the material for the good section came from a coarser portion of the same pit.

Space does not permit the listing of other examples but the above do indicate that high density is no panacea for base materials that are subject to frost damage This is reasonable because it is axiomatic that if a material is subject to damage by frost action, some volume change and therefore loss of density, is inevitable, even though it may be temporary. For example: the previously mentioned base with 99 percent relative compaction contained 8 percent moisture, approximate optimum, in the fall when the measurements were taken The following spring the moisture content was approximately 17 percent and the base was quite unstable. It is self evident that the original degree of compaction held little significance during the spring thaw.

Mr Campen also comments that some of the base mixtures are "poorly graded." It is part of the theme of this paper that bases which are poorly graded in the sense that the grading affects capillarity, are subject to frost damage.

The use of the term "supersaturation" has been questioned. Webster's dictionary defines "supersaturate" as "to add to beyond saturation". This definition describes what takes place in reaching a state of supersaturation. The distinction between the conditions "saturated" and "supersaturated" have been further carefully described in the text in order to avoid confusion in the use of the terms. If a better and more descriptive word for the condition here termed "supersaturated" is available, the suggestion would be appreciated.

PRINCIPLES AND TECHNIQUES OF SOIL IDENTIFICATION

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SYNOPSIS

The accurate complete identification of soils is the first and most fundamental step in all soil investigations for engineering works. Identification not only refers to the physical techniques of identifying soils, but also as an integral part refers to the careful, systematic and precise written and spoken identifications of soils, which can be made to convey definite and significant information on soil character An appraisal of the classification and identification approaches in soil investigations is made to show the fundamental importance and possibilities of the identification approach Identication places the emphasis on recognizing and establishing the identity and individuality of soils, and on identifying accurately and completely the inherent characteristis of each soil. The significant characteristics of the soil material, which determine behavior, and by which soils may be identified, are composition and inherent character with regard to the proportions and gradations of the granular gravel, sand and silt components, and the proportion, plasticity and clay qualities of the clay component The identification approach recognizes the inherently variable and complex character of soils and of natural situations, of which the soil is an essential part The behavior of soils must be considered in relation to the specific conditions that control in a situation Accurate complete identifications of soils, the rating of soils with regard to potential behavior characteristics, and the appraisal of natural situations with regard to the controlling conditions that determine the actual behavior of soils are fundamental and most important analyses in soil investigations. The principles of soil identification and a significant naming and identification of soils are discussed for granular soils and clay-soils. Interpretative ratings of soils are given with regard to fundamental behavior characteristics in order to give point to the principles and techniques of soil identification. The techniques of soil identification by visual and manual methods are presented in tables of identification techniques for three basic soil types: (a) Composite granular soils with less than five percent silt; (b) composite granular soils with more than five percent silt, and (c) composite clay-soils The techniques of identification are illustrated for each of these types. Soil identifications by visual and manual methods can be performed rapidly in the field and in the laboratory, and can be made accurate and significant. The great practical importance and use of soil identification may be judged by the fact that visual and manual methods probably suffice for 75 percent or more of all soil and foundation investigations, if properly made.

The purpose of this paper is first of all to bring to the attention of engineers and to emphasize the fundamental importance of complete accurate identification of soils in soil investigations for engineering works; second, to show that soil identifications by visual and manual techniques can be made rapidly in the laboratory and in the field, so that an experienced soil engineer can properly identify 10 to 20 or more samples per hour, depending upon the types of soils and upon the conditions under which the identifications are made; and third, to present basic concepts, principles and techniques for visual and manual identification of soils, as a practical beginning of a growing technique, and as a means for conveying more precise and significant information on the identity and character of soils. Some of these techniques have been quite commonly used, others have been developed and used successfully in practice and in student instruction by the writer over the past ten years. The great practical importance of soil identification may be judged from the fact that visual and manual methods probably suffice for 75 percent or more of all soil and foundation investigations, if properly made. When a soil has been properly identified, then ts significant characteristics that determine behavior become known and are relevant to any situation and to any field of soil work.

The first and most basic concept and requirement of the scientific method, as applied to soil and foundation engineering, is that the soil engineer must adequately and reliably know the soils and the controlling conditions with which he is dealing. The prime purposes and objectives of soil investigations for engineering works are first to provide adequate and reliable information on soil character and soil behavior, as a basis for making the decisions for design and construction; second, to make full and effective use of past experiences in soil work, so as to avoid costly mistakes, and to reduce the uncertainties and hazards inherent in soil and foundation work; and third, to take advantage to the fullest extent of the new developments and economies in design and construction of engineering works.

APPRAISAL OF THE CLASSIFICATION APPROACH

The present approach in soil and foundation work for highways, earthdams and airports has placed the emphasis almost exclusively on the classification of soils. The term classification has been used to mean many different things. Strictly speaking, to classify soils is to place or to arrange the soils into classes. A classification is a systematic arrangement of classes according to certain common characteristics. The classification approach has grown out of the idea that the difficulties not only of accurately identifying soils, but also of precisely naming and describing individual soils were considered to be too great to be surmounted with any degree of success, because of the inherently variable and complex character of soils. The classification of soils into classes for particular fields of soil work was therefore considered to be the simpler and more practical approach.

The growing acceptance and use of classification in all fields of soil work, however, is setting a pattern of thinking and of doing, which is falling short of the basic concept and requirement of the scientific method and of the prime objective of soil identifications, namely, that of adequately and reliably knowing the soils and the controlling conditions. As an example of what may be accomplished by fulfilling these basic requirements, we should consider the outstanding achievements in the field of pure and applied chemistry. These have come directly from painstaking research to identify and to know materials, and from a willingness to use extraordinary refinements, if need be. Of equal importance is the fact, that every individual chemical is given a significant precise name and is expressed in an exact chemical formula, which conveys precise quantitative information to the chemist on the composition and essential nature of the chemical. The implications with regard to soil and foundation engineering should be clear.

First of all we should recognize classification for what it really is, namely, a rating of soils with regard to a certain limited number of qualities and potential behavior characteristics only, that are considered to be significant in a certain field of soil work. The rating of soils is an important and fundamental step in soil investigations, because it informs the soil engineer regarding certain potential behavior characteristics, which may control in a given situation, and provides a basis for judgment in evaluating and using factual information. But it must be recognized that a rating as to probable or potential behavior is essentially interpretative and not factual information, because it is deduced or inferred by interpretations of identifications of soils or of soil test data Identification, on the other hand, is factual information, because it is based upon observed or experimentally determined facts, namely the identifying and distinguishing characteristics of soils Soil test data and actual observed or measured behavior of soil in the field are likewise factual information. These distinctions between factual and interpretative information must be clearly drawn.

The present confusion has resulted from the attempt to make classification assume the dual role of both identification and classification or rating, and in so doing to combine factual and interpretative information. As a consequence classification is considered to be of factual nature and to carry the weight of facts. But because of the primary purpose and nature of classification, more importance and significance is really given to the interpretative rating aspect than to the factual identification aspect In classifying soils into particular classes pertaining to a given field of soil work, there is the tendency to consider that classification is a sufficiently adequate identification, and to obtain only sufficient soil identification data to place a soil into a particular class, as a routine procedure. Of necessity the soils of a class or sub-class must be defined in relatively broad terms of a range of a certain limited number of soil characteristics only, as a basis for the rating, which fix the limits of the soil class and which are considered significant with regard to the particular field of soil work. It is evident that, when a soil is designated only by its classification, it loses its specific identity and individuality within the broad limits of a class. Hence the real character of a soil can only be very roughly known from its classification, because only that part of the identification, even if complete, remains or is known, which was the basis or criteria for the rating. In the application of classification a person can not make full and effective use of the original soil test data, unless he goes back directly to such data, in which case, classification loses its reason for being. Hence classification of itself, is not a sufficiently adequate identification of soils, because it can not disclose those inherent characteristics, which my be responsible for the actual behavior of soils

Many people using a particular classification naturally come to think, speak and write about soils almost exclusively in terms of their convenient short-hand class names or class symbols As a consequence, under the present classifications the accumulated information and experience on soils and soil behavior in one field of soil work can not be easily translated into terms readily understood and used by those engaged in other fields of soil work, who are not familiar with the particular classification used; or even in different aspects of the same field of soil work, where the given rating may have little or no significance, for example, where quite different information is required on the same soil, when used for a subgrade for a highway, stable slopes for a cut, backfill for a retaining wall, excavation and unwatering of the foundation site of a highway bridge, or for supporting the foundations of the bridge. There is a serious lack of a significant precise naming and identification of soils to disclose completely the inherent characteristics that may be responsible for behavior and to convey precise information of general application in all fields of soil work.

