasting layers must be less than 12.5 cm (4 in) thick to be designated as strongly contrasting. Examples of strongly contrasting particle-size classes are (a) sandy over clayey, (b) loamy-skeletal over fragmental, and (c) fine-silty over sandy. Forty combinations listed in Soil Taxonomy qualify for strongly contrasting particle-size classes (1).

CONTROL SECTION

The control section is the depth range through which particle-size and mineralogy data are averaged. It is a concept that should be favored by engineers, particularly when it is contrasted with the previous practice of designating the texture of the A horizon only, which ordinarily is not even used in engineering. The control section reaches much deeper, although for engineering purposes it probably can never go deep enough. The control section shown in Figure 5 is 0.25 to 1 m (10 to 40 in) in depth. Textural and mineralogical data from the control section are now averaged for classification at the family and series levels. The A, B, and C horizons in the soil profile still designate topsoil, subsoil, and parent materials.

The control section roughly means the following:

1. In shallow soils less than 0.36 m (14 in) thick over rock or a hard layer (fragipan or duripan or petrocalcic horizon) or perennial frost, the entire thickness above the contact is used.
2. In deeper soils with argillic horizons, the control section is the upper 0.5 m (20 in) of the clay-enriched horizon or the entire horizon if it is thinner than this. Overlying A horizon and underlying fragipan or duripan or petrocalcic horizon are not included.
3. In deeper soils with argillic horizons and contrasting textures, the depth is extended to 1 m (40 in) and both textures are named, e.g., sandy over clayey.

Detailed definitions of the control section are found in Soil Taxonomy (1). Advantages for engineering use are that the subsoil rather than the topsoil is emphasized and data are averaged over a significant depth rather than presented for minuscular sublayers such as B_{21}. It must be recognized that little or no emphasis is given the underlying material, which may still comprise a major portion of what engineers use. Instead, the control section tends to represent a finer grained extremity of the soil, which also supplies some of the most aggravating engineering problems.

MINERALOGICAL CRITERIA

Clay Mineralogy

The dominant clay mineral in the <0.002-mm (clay-size) fraction of clayey soils gives a classification of halloysitic, kaolinitic, montmorillonitic, illitic, vermiculitic, or chloritic. If no one clay mineral dominates, the class is referred to as mixed. Because the clay mineralogy determined by X-ray diffraction is not absolutely quantitative, other properties such as volume change and chemical properties often provide clues, and the domi-

Figure 4. Engineering soil classifications adapted to textural triangles.