People using a particular classification also come to think of soils primarily in terms of soil classes and of soil behavior in terms of class behavior characteristics. Since soil character can only be very roughly known from classification to be within the broad limits of a soil class, then the qualities and behavior likewise can only be very roughly known within broad limits. It must be emphasized that the fundamental behavior characteristics of soils cut across all soil classes of every classification in some degree, for example: (1) drainage, capillarity and frost heaving characteristics; (2) plasticity, swelling and shrinkage characteristics; (3) compactibility to high density, (4) relative supporting value and permanence of support, etc As a consequence the variations of these fundamental behavior characteristics, both as to kind and degree within the limits of a soil class are too important to permit the soil classes being really significant for the essential purposes of rating soils specifically and adequately for a given situation.

In the use of classification the thinking of soil identity and soil character only in terms of soil classes, and the thinking of soil behavior in terms of class behavior characteristics only, leads to an over-simplification of the conceptions of the character and actual behavior of soils. Hence the real nature of a situation and the particular inherent controlling conditions may not be fully visualized, comprehended and taken into account Classification attempts to be inclusive and to bring together into a greatly over-simplified routine technique the fundamental techniques and analyses of identification and rating. The tendency is for people to accept classification and to depend too much upon classification, and even to expect to find simple ready-made answers to all types of soil problems, requiring a minimum of real thinking and of judgment. But in view of the short-comings and limitations, classification in many situations is not capable of disclosing the relative dominance of the particular fundamental behavior characteristics, which will be responsible for the actual behavior of the soils under different controlling conditions inherent in different natural situations. Therefore classification can not provide sufficiently adequate, complete and accurate factual and interpretative information in such cases. The inherent variability and complexity of natural soils and of natural situations and construction practices impose definite limitations on what classification can and can not do, contrary to the opinion that classification is the simpler and more practical approach. In the final analysis it is this variability and complexity, which will have to be thoroughly investigated and evaluated before further progress is made. But to be of practical value, the information obtained must be expressed in significant, precise and readily understood terms of universal application.

Factual information does not change with time, except when errors have to be corrected, or when it can be made more complete as additional facts are discovered. Factual information forms a growing body of authoritative information. But in the nature of things interpretative information must be constantly checked against actual experience and be brought up to date. Classification, because of its dual role of combining factual and interpretative information, has crystallized into fixed forms. The present classifications thus form too restrictive and inflexible frameworks to readily permit of adaptation, revision and growth fully in keeping with scientific developments in soil mechanics and foundation engineering, and with the increase in knowledge and experience. The shortcomings of classification are inherent in the classification approach, and can not be corrected properly or eliminated by modifying and expanding the present classifications, by subdividing the soil classes, and by setting different class limits, because these devices are not fundamental and do not go to the root of the difficulty.

First of all, in order to resolve these difficulties and to satisfy the basic and essential requirements of the scientific method and of the objectives of soil investigations, namely, that of adequately and reliably knowing the soils and the controlling conditions, there must be a rigorous, definite and complete separation of identification from classification. The proper emphasis must be given to identification as the first and most fundamental step in soil investigations. When identification is meant, the word identification must be used exclusively. Second, there must be a significant, accurate and complete naming and identification of soils, in order to convey definite precise information of general application in any field of soil work, and to disclose accurately and completely the inherent characteristics of soils that are responsible for behavior. The complete identification should be given for every soil The classification or rating should never be given alone, as now done, but should be attached to the identification as a qualifying term. Third, the present classifications should be broadened to adequately cover specific ratings regarding the relative dominance of the fundamental behavior characteristics, which cut across all soil classes of every classification. The classifications must be made flexible and adaptable, so as to permit of being checked against experience and brought up to date with increasing knowledge and experience.

This would probably appear at first sight to be quite unsatisfactory and even unworkable to those using classification, because it would seem as though familiar ground and practices were cut out from under them. The change to the identification approach, however, may not be as difficult or as disturbing as first thought. It would invole primarily a change in emphasis from the thinking of the identity of soils in terms of soil classes and of soil behavior in terms of class behavior characteristics to the thinking of the identity and individuality of each soil with regard to its specific character and potential behavior characteristics, that may be responsible for the actual behavior. This does not mean that the experiences and information accumulated under classification are to be discarded or lost, but on the contrary that part which is fundamental and sufficiently complete and correct, particularly where the factual original soil test data is available, will become more significant and more generally useful.

THE IDENTIFICATION APPROACH

Identification places the emphasis on recognizing and establishing the identity and individuality of soils, and on identifying accurately and completely the composition and inherent characteristics, that may be responsible for the actual behavior. Identification not only refers to the physical techniques of identifying soils, but also, as an integral and essential part, refers to the careful, systematic and precise written and spoken identification or naming of soils, which can be made to convey definite and significant information on the identity and inherent character of individual soils of universal application of soil engineering work.

The identification approach recognizes the inherently variable and complex character of soils, of natural situations and of construction practices, and emphasizes the essential need for the best information obtainable within practical, time and economic limits. Identification, as a growing technique, can be made to keep pace with the increase in knowledge and experience, and with the need for better techniques and for more adequate and reliable information. Each soil investigation is really a work of discovery and research to uncover and to recognize the existence of soil problems, to interpret and to comprehend fully their essential nature, to make full and effective use of past experiences, and to provide basic and specific information on soil behavior. In order to emphasize the fundamental role of identification, as the first and most fundamental step in soil investigations, and to give point to the basic fact that the soil engineer must adequately and reliably know not only the soils but also the conditions with which he is dealing, the fundamental steps and analyses in the investigation of soil and foundation problems are given in sequence in Table 1.

The second important and fundamental step in soil investigations is to interpret soil character and to rate soils with regard to their qualities and potential behavior characteristics A complete rating of soils is of fundamental importance, because it informs the engineer first of all regarding those behavior characteristics, which may control or dominate in a given situation, and second, indicates what soil tests and investigations may be needed to provide basic and specific information on soil behavior. A number of tentative ratings of soils are given in this paper in the section on *Interpretation and Rating of Soils*. The ratings can be based upon significant criteria of accurately identified soil characteristics and of accurately determined physical and strength properties of soils from soil tests. These criteria can be properly established and checked from experience, and can be improved with the growth in knowledge and experience A few of the fundamental behavior characteristics of soils, which cut across all fields of soil work, and with regard to which soils can be potentially rated, are given in Table 2.

In order to have a proper perspective regarding soil behavior and the nature of soil problems, it must be recognized that the actual behavior of soils under any given circumstances is not only determined by the inherent characteristics by which soils may be identified and by the potential behavior characteristics with regard to which soils may be rated, but is conditioned by and is a part of a situation in its natural setting and as modified by construction practices. The actual behavior of a soil represents the complex interaction of its own potential behavior characteristics and of the controlling conditions inherent in a situation. But no simplicity of action is to be expected. The controlling conditions may considerably modify the potential behavior characteristics of soils, either to accentuate or to diminish the favorable or unfavorable characteristics. Situations may be expected to differ widely in the character and the importance of the controlling conditions, and to vary with seasonal moisture changes and with different construction practices. The character and behavior of soils must be considered in relation to the specific conditions that control in a given situation. The third important and fundamental step and analysis in soil investigations is to make a careful and complete appraisal of the natural situation of which the soil is an essential part with regard to the inherent controlling conditions and with regard to the probable actual behavior of the soils. The major problem in soil investigations is to recognize and to identify significant differences in soil character, and to recognize and to appraise significant differences in situations that are or may be responsible for differences in actual behavior of soils. In order to make full and effective use of past experiences in analyzing present situations, these experiences must be fully interpreted and comprehended by comparing what really happened with what was expected and by determining what qualities and behavior characteristics of the soils and what controlling conditions dominated and were responsible for the discrepancies

In soil and foundation work a person must be constantly on guard against allowing the

TABLE 1

THE FUNDAMENTAL STEPS AND ANALYSES IN SOIL INVESTIGATIONS

A. *Subsurface Explorations*

(1) Adequate information on subsurface soil conditions from boring records

(2) Representative samples of soils for identification and soil tests

(3) Adequate information on the controlling conditions inherent in a natural situation, which control actual behavior of soils

B. *Investigations and Analyses*

(1) Accurate and complete identifications of the soils by visual and manual techniques and (or) by laboratory identification tests

(2) a—The interpretation of soil character and the rating of soils with regard to their qualities and potential behavior characteristics

b—Detailed laboratory soil tests and investigations, as required to provide accurate and basic information on the strength and behavior characteristics of soils

(3) a—The appraisal of natural situations to determine the real nature and the inherent controlling conditions, and the probable actual behavior of soils under these conditions.

b—The appraisal of the physical factors, special requirements and limitations inherent in or imposed by the particular structure to be built, and by the probable construction methods and practices, that may influence or control the actual behavior of soils, or may be limiting in any way.

(4) The application of the information obtained above, and of the principles and concepts of soil mechanics to the analysis of the soil problems involved in a situation, and to the making of the decisions of design and construction.

TABLE 2

FUNDAMENTAL BEHAVIOR CHARACTERISTICS OF SOILS

1. Drainage, capillarity and frost heaving characteristics
2. Plasticity, swelling and shrinkage characteristics
3. Compactibility to high density and compaction characteristics
4. Compressive strength and compressibility characteristics
5. Shearing strength and plastic displacement characteristics
6. Consolidation characteristics with regard to magnitude and time rate of consolidation and to pore pressure development
7. Relative supporting value of soils in the natural and compacted states and permanence of support
8. Relative stability characteristics of soils in natural slopes and of compacted earth embankments.

techniques and analyses of identification, interpretation and rating, and appraisal to become merely a routine matter, and thus to lose their principal significance The failure to recognize, to comprehend and to take into account one soil characteristic or one controlling condition, or the failure to estimate properly their importance, may introduce uncertainties and difficulties into a situation of which the engineer may be quite unaware He then may never fully understand why soils behaved erratically or differently from what was expected Adequate reliable information is an insurance against unforeseen difficulties and reduces the uncertainties inherent in soil and foundation work by directing attention specifically to those conditions and difficulties in a situation Hence the subsurface explorations and field investigations should supply all significant information relevant to a given situation The soil identifications should supply adequate and reliable information on the identity and character of the soils. In order to give point to the identification approach to soil investigations, some of the controlling conditions in situations that may influence or control soil behavior are given in Table 3. It must be emphasized that continuing scientific and practical progress in soil and foundation engineering first of all is in direct proportion to the continuing increase in insight into and understanding of the inherent character of soils and of their potential behavior characteristics; second, is in proportion to the degree to which the controlling conditions in natural situations and construction practices are recognized, interpreted and comprehended that control the actual behavior of soils; and third, is in proportion to the degree to which experiences in soil and foundation work are fully and properly interpreted and comprehended with regard to what was expected, what really happened, and why.

TABLE 3

SOME CONTROLLING CONDITIONS IN SITUATIONS, WHICH MAY INFLUENCE OR CONTROL THE ACTUAL BEHAVIOR OF SOILS

A. *Natural Situations*

(1) Geological origin and processes of formation of soils

(2) Climatic conditions —precipitation, temperature, evaporation, depth of freezing

(3) Soil Profile—pedological character, type and extent of weathering, horizons, or stratification, depth to bed rock

(4) Surface and subsurface drainage conditions, Ground slopes, Ground water level and probable seasonal variations

(5) Natural compactness and coherence of granular soil deposits, Natural consistency, structure and state of aggregation of clay-soil deposits

(6) Natural moisture content and degree of saturation with respect to the optimum moisture content and plastic limit

(7) Chemical factors in the soil or in the ground water of a corrosive nature.

B. *Structures*

(1) The type and character of the structure and materials of construction

(2) The size and shape of the structure and depth below ground surface

(3) Amount of unloading of the soil deposit by excavation

(4) The character of the foundation loading-magnitude, distribution, proportion of dead load and permanent live load and rate of loading, repetitive loadings, vibrations, loading due to backfill

(5) The permissible total and differential settlements of foundations

(6) The permissible total and differential lateral movements of the foundations, retaining structures, etc

C. *Construction Practices and Sequence of Operations.*

(1) Excavation practices in unsheeted open excavations and in sheeted and braced excavations with regard to rate of excavation, disturbance effects, loss of ground, stability of excavation slopes, stability of sheeting and bracing

(2) Drainage practices by ordinary methods or by pre-drainage methods

(3) Foundation installation practices, and backfilling practices

(4) Compaction methods in embankments, field control, effective compacting effort expressed in terms of roller pressures and number of coverages for different types of soils and different field moisture conditions

PRINCIPLES AND TECHNIQUES FOR THE IDENTIFICATION OF GRANULAR SOILS

The identification of soils involves establishing the identities and individuality of soils by recognizing and identifying their composition and inherent character. The significant characteristics of the soil material, by which soils may be identified, are composition and inherent character with regard to the proportions and gradations of the granular gravel, sand and silt components, and the proportion, plasticity and clay mineral qualities of the clay component. Identification not only refers to the physical techniques of accurately and completely identifying soils, but also as an integral and essential part refers to the careful, systematic and precise written and spoken identifications or naming of soils, which can be made to convey definite and significant information on the identity and inherent character of individual soils of universal application in soil engineering work. Accuracy and completeness in the physical identification of soils must be matched by an equal completeness and preciseness in the written and spoken identifications, if identification is to serve its essential purpose in soil investigations. Identifications must significantly and adequately disclose soil character. The principles and techniques of soil identification are considered first for granular soils. The basic concepts and principles are applicable to identifications by visual and manual methods and to identifications by detailed laboratory soil tests.

Definitions of Soil Components and Soil Fractions.—Natural soils are composite materials, consisting of various proportions of the gravel, sand and silt components. In order to provide a common basis for understanding and clear definite meanings for soil identifications, the ASEE Definitions of Soil Components[1] are used to define the size limits of the soil components and soil fractions of these components. These definitions given in Table 4 form a significant and practical basis for the identification of soils.

These definitions convey a definite idea of particle size, because actual separations of sizes can be made. The upper size limit of gravel (3 inches) is based primarily upon common usages and practical considerations of compactibility in highway and airport construction. The size limit between gravel and sand at the No. 10 sieve (2 mm. or a little less than 0.1 in.) is quite generally accepted. Gravel particles larger than 0.1 in., as distinguished from sand, can be readily picked out of a soil by hand. The constituent grains of gravel and sand can readily be recognized visually. The fractions defined by the sieve sizes noted divide each component approximately into three equal coarse, medium and fine fractions. The size limit between sand and silt is more important and less arbitrary than that between gravel and sand, and is defined at the No. 200 sieve (0.074 mm.) for the following reasons: (1) separations of sand and silt can be made, if considered significant, (2) the individual particles of silt passing the No. 200 sieve can not be readily distinguished by the unaided eye in contrast to the fine sand fraction; and (3) such important properties as capillarity and poor drainage characteristics, which play the important roles in determining soil behavior, become increasingly manifest in the silt soils with increasing fineness.