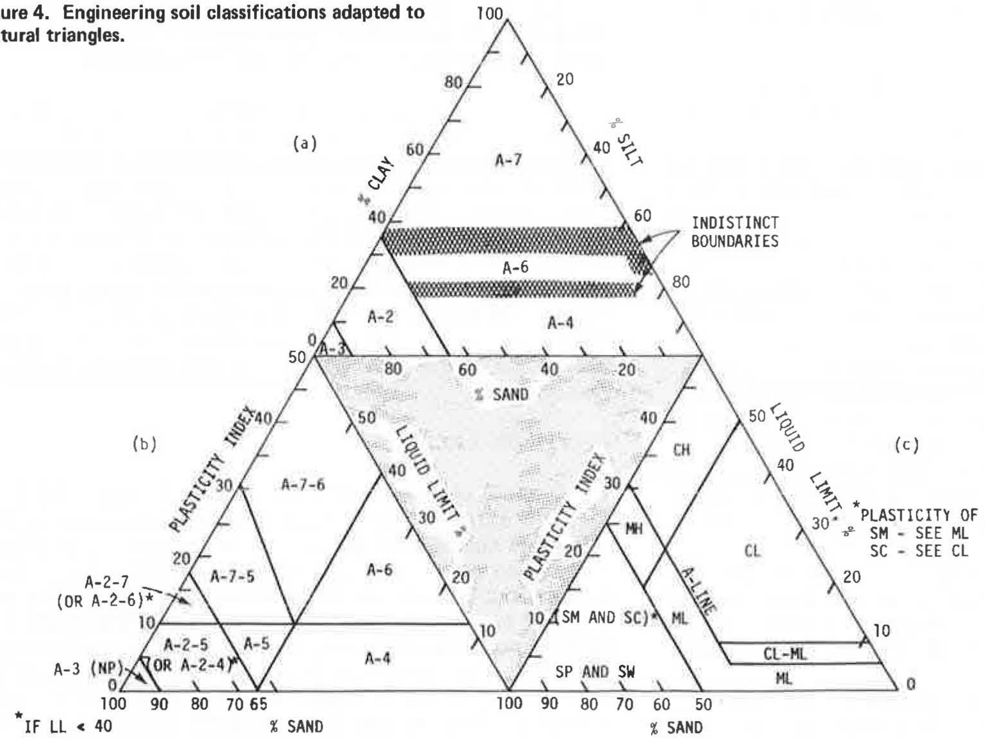
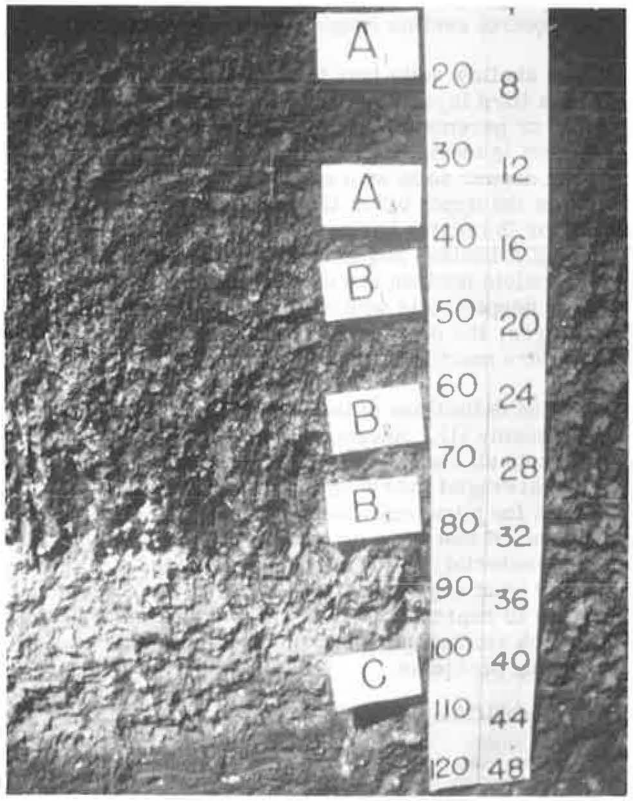


Figure 5. Control section.



nant mineral may be identified insofar as it affects behavior. Amorphous material may be identified by the absence of a substantial X-ray pattern and by a very high pH-induced cation exchange capacity (1).

A supplementary volume-change test referred to as the coefficient of linear extensibility (COLE) takes the following form:

Table 1. Contents of loamy particle sizes.

	Content			
	Fine Sand or Coarser Particles			
Particle Size	Percentage by Weight	Size (mm)	Fragments (cm)	Clay in Fine-Earth Fraction (%)
Coarse loamy	≥15	0.25 to 0.1	≤7.5	<18
Fine loamy	≥15	0.25 to 0.1	≤7.5	18 to 35
Coarse silty	<15	0.25 to 0.1	≤7.5	<18[a]
Fine silty	<15	0.25 to 0.1	≤7.5	18 to 35

[a] Carbonates of clay size are not considered clay but are treated as silt.

$$COLE = (L_m - L_d)/L_d = (L_m/L_d) - 1 \qquad (1)$$

where

L_m = length of an intact soil clod after equilibration at 0.33-bar (33-kPa) moisture and
L_d = length when dry.

Hallberg (3) recently showed the relations between COLE and the more conventional engineering measures, shrinkage limit (SL) and shrinkage ratio (SR):

$$SL = 100\,[MC - (1/Dbm) - (1/Dbd)] \qquad (2)$$

$$SR = Dbd \qquad (3)$$

$$COLE = (Dbd/Dbm)^{1/3} - 1 \qquad (4)$$

$$VC = 100[(COLE + 1)^3 - 1] \qquad (5)$$

where

MC = moisture content as a fraction,
Dbd and Dbm = dry and moist bulk densities respec-

tively measured in the COLE test, and
VC = percent volume change.

It would appear that the COLE test may give a more meaningful measure of volume-change characteristics than shrinkage limit because it is performed on undisturbed soil samples rather than after drying, pulverization, and sieving and thus includes effects from the natural soil structure.

Silt, Sand, and Whole-Soil Properties

Class names are also designated if nonclay minerals such as carbonates, iron oxides, or micas tend to dominate soil properties. Selected examples of these mineralogy classes are given below.