TABLE 4

THE ASEE DEFINITIONS OF SOIL COMPONENTS AND FRACTIONS

Gravel—Material passing the 3-in. sieve and retained on the No. 10 sieve

Fractions	*Upper Sieve Limit*	*Lower Sieve Limit*
coarse	3 in.	1 in.
medium	1 in.	⅜ in.
fine	⅜ in.	No. 10 sieve

Sand—Material passing the No. 10 sieve and retained on the No. 200 sieve

Fractions	*Upper Sieve Limit*	*Lower Sieve Limit*
coarse	No. 10 sieve	No. 30 sieve
medium	No. 30 sieve	No. 60 sieve
fine	No. 60 sieve	No. 200 sieve

Silt—Material passing the No. 200 sieve that is non-plastic in character and exhibits little or no strength when air-dried

Fractions	*Upper Sieve Limit*	*Lower Sieve Limit*
coarse	No. 200 sieve	0.02 mm.
fine	0.02 mm.	—

Clay-Soil—Material passing the No. 200 sieve, which can be made to exhibit plasticity and clay qualities within a certain range of moisture content, and which exhibits considerable strength when air-dried

[1] Report of Committee VII on Foundations and Soil Mechanics, Civil Engineering Division, American Society for Engineering Education. Civil Engineering Bulletin, Vol. 12, Nov. 2, November 1947.

The distinction between silt and clay cannot be based significantly on grain size. Silts are composed of mineral grains produced by physical disintegration and natural grinding processes with little alteration from the parent material, or by crystallization of colloidal silica. The true clay minerals are formed by processes of chemical weathering and decomposition. There is a considerable overlapping of grain sizes of silt and the clay minerals. Clay minerals owe their distinctive character and qualities not to grain size but to the mineralogical and chemical composition and proportion of the true clay minerals Plasticity and clay qualities are the most characteristic qualities of clay-soils The term clay-soil is used for the material passing the No. 200 sieve, because the silt component cannot be separated out to determine the character and proportion of the true clay minerals As the true clay content increases, clay qualities dominate over the influence of grain size distribution of the granular components Organic soils owe their character and properties to the character and proportion of colloidal organic matter and to grain size distribution of the granular component. Organic silts exhibit plasticity and fine granular characteristics. These distinguishing characteristics of the soil components are readily recognized and are sufficiently obvious to serve as a significant and reliable basis for identification of soils

Principles for the Identification and Naming of Composite Granular Soils—Natural soils of granular character are composite materials with possible variations in the proportions of the gravel, sand and silt components from zero to 100 percent. In order for identification to serve the essential purposes in soil investigations, there must be a significant naming of soils to disclose accurately and completely the inherent characteristics that may be responsible for behavior under any given circumstances, and to convey precise and complete information of general application in all fields of soil work.

The accurate complete identification of granular soils requires the formulating and using of significant descriptive and identifying terms, as a common language to identify adequately and precisely the proportions of the gravel, sand and silt components and the gradations of these components. The identifying terms[2,3,4] which are defined in Table 5 are

TABLE 5

DEFINITIONS OF IDENTIFYING TERMS FOR THE IDENTIFICATION OF GRANULAR SOILS

Definitions of Terms Identifying the Composition of Granular Soils

Component	Identification		Terms Identifying Proportions		Defining Range of Percentages by Weight
	Written	Symbol	Written	Symbol	
1	2		3		4
					%
Principal component	*GRAVEL* *SAND* *SILT*	*G* *S* $\bar{S}$			50 or more
Minor component	*Gravel* *Sand* *Silt*	*G* *S* $\bar{S}$	*and* *some* *little* *trace*	*a*· *s*· *l*· *t*·	35 to 50 20 to 35 10 to 20 1 to 10

Note—Proportions refer to percentages of the whole soil finer and coarser than the principal component

Closer designations of proportions may be used, if considered significant, particularly for the gravel component.

Plus (+) nearer the upper limit of a proportion
Minus (−) nearer the lower limit of a proportion
No sign middle range of a proportion
For example—"*some*−" nearer 20%
"*little*+" nearer 20%.

Definitions of Terms Identifying the Gradation of Granular Components

Gradation Designation for Identification		Defining Proportions
As Written	Symbol	
5		6
coarse to fine or *coarse medium to fine*	*cf* *cmf*	All fractions greater than 10% of the component, but the medium component predominates.
coarse to medium	*cm*	less than 10% fine
medium to fine	*mf*	less than 10% coarse
medium	*m*	less than 10% coarse and fine
fine	*f*	less than 10% coarse and medium

Note—The predominating fraction, especially for the gravel component, may be designated by adding a plus sign (+) immediately following the fraction term, if considered significant

For example—"*coarse+ to fine Gravel*"
or "*medium to fine+ Sand*"

[2] D. M. Burmister Practical Methods for the Classification of Soils. *Proc.* Purdue Conference on Soil Mechanics and Its Applications, Sept 1940, p 129.

[3] D M. Burmister Classification System for Composite Soils, *Engineering News-Record*, July 31, 1941, p 61

[4] D. M Burmister. Soil Mechanics, Vol. I. Kings Crown Press, (Mimeographed Notes), Columbia University, NYC. 1948.

to be used not only to form a systematic and precise written and spoken identification or soil name, which can be made to convey definite meanings, but also as the essential basis for the techniques for physically identifying soils. It must be realized that for variable composite materials like soils, no such simple soil names as sandy gravel, silty sand or silt loam can be significant and adequate for the essential purposes contemplated. The identification of soils, like the exact quantitative chemical formula for complex silicate minerals of clays, must significantly disclose the composition and inherent character of soils, and must be written and spoken in a systematic, logical and precise manner in accordance with definite principles.

The identifying terms for the principal component and the minor components are written, as shown in Col. 2 for emphasis. The identifying proportion terms in Col. 3 define and identify the entire range of composition of granular soils with regard to the principal component, which is capitalized to direct attention, and to the proportions of the minor gravel, sand and silt components. These proportion terms cover recognizable ranges of percentages in Col. 4, which represent sufficiently obvious and significant variations in composition. These proportion terms serve a similar purpose in the soil identification or soil name, as do the valence numbers in a chemical formula, for example, H_2SO_4 or $CaCl_2$ in disclosing composition. The proportions of the components of soils, however, can vary in all proportions from zero to 100 percent. The range of composition and character implied in the identifying terms is sufficiently narrow to be significant, but will in many cases cover the variations in soil character normally encountered or to be expected from sample to sample in similar soils within relatively short distances or depths in the same horizon or stratum.

It should be noted especially that the proportion terms in Col. 3 have been used to a considerable extent by field engineers and boring foremen in soil work, but without the precise, well-defined and easily remembered meanings defined in Col 4. Furthermore these easily remembered terms are sufficiently inclusive and significant in character, so that the entire range of composition of natural composite gravel-sand-silt soils can be accurately and positively identified without recourse to special charts or diagrams or to the ambiguous catch-all term loam. The identifications as to composition of granular soils composed of two components (gradations not designated in this Table) are illustrated in Table 6 by the identifications of the samples of a standard set of identification samples, which form a systematic symmetrical naming of soils. It is to be emphasized that the proportion terms identifying composition always refer to the range of percentages of the whole soil finer than and coarser than the principal component given in Col. 4 The proportion terms in Col. 3 will be used exclusively in the written and spoken identifications rather than the defining percentages, because these terms form a shorter, more significant, systematic and practical identification or soil name. The use of percentages would imply an accuracy in identification, which is unwarranted in visual and manual identification techniques, and is also not significant for laboratory soil tests, where the grain size curves obtained from two specimens of the same sample may be expected to differ appreciably. In those cases where the proportions can and are identified to be close to the border line between two proportions, closer estimates and identifications of proportions may be made, if considered to be significant, by the simple use of the plus (+) or minus (−) signs immediately following the proportion term, as indicated in Table 5 and in Table 6 by the first two identifications in Col. 8 These identifying terms and notation are a matter of definition.

The identifying terms of the soil fractions, which identify the gradations of the components, are defined in Table 5. The identification of the coarse, medium and fine fractions is essential in order to achieve the necessary and readily attainable accuracy and completeness in the identification of soils, and in order properly to interpret soil character, as discussed later in this paper. The coarse, medium and fine fractions of gravel and sand are readily recognizable visually. It is to be noted in Col. 6 of Table 5, that the identification of the gradation of the soil components involves first of all recognizing whether or not the coarse, medium and fine fractions of a soil component are present in amounts exceeding 10 percent, as a percentage of the component itself. and second recognizing which fraction predominates. The predominating fraction, particularly for the gravel component, may be designated in the written and spoken identification by adding a plus immediately following the fraction, as noted in Table 5. The coarse, medium and fine terms are preferably written out in full in lower case letters, where identifications are used in discussing or interpreting individual soils in reports or technical papers The essential principles of writing systematic significant identifications will be discussed and illustrated in the sub-section, *Identification of Soils.*

Techniques for Visual and Manual Identification of Granular Soils—The identification of soils is a systematic, reliable and growing technique, which can be made accurate and complete, and involves establishing the identity and individuality of soils by recognizing and identifying their composition and inherent character The visual and manual techniques of identification must be learned and acquired through careful training. It must be recognized, as with the techniques in all scientific fields, that identification is not a simple technique, which anyone can pick up in a short time without regard to his background of knowledge and experience in soil work. By being shown the techniques, by having the significant distinguishing characteristics of soils pointed out and interpreted, and by observing carefully and with understanding, a person can develop the ability to recognize and to identify soils, but more important, can acquire insight into and understanding of the significant characteristics of soils that are responsible for behavior, as a basis for judgement. The techniques and judgement can be improved by practical applications and experience in soil work. Because of the accuracy and completeness readily attainable in the techniques of identifying soils, the principal aim should be to attain and to maintain a high standard of excellence in identification work. It is possible for an experienced soil engineer to identify properly 10 to 20 samples of soil per hour, depending upon the types of soils and upon the conditions under which the identifications are made, whether in the field or laboratory.

A standard set of identification samples, such as suggested in Table 6, may be made up for the gravel, sand and silt components in accordance with the identifying proportion terms of Table 5, and in accordance with the gradation terms of Table 5 and Table 4. This set of samples may be used in the laboratory or in the field office for reference and as a guide. A person who is learning to identify soils, or one who is not working continuously with and identifying soils can refer to these standard samples and check himself until he has (again) acquired the techniques and judgments for identifying soils accurately and completely with regard to their proportions and gradations.

Composite sand-gravel soils with not more than *trace silt* (5%) can readily be identified in an air-dried or moist condition by visual and manual techniques with regard to the proportions of the components and the gradations of the components. The identification of soils should always be started with the coarsest component, that is, gravel if present, and should proceed by steps to the finest component. In many sand-gravel soils the coarser fractions of the gravel predominate, and hence should be identified with care, because of their influence on the strength characteristics and behavior of the soil. The proportion of the gravel component referred to the whole soil and the gradation are identified visually by the techniques given in Table 14 The composite sand-silt components with regard to proportions of the whole soil and to gradation are identified by the techniques of Table 15.

When the silt component, identified as silt by its non-plastic character at any moisture content, exceed 5 percent, it begins to dominate the character of the soil and to mask almost entirely the sand component for visual identification. The proportions and gradations of the sand and silt components are somewhat more difficult to identify properly, but it is more important to identify them accurately and completely, because of the increasingly important influence of silt on soil behavior. Sand has negligible capillarity and good to excellent drainage characteristics, whereas sand containing more than 5 percent silt exhibits increasingly important capillarity and poorer drainage characteristics as the proportion of silt increases and dominates the soil character. The gradation of the silt is important, but only two fractions of silt can be recognized readily and identified, namely *coarse Silt* and *fine Silt,* as noted in Table 4. If the silt component contains more than 20 percent of fine silt, the silt as a whole appears to be fine silt

It must first of all be recognized, as a cardinal principle of identification, that composite sand-silt soils cannot be properly identified by manual techniques without the use of water in certain relatively simple but effective identification tests, which may be performed readily in the laboratory and in the field for reliably estimating the proportions and gradations of the sand and silt components. Otherwise the identification is not much better than a guess Therefore there is introduced the basic concept of a characteristic moisture content for identification purposes This characteristic moisture is sufficiently definite and obvious to provide a significant comparative basis for identification. Natural composite sand-silt soils below the zone of surface evaporation and above the ground water level are frequently at about this characteristic moisture.

In addition to the simpler manual test, a capillary strength or ball test is suggested for identifying composite sand-silt soils and to provide a significant index of potential capillarity. The ball test involves determining the height of drop of a hand compacted ball, 1½ inches in diameter, of soil at the characteristic moisture to cause a slight vertical cracking around the flattened contact surface. This cracking is evidence that the impact stresses on the contact surface have overcome by a tension failure the maximum capillary forces induced in the hand compacted ball in the capillary moisture films at the grain contacts. Research by Deakman[5] and by the writer have correlated the ball-drop test with centrifuge tests on balls and with compression tests on cylinders and balls of compacted composite sand-silt soils, in order to establish approximate force-deformation relations. It was found that for inelastic deformations the area of the flattened contact surface was a linear function of the vertical shortening of the ball, and that the external work of the drop

TABLE 6
STANDARD SET OF IDENTIFICATION SAMPLES OF GRANULAR SOILS
Percentage Proportions in accordance with Table 5
Fraction Designations in accordance with Tables 4 and 5

Dry Gravel Fractions 1	Dry Sand Fractions 2	Dry Sand Components 3	Dry Silt Fractions 4
coarse medium fine	coarse medium fine	coarse to medium medium to fine coarse to fine	coarse fine

Composite Sand-Gravel Soils, Dry		Composite Sand-Silt Soils, Moist A set each of coarse and fine Silt	
Percentages 5	**Identification 6**	**Percentages 7**	**Identification 8**
	GRAVEL, trace Sand		*SAND, trace— Silt*
90–10		95– 5	
	GRAVEL, little Sand		*SAND, trace+ Silt*
80–20		90–10	
	GRAVEL, some Sand		*SAND, little Silt*
65–35		80–20	
	GRAVEL, and Sand		*SAND, some Silt*
50–50		65–35	
	SAND, and Gravel		*SAND, and Silt*
35–65		50–50	
	SAND, some Gravel		*SILT, and Sand*
20–80		35–65	
	SAND, little Gravel		*SILT, some Sand*
10–90		20–80	
	SAND, trace Gravel		*SILT, little Sand*
		10–90	
			SILT, trace Sand

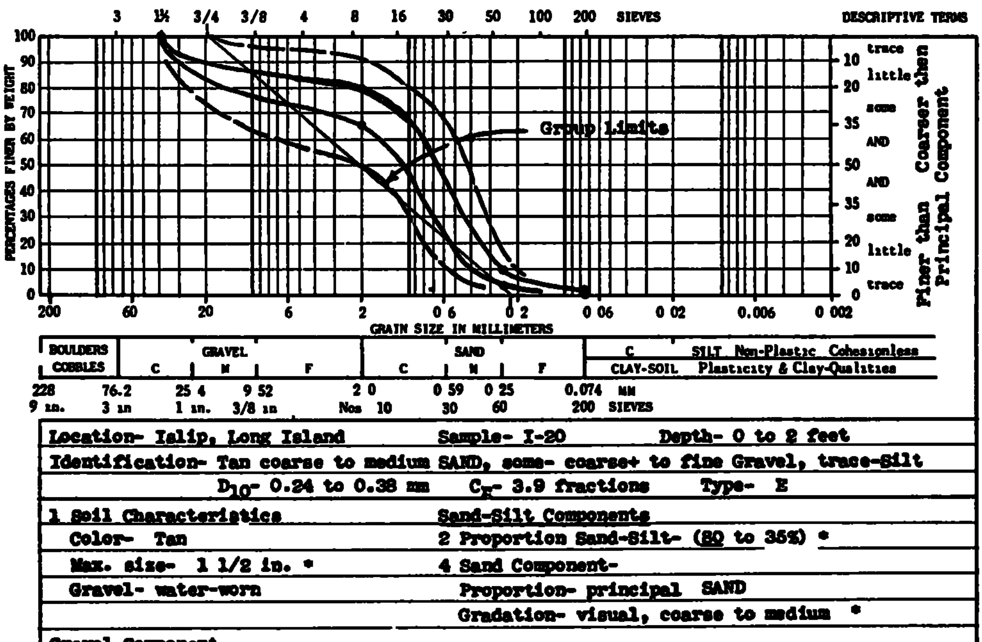
Note—Gradation terms are not included in these identifications. The Gravel should be at least medium to fine The Sand should be preferably coarse to fine

[5] H W. Deakman Identification of Silt Soils by Capillarity, Master of Science Thesis No 584, Dept of Civil Engineering, Columbia University, NYC (Not published)

and the internal work of deformation may be equated on the basis of equal flattened areas. By an analysis approximate relations were obtained between the height of drop and the maximum capillary tension or potential capillarity for composite sand-silt soils. The height of drop therefore serves as a useful, though approximate index of capillarity, which is in quite good agreement with capillary rise tests in such materials, and hence serves as an index of the proportion and fineness of the silt

The identification of composite sand-silt soils with more than 5 percent silt, involves first identifying the gravel component, if present by the techniques of Table 14. The sand and silt components are then identified with regard to their proportions and gradations by the techniques of Table 16.