Class	Description
Carbonatic	>40 percent carbonates plus gypsum, of which carbonates are 65 percent
Gypsic	>35 percent carbonates plus gypsum, of which carbonates are 65 percent
Micaceous	>40 percent mica (by weight, based on grain counts)
Siliceous	>90 percent quartz, chalcedony, and opal
Ferritic	>40 percent iron reported at Fe_2O_3
Oxidic	>40 percent iron, but percentage iron plus percentage gibbsite exceeds ⅕ of percentage clay
Mixed	<40 percent any one mineral except quartz

Calcareous and reaction classes are recognized in selected taxa. Calcareous classes are applied to a section between a depth of 25 and 50 cm (10 and 20 in) unless a lithic or paralithic contact is present. They are used only in the names of families of Entisols, Aquepts, and most Aquolls. Calcareous is applied to the above taxa when the fine-earth fraction effervesces in all parts of the depths listed above with dilute HCl. Noncalcareous indicates that the soil does not effervesce in all parts listed above, but it is not used as a part of the family name. The term calcareous, if used as a part of the family name, is considered to be a subclass of mineralogy and is shown in parenthesis, i.e., fine-loamy, mixed (calcareous) mesic Typic Haplaquoll.

Reaction classes of acid and nonacid are used in selected taxa and are defined as follows:

1. Acid—pH is 5.0 in 0.01 mole $CaCl_2$ (2:1) throughout the control section (or about 5.5 in H_2O, or 1:1).
2. Nonacid—pH is 5.0 or more in 0.01 mole $CaCl_2$ (2:1) in at least some part of the control section. The term nonacid is not used in the family name of calcareous soils.

Reaction classes are used only in names of families of Entisols and Aquepts; they are not used in sandy, sandy-skeletal, and fragmental families of these taxa nor in Sulfaquepts and Fragraquepts or families that have carbonatic or gypsic mineralogy.

Except for the calcareous classes, the control section for mineralogy classes is the same as that used for particle-size classification. Contrasting mineralogy modifiers are not recognized except where substitutes for particle-size class modifiers have been used. If there are layers of contrasting particle size in the control section, the mineralogy class of the upper part of the control section is definitive of the family mineralogy.

LIMITATIONS

Parent Material

The family category was designed to provide the primary grouping within a subgroup for properties that are useful in evaluating the potential for plant growth as well as engineering purposes. However, at present there are contrasting soils not separated at the family level.

Mahaska and Adair are two midwestern soil series with contrasting properties that are important to recognize for either agronomic or engineering uses. Both are classified as members of the fine montmorillonitic mesic family of Aquic Argiudolls. Properties of soils in these two series are estimated in Tables 2 and 3.

The Adair series (Table 2) consists of moderately well-drained to somewhat poorly drained soils with clayey subsoils. These soils form in reddish clayey Late Sangamon Paleosols developed in Kansan glacial till, under a native vegetation of tall prairie grasses. Adair soils typically have a black to very dark gray clay loam surface layer 43 cm (17 in) thick. A stone line is at the base of the surface layer. The subsoil from 43 to 63 cm (17 to 25 in) is a mottled dark brown and dark reddish-brown clay. Below this is a mottled dark yellowish-brown clay loam to a depth of 152 cm (60 in). The Adair series soils in Table 2 had a few concretions of lime in the lower part and slopes from 5 to 18 percent.

The Mahaska series (Table 3) consists of nearly level to gently sloping, somewhat poorly drained soils formed in Wisconsin loess under a native vegetation of tall prairie grasses. These soils occur on moderately wide upland ridges, in coves of drainageways, and on high stream benches. Mahaska soils typically have a black silty clay loam surface layer 45 cm (18 in) thick. The subsoil, which extends to 152 cm (60 in), is mottled dark grayish-brown to olive-brown silty clay loam in the upper part and mottled light olive-gray medium silty clay loam in the lower part. The substratum is gray silty clay loam, and slopes range from 1 to 5 percent.

Maximum dry density of these loess-derived soils ranges from 1400 to 1600 kg/m^3 (90 to 100 lb/ft^3). The glacial till in the lower solum of Adair soils has a maximum dry density of 1750 to 1900 kg/m^3 (110 to 120 lb/ft^3). The AASHO classification of Mahaska is A-7; the Adair soils generally classify as A-6. Other significant differences not recognized at the family level concern the percentage of material less than 7.5 cm (3 in) in diameter passing selected sieve sizes, especially the No. 40 and 200 sieves, and the liquid limit and plasticity index (Tables 2 and 3).

It is important in evaluating the potential of an area for engineering purposes to recognize the type of parent material from which the soils formed (such as Wisconsin loess or Kansan glacial till). Because the new Soil Taxonomy is nongenetic, soils from contrasting parent materials occurring on the same landscape may be grouped in the same family. Figure 6 shows an example of loess (the lighter soil in the figure) overlying glacial till. The physical properties of loess-derived soils in situ often are in strong contrast to the properties of till-derived soils, mainly because of a difference in density. Loess-derived soils are normally consolidated and, close to the source, are underconsolidated or collapsible (4); till-derived soils are normally consolidated or overconsolidated. Loess is more erodible and generally has a higher permeability and a much lower bearing capacity than glacial till with the same clay content. Loess soils exert a much higher active pressure on retaining walls and bridge abutments. These characteristics are closely related to and predictable from the parent material, which should therefore be recognized in the family category.

Depth to Rock

Another contrasting property not recognized at the family

Table 2. Estimated properties of Adair series soils.

Item	Depth (cm) 0 to 43	 43 to 86	 86 to 152
USDA texture	CL	SIC, C, CL	CL
Classification			
Unified	CL	CL, CH	CL
AASHO	A-6	A-6, A-7	A-6
Fraction >7.5 cm, %	0	0	0
Material <7.5 cm passing sieve, %			
No. 4	95 to 100	95 to 100	95 to 100
No. 10	80 to 95	80 to 95	80 to 95
No. 40	75 to 90	70 to 90	70 to 90
No. 200	60 to 80	55 to 80	55 to 80
Liquid limit	30 to 40	45 to 55	35 to 40
Plasticity index	11 to 20	20 to 30	15 to 25
Permeability, cm/h	0.5 to 1.5	0.15 to 0.5	0.5 to 1.5
Available water capacity, cm/cm	0.43 to 0.48	0.33 to 0.4	0.35 to 0.4
Soil reaction, pH	5.6 to 6.5	5.6 to 6.5	5.6 to 6.5
Shrink-swell potential	Moderate	High	Moderate
Corrosivity			
Steel	High	High	High
Concrete	Moderate	Moderate	Moderate
Erosion factors			
K	0.43	0.43	—
T	3	—	—
Wind erosion group	6	—	—

Notes: 1 cm = 0.39 in.
Iowa soils examined in November 1973. No measurable salinity.

Table 3. Estimated properties of Mahaska series soils.

Item	Depth (cm) 0 to 45	 45 to 129	 129 to 185
USDA texture	SICL	SICL	SICL
Classification			
Unified	CL, OL	CH	CL
AASHO	A-7	A-7	A-7
Fraction >7.5 cm, %	0	0	0
Material <7.5 cm passing sieve, %			
No. 4	100	100	100
No. 10	100	100	100
No. 40	100	100	100
No. 200	95 to 100	95 to 100	95 to 100
Liquid limit	41 to 50	50 to 60	41 to 50
Plasticity index	15 to 25	20 to 30	15 to 25
Permeability, cm/h	1.5 to 5	0.5 to 1.5	1.5 to 5
Available water capacity, cm/cm	0.53 to 0.58	0.35 to 0.45	0.45 to 0.5
Soil reaction, pH	5.1 to 6	5.1 to 5.5	5.6 to 6.3
Shrink-swell potential	Moderate	High	High
Corrosivity			
Steel	High	High	High
Concrete	Moderate	Moderate	Moderate
Erosion factors			
K	0.37	0.43	—
T	4	—	—
Wind erosion group	7	—	—

Notes: 1 cm = 0.39 in.
Iowa soils examined in March 1973. No measurable salinity.

Figure 6. Loess overlying glacial till.

Figure 7. Bedrock at a depth not recognized in the family category.

level is the presence of bedrock at a depth of 0.5 m (20 in) or more. For example, Dubuque soils are developed in the 0.5 to 1 m (20 to 40 in) of loess overlying limestone bedrock and are classified as members of the fine-silty mixed mesic family of Typic Hapludalfs. The family name gives no indication of the bedrock hazard within the 0.5 to 1-m (20 to 40-in) depth. The engineering significance of bedrock at the 0.5 to 1-m (20 to 40-in) depth scarcely needs elaboration: Rock may increase the cost of excavation by a factor of 10 or more and will severely restrict the amount of soil available for borrow. Bedrock at the depth shown in Figure 7 is not currently recognized at the family level. Recognition of lithic content would greatly improve the usefulness of the family category for engineering purposes. Identifying the rock type would further aid in predicting leakage potential for ponded reservoirs or pollution of aquifers from sanitary disposal sites.