It is important to organize the identification work in order to expedite it and to maintain the high standard of excellence. Samples of soil from the same horizon or stratum may be



Location- Islip, Long Island	Sample- I-20 Depth- 0 to 2 feet
Identification- Tan coarse to medium SAND, some- coarse+ to fine Gravel, trace-Silt	
D_{10}- 0.24 to 0.38 mm	C_E- 3.9 fractions Type- E
1 Soil Characteristics	Sand-Silt Components
Color- Tan	2 Proportion Sand-Silt- (80 to 35%) *
Max. size- 1 1/2 in. *	4 Sand Component-
Gravel- water-worn	Proportion- principal SAND
	Gradation- visual, coarse to medium *
Gravel Component	
2 Proportion- some- (20 to 35%) *	5 Silt Component-
3 Gradation- coarse+ to fine *	Dusty, 1 to 2 % trace- *

Figure 1. Identification of Composite Sand-Gravel Soil

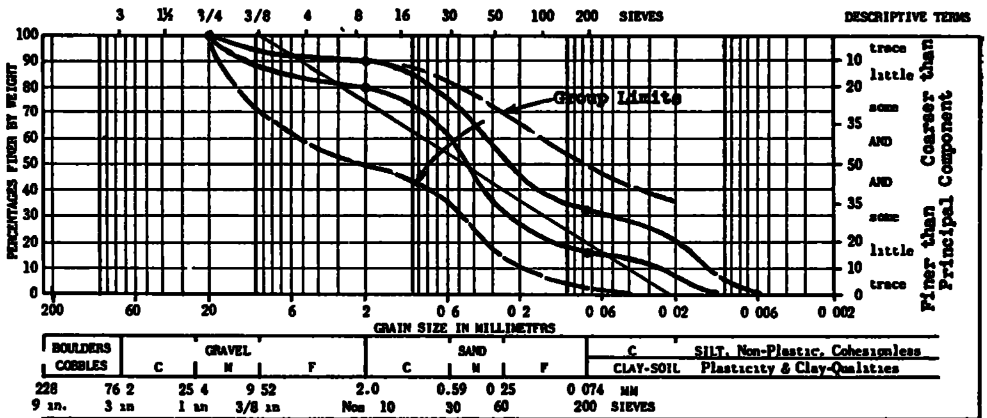
component in composite sand-silt soils. The capillarity of a composite sand-silt soil may be expressed by Eq. 1, in which H_C is the potential capillary rise in feet, and H_D is the height of drop of the ball in feet to cause a very slight cracking The firmly hand compacted soil is really in a relatively loose state, due to capillary forces resisting compaction The potential capillarity of the soil in the dense state may be of the order of twice that in the loose state, as given in Eq 1.

$$\text{Loose State } H_c = 15H_D \qquad (1)$$
$$\text{Dense State } H_c = 30H_D$$

expected to be quite similar in composition and character. When a large number of similar soils from an horizon or stratum are to be examined and identified, they can be readily separated and formed into groups of essentially similar character by visual and manual techniques The range of soil character included in a group should not be made so broad that the variations in soil character and in soil behavior between the limits of the group is too great for the group to be really significant in a given situation' The limits of such groups are illustrated in Figures 1, 2, and 3.

The first few samples of a group and such other samples, as found later to represent the limits of the group, should be identified with accuracy and completeness in order to obtain basic information on composition and inherent character and on the range of variations for the group. Thereafter the principal identification problem for the remainder of the soils of the group is to recognize and to identify significant differences in composition and gradations of each soil, using the first few samples lose significance. He should keep in mind the prime purposes of identification, namely, to disclose those significant differences in soil character, which may be responsible for significant differences in actual soil behavior.

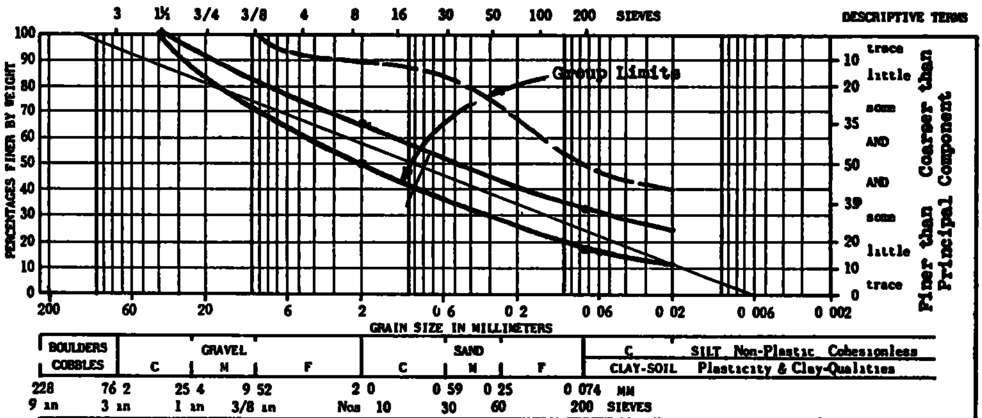
Checks on the visual and manual identifications should be made by laboratory identification tests on representative samples near the limits of a group, possibly 2 to 5 percent or so of the number of samples in the group, or as required. When an interpretation and rating



Location- Islip, Long Island	Sample- I-1A Depth- 1 to 6 feet
Identification- Light brown coarse to fine SAND, some fine Silt, little medium+ to	
D_{10}- 0.13 to 0.26 mm. C_r- 5.3 Type- ED	fine Gravel. Water-worn
1 Soil Characteristics	Sand-Silt Components
Color- Light brown	2 Proportion Sand-Silt- (90 to 80%) *
Max. size- 3/4 in. *	4 Sand Component-
Gravel- waterworn	Proportion- principal SAND
	Gradation- feel, coarse to fine *
Gravel Component	5 Silt Component
2 Proportion- little (10 to 20%)*	Gradation- shaking and capillarity- fine *
3 Gradation- medium+ to fine *	Proportion- Ball-drop, 6-12 in. some* (20 to 35%)
	Adjusted %- (90 to 80) x (20 to 35) = (16 to 32%)*

Figure 2. Identification of Composite Sand-Silt Soil

directly as references for comparison. All samples, however, should be given their accurate and complete identification for interpretations and study. The above procedure should be repeated for each group of similar soils from different horizons or strata, or where significant changes in composition and character of soils occur with distance or with depth within the same horizon or stratum. The soil engineer should be constantly on guard against allowing identification to become merely a routine matter, and thus to of the samples in the group and an appraisal of the situation with regard to the controlling conditions indicates that detailed soil tests and analyses are required in order to provide the basic information on soil behavior for making the important decisions of design and construction, then a suitable program of laboratory soil tests should be carefully set up. Representative samples should be carefully selected near the coarser and finer limits of each group of granular soils, and near the more plastic and least plastic limits of each rather limited group of composite clay-soils. Thus having detailed information on soil behavior, which brackets satisfactorily the probable limits for each group of soils, and the accurate and complete identifications of all soils of the group, the behavior characteristics of the entire range of soils in each group can be reliably known. When the actual behavior of the soils have been observed carefully and in detail in the field and have been compared and interpreted fully with regard to definite and significant information on the identity and inherent character of individual soils of universal application in soil engineering work. The identification of soils, like the exact quantitative chemical formula, must disclose significantly those inherent characteristics of composition and gradation, which may be responsible for their actual behavior under the varied conditions encountered in engineering practice, and must be written and spoken in a systematic, logical and pre-



Location- Newburgh, New York	Sample- N-100 Depth- 1 to 5 feet
Identification- Gray coarse to fine Sand, some Silt & Clay, and coarse+ to fine Gravel	
Low Plasticity C_r- 8.5	Type- C Shale fragments
1 Soil Characteristics	Sand-Silt-Clay Components
Color- Gray	2 Proportion- Sand-Silt-Clay- (65 to 50%) *
Max. size- 1 1/2 in. *	4-5-6 Identification-
Shale fragments, hard	Plasticity- 1/8 in. thread, Low Plast. Silt & Clay
	Proportion Sand- smear, washing- (50 to 65%)
Gravel Component	Gradation Sand- coarse to fine
2 Proportion- and (35 to 50%) *	Proportion Silt & Clay- (50 to 35%)
3 Gradation- coarse+ to fine *	Adjusted proportion-
	(65 to 50) x (50 to 35) = (32 to 17%) *

Figure 3. Identification of Composite Sand-Clay Soil

what was expected, then the identifications of the soils will have greater significance and meaning for future works, involving similar types of soils

The Written and Spoken Identifications—As stated previously, identification not only refers to the physical techniques of accurately and completely identifying soils, but also as an integral and essential part refers to the careful systematic and precise written and spoken identifications, which should convey cise manner in accordance with definite principles. It must be realized that for variable composite materials like natural soils, no such simple soil names as sandy gravel, silty sand or silt loam, nor purely local names can be significant and adequate for the essential purposes of soil investigations.

The identification of soils can readily be written or spoken directly from grain size curves obtaied by sieve and hydrometer tests for granular soils and from consistency tests for clay-soils, by using the identifying proportion and gradation terms given in Table 5. This will be illustrated later. But in order for the identifications obtained by visual and manual techniques to be significant and of practical value for interpretations of soil character and for ratings with regard to their potential behavior characteristics, it should be possible from the written and spoken identifications or from the identification data obtained by manual and visual techniques readily to draw representative grain size curve limits for the granular components Otherwise the identifications are not good enough and are not sufficiently accurate and complete to serve the essential purposes in soil investigations.

To illustrate the essential principles of the physical identifications of soils by the techniques of Tables 14, 15, and 16, and of formulating the identification or soil name the complete identifications of a composite sand-gravel soil with less than 5 percent silt and of a composite sand-gravel soil with more than 5 percent silt are given in Figures 1 and 2. The physical steps in the identifications are noted by the same item numbers as those of Tables 14, 15 and 16 in the work-sheet portions of Figures 1 and 2. The upper three lines are reserved for recording the essential data on each sample and for the accurate and complete written identification. The work-sheet should be filled out in such detail for the first few samples of a group of similar soils from an horizon or stratum, as may be necessary for reference and for direct comparison In these two cases the work-sheets are carried through in somewhat more detail than usually necessary for an experienced soil engineer, in order to illustrate the principles of the techniques fully Thereafter for the remainder of the group of similar soils the complete identifications of each soil can be written out in a table, keeping in mind the significant identifying characteristics, as they are recognized until the identification of the soil has been completed. The major identification problem is to detect, recognize and to identify accurately and completely those significant and inherent characteristics of soils, which will or may be responsible for the actual behavior, and also those significant differences in character in a group of similar soils, which may be responsible for significant differences in behavior

After completing the techniques of identification for each of the first few samples of soil done in detail, two grain size curve limits should be drawn for each soil, corresponding to the range of proportions identified, because these curves give a better insight into and understanding of the character of the soils for making proper interpretations. The plotting points for the grain size curve limits shown by the large dots in Figures 1 and 2 are obtained directly from the starred (*) values noted in the work sheet The estimates of the proportions and gradations of the components of the soils were made by the techniques in Tables 14, 15 and 16 having the same item numbers noted in the work sheet For illustrative purposes both proportion term and the defining percentages from Table 5 are given for reference. Consideration is given in drawing the grain size curve limits to the fact that the predominating fraction of the gravel component is medium gravel, as identified by the plus sign, which gives the curve a characteristic downward curved form in the gravel sizes and produces a slight hump in the sand sizes, because the grain size curve must be continuous without any sharp breaks. Consideration is also given to the closer estimtes of the proportion of gravel, which was estimated to be nearer 20 percent, *some* −, by drawing the upper grain size curve limit heavier in this region The plotting of the grain size curve limits is an essential part of learning and applying the techniques of visual and manual identification of granular soils. First, it permits a direct check by means of sieve analyses of the accuracy of the identification being attained, so that a person learning the identification techniques may observe exactly where he tends to overestimate or to underestimate proportions and gradations The accuracy and completeness and the great practical value of identifications by visual and manual techniques in soil investigations may be judged by the fact that a soil engineer experienced in the identification techniques can consistently obtain identifications sufficiently accurate and complete, so that the grain size curves from a sieve and hydrometer analyses would fall within the grain size curve limits of his identifications. This being so, only a limited number of check identification tests are necessary on representative samples near the limits of each group of similar soils. Second, the drawing of the grain size curve limits for the first few soil samples of a group done in detail, and also for the extreme limits of the group, as shown by the light dotted curves in Figures 1 and 2, gives a better conception of the inherent character of the soils and the range of possible behavior characteristics of the group. The grain size curve limits thus give a greater meaning and significance to the written and spoken identifications.

Grain size distribution is important because composition and gradation are the inherent characteristics of the granular soil material, that determine soil behavior. Grain shape is of secondary importance, except in the case of such peculiar constituents, as mica, etc. The different geological processes tend to form granular soil deposits having characteristic grain size distributions, as to fineness, range of grain sizes and type of grading (Ref. 1).

It may be stated as a principle that the entire grain size curve must be consistent with no sharp breaks in passing from gravel to sand, or from sand to silt. The grain size curves of sand with less than 10 percent of gravel or silt, which are formed by sedimentation processes in flowing water must have a characteristic S-shape with approximately equal tails of the coarse and fine fractions always becoming tangent to the horizontal axes. When the gravel component exceeds 10 percent, the coarse end of the grain size curve in the gravel sizes is seldom tangent to the horizontal axis, as noted in Figures 1 and 2. The identification of the gradation of the gravel component will indicate the form of the grain size curve. Such gravelly soils are typical of certain coarse glacial outwash, piedmont and beach deposits. The grading of the sand fraction, however, is almost without exception S-shaped. For soils formed by geological processes other than sedimentation no part of the grain size curve is likely to be S-shaped. A person working with soils should study at every opportunity the grain size curves of soils formed by the different geological processes, as to their typical fineness, range of grain sizes and shape of curve, in order to become familiar with them and to acquire insight into and understanding of soil character. The identifications of soils will then have greater significance with regard to the geological processes of formation of soil deposits and with regard to the soils in their natural setting.

The complete and precise identification can be written, as noted in the second line of Figures 1 and 2 in a definite and systematic manner from the data in the work sheet or directly from the grain size curve limits in terms of the proportion designations at the right hand side of the figure. The identification identifies the composition and the inherent character of the soil explicitly with regard to the proportions and gradations of the components. The identification is started with the color and is followed by the principal component with its gradation. The name of the principal component is always written out in capital letters to direct attention. The gradation terms always precede the component name. For composite sand-gravel soils with less than 5 percent silt the identification then proceeds to the minor component of next importance with its proportion term, gradation and name, etc. For composite sand-gravel-silt soils with more than 5 percent silt the identification of the principal component is followed by the identifications of the next finer components in sequence to the finest component, thereafter returning to the components coarser than the principal component in sequence to the coarsest component. It is to be noted specially that the proportion of the principal component is not and need not be given explicitly in the identification, because it is identified by writing the name in capital letters for emphasis, but is equal to 100 percent minus the sum of the proportions (using the appropriate percentage limits of the proportion terms) of the minor components, two in number at most, expressed as percentages of the whole soil finer than and coarser than the principal component. It is also to be noted that an adjustment has been made in Figure 2, Item 5, to express the proportion of the silt component to the basis of the whole soil, since in the techniques the silt proportion was estimated first on the basis of the cmbined sand-silt components only. The plus and minus signs, when considered significant and used are included in the written and spoken identification immediately following the term, which they are intended to modify without a space between the term and the sign, as noted.