Clay Mineralogy

A question can be raised as to why the clay mineralogy of soils classified as fine-silty or fine-loamy (clay content of 18 to 35 percent) is not recognized at the family level. Soils with different clay mineralogies have contrasting behavior and nutrient-supplying potential at the lower clay contents as well as within the clayey range. Clay mineral differences in fine-silty and fine-loamy particle-size classes could be recognized at the family level by using criteria currently used for clayey soils.

SUMMARY AND RECOMMENDATIONS

1. Soil Taxonomy, the new soil classification system adopted by the Soil Conservation Service of the U.S. Department of Agriculture, emphasizes various measured soil properties, including particle size, clay mineralogy, color, and field relationships, to define soil orders, suborders, great groups, subgroups, and families. This is in contrast to earlier systems, which had a genetic emphasis. The advantage of the new system for engineering is that it rests on hard data and thus reduces the role of speculation and changing opinion concerning soil origins.

2. The expressed intent of the family category is to group soils having similar physical and chemical properties that affect their response to management and manipulation. One disadvantage of going to a nongenetic classification is that important information that does relate to soil genesis may be lost or relegated to a secondary role. An example cited in this paper is that of loess and till-derived soils occurring in the same family despite significant differences in physical properties. In that case a family distinction could be made on the basis of dry density or other factors. Such separations seem appropriate to increase the usefulness of the system for engineers.

3. The new Soil Taxonomy uses the concept of the control section to define the range of depths over which soil properties are averaged for classification. The control section emphasizes soil properties at greater depths than did previous classifications, which tended to emphasize properties of topsoil, a concept little used in engineering. The definition and use of control sections are therefore highly advantageous for engineers.

4. In this connection, an important contrasting property not presently recognized in the family category but that appears to deserve recognition because of its major influence on engineering uses is bedrock deeper than 50 cm (20 in). Although it may be argued that such an occurrence does not in itself strongly influence soil properties, the family designation is intended to be pragmatic in purpose and, from an engineering viewpoint, nothing could be more pragmatic than the knowledge that rock occurs at a depth of 0.6 to 0.9 m (2 to 3 ft).

5. The COLE value, a measure of the shrinkage of undisturbed soil clods, should be relevant to engineering uses and in fact may be more relevant than traditional engineering tests such as the shrinkage limit, which uses mixed and remolded soil.

6. Finally, the authors feel that the clay mineralogy of soils classified as fine-silty or fine-loamy (clay content of 18 to 35 percent) is pertinent and should be recognized at the family level.

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Soil Series and Soil Taxonomy

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Soil series are the lowest and most narrowly defined units in Soil Taxonomy. They have from the beginning been the primary vehicle through which information gained from experience with and research on soil performance has been accumulated, organized, and presented to assist with land-use and management decisions. Soil series are defined according to the kind, sequence, and thickness of soil horizons and the physical and chemical properties of each horizon. The occurrence of a soil series is limited to unique kinds of geologic formations, landscape positions, and climates. Most soil series are subdivisions of soil families in which specific ranges in composition, thickness, structure, or other properties are narrower than they are for the soil family. Some soil series include the full range of the soil family. Among the soil properties used to define each horizon of soil series are those that determine the performance of the soil as an engineering material. Important in situ properties such as density and seasonal moisture content have narrow ranges in each horizon of soil series.

Soil series are the lowest categorical level of Soil Taxonomy (13). They have a narrower range in properties and thus in occurrence and in performance than classes at the five higher categories in the system. Each soil series is uniquely placed into one of the classes of higher categories. Because all classes in Soil Taxonomy are mutually exclusive, the limit in all definitive properties used at categories above the series becomes part of series definitions. A soil series is thus confined within the range of one family. Most series are defined to include only a portion of a family although some cover the entire range of the family in most or all properties.

Soil series have been used as the basic unit of soil classification since the beginning of soil surveys in the United States in 1899. Soil series are the focal point of all of the information that soil scientists accumulate about soils. They are named after places where they were first identified, e.g., Miami.