The identifications thus represent a systematic and significant naming of soils, which can be made accurate and complete, and can be read or spoken in a logical straight forward manner to convey definite information on the identity and character of soils. The identification lends itself readily to significant abbreviations and symbol forms, which do not lose significance or completeness, which are now illustrated. These different forms of the identification, however, should not be used indiscriminately, but should be used in their proper places as a part of good technical English It should be noted especially that these forms of identification are identical as to accuracy, completeness and significant meaning, the differences being a matter of suitable abbreviation only The identification would lose significance, if shortened by leaving out the gradation terms or the smallest of the minor components, because they describe significant aspects of the inherent character of soils, which may be responsible for the actual behavior, rather than playing a minor role, as usually assumed These identification forms are discussed as follows. (a) Where identifications are used in discussing or interpreting individual soils in reports or technical papers, the full identification should be written out in its complete form, as noted below in Form-(a), for samples No I-20 and No. I-IA from Figures 1 and 2, respectively; (b) For tabulations of identifications to be used for study and analysis, the component terms should be written out in full to direct attention, but the proportion and gradation terms may be abbreviated, as indicated in Table 5, and as noted in Form-b; (c) For soil profiles, soil maps, and for the tabulation of identifications and in the identification work sheet for the remainder of a group of soil samples after the first few samples have been identified in detail, the identifications may be expressed in the symbol form, like a complete chemical formula, in order to conserve space, as noted below in Form-c If the plus and minus signs are not considered to be significant, they may be left out of the symbol form of identification, with the exception of the plus designation for the predominating fraction of gravel, which is significant with respect to the behavior of gravelly soils. In the spoken identifications the symbol form should never be used, but all forms should be spoken in the full and complete form-a, since they all are expressed in a logical straight forward manner.

Identification Forms

Sample I-20

Form-a "*tan coarse to medium SAND, some – coarse + to fine Gravel, trace – Silt*" Gravel waterworn

Form-b "*cm SAND, s·–m+f Gravel, t -Silt*"

Form-c "*cmS, s –m+f G, t· –*$\bar{S}$"

Sample I-1A

Form-a "*light brown coarse to fine SAND, some fine Silt, little medium+ to fine Gravel*" Gravel waterworn.

Form-b "*cf SAND, s f Silt, l·m+f Gravel*"

Form-c "*cfS, s f*$\bar{S}$*, l m+f G*"

There are some cases where the proportions are such that there is no principal component with all components less than 50 percent The following examples will illustrate the manner of writing the identifications in this case.

"*coarse to fine Sand, some fine Silt, some medium+ to fine Gravel*"

"*coarse to fine Sand, and fine Silt, some medium+ to fine Gravel*"

"*coarse to fine Sand, some fine Silt, and medium+ to fine Gravel*"

The principle to follow in writing the identification, where there is no principal component, is to start the identification with the sand component with its proportion undesignated, but equal to 100 percent minus the sum of the other two proportions. In this case no one of the component names is written out in capital letters.

There are two other cases, where the proportions are such that either silt or gravel is the principal component, which should be noted specially as to the manner of writing the identification, so that it has a definite meaning, as follows.

"*fine SILT and, coarse to fine Sand, little medium+ to fine Gravel*"

"*medium to fine GRAVEL some, coarse to fine Sand, trace fine Silt*"

In these cases the proportion term is considered to belong to the principal component and is so designated by placing the comma after the proportion term, instead of before the term, as is done in all other cases. "*SILT and,*" then signifies 50 to 65 percent silt, and "*GRAVEL some,*" then signifies 65 to 80 percent gravel, instead of the usual defining percentages for minor components given in Table 5 The proportion of sand is not given explicitly, but is equal to 100 percent minus the sum of the proportions of the other two components, which are coarser than and finer than the sand component. Again it should be emphasized that the identifications of soils must significantly disclose the composition and inherent character of soils, and must be stated in a systematic, logical and precise manner.

PRINCIPLES AND TECHNIQUES FOR THE IDENTIFICATION OF CLAY-SOILS

The identification of the granular components, sand and gravel of composite clay-soils follows the principles and techniques given in the preceding section The identification of the clay-soil components can not be made significantly on a grain size basis The essential basis for the identification of the combined silt-clay components of composite clay-soils are plasticity and clay qualities, and for organic silts are plasticity and fine granular characteristics. When the proportion of clay or colloidal organic matter is sufficient to give a soil appreciable plasticity, other additional techniques are required to identify such soils, because the clay or the colloidal organic matter begins to dominate the soil character. It is important to identify these soils accurately and completely, because of their marked and often objectionable qualities and behavior characteristics. Plasticity is the most distinctive and characteristic quality of clay-soils and organic soils, and is determined principally by the mineralogical and chemical character and proportion of the true clay minerals in clay-soils, and by the character and proportion of the colloidal organic matter in organic silts But plasticity is also considerably influenced and modified by the proportions and gradations of the granular components. Variations in plasticity of soils are indicative of important and consistent variations in the behavior characteristics of such soils, particularly with changes in moisture content.

Principles for the Identification and Naming of Composite Clay-Soils—The accurate and complete identification of composite clay-soils requires the formulating and using of significant terms to identify such materials adequately and precisely with regard to plasticity, composition and inherent character of the combined silt-clay components, and with regard to the composition and gradation of the granular gravel and sand components. The identifying terms in Table 7, in which the silt and clay components are coupled directly together, as a combined soil material finer than the No 200 sieve, are to be used not only for the written and spoken identifications, but also as the essential basis for the techniques for identifying such soils

The terms identify the combined silt-clay components on a significant plasticity basis, because the silt component cannot be separated to determine the proportion and char-

TABLE 7

DEFINITIONS OF IDENTIFYING TERMS FOR THE IDENTIFICATION OF COMPOSITE CLAY-SOILS ON AN OVERALL PLASTICITY BASIS

Degree of Overall Plasticity PI′		Overall Plasticity Index Sand-Silt-Clay Components	Identification Principal Component		Identification Minor Component	
			Written	Symbol	Written	Symbol
1		2	3		4	
Non-plastic		0	*SILT*	$\bar{S}$	*Silt*	$\bar{S}$
Slight	*Sl*	1–5	*Clayey SILT*	$CY\bar{S}$	*Clayey Silt*	$CY\bar{S}$
Low	*L*	5–10	*SILT & CLAY*	$\bar{S}$-C	*Silt & Clay*	$\bar{S}$-C
Medium	*M*	10–20	*CLAY & SILT*	C-$\bar{S}$		
High	*H*	20–40	*Silty CLAY*	$\bar{S}YC$		
Very high	*VH*	40 and greater	*CLAY*	C		

Note—Designations of the degree of overall Plasticity in the identification of soils may be written in symbol form as follows, for example—
Slight Plasticity, *S PI′*
High Plasticity, *H·PI′*

acter of the true clay component. The identifying terms are given well-defined meanings on a plasticity basis, and are descriptive not only of the inherent character and qualities of composite clay-soils, but also of the relative dominance of the true clay minerals component These terms cover recognizable ranges of plasticity, which represent sufficiently obvious and significant variations in composition and inherent character for the purposes of identifications. These easily remembered terms form a symmetrical naming of clay-soils with regard to the dominance of the clay component and are sufficiently significant and inclusive, so that the entire range of plasticity, composition and character of natural composite clay-soils can be identified accurately and completely without recourse to the ambiguous catch-all term loam. The identifying ranges of plasticity index limits have been adjusted, so as to be more suitable and significant not only for identification purposes, but also and more important for the purposes of interpreting the inherent character of the whole soil and of rating the soils with regard to their potential behavior characteristics on a plasticity basis

There is therefore introduced the basic concept that the *Overall Plasticity* of the combined sand-silt-clay component is a significant and basic characteristic of composite clay-soils. In contrast to an arbitrary definition of plasticity, based on determinations of the plasticity of the material passing the No 40 sieve only, as commonly used, the overall plasticity has a more significant and direct bearing on the actual qualities and behavior characteristics inherent in the whole composite clay-soil material. The gradation and proportion of the sand component have an important modifying influence on the plasticity, behavior and strength characteristics of the whole soil, which is what the engineer is always dealing with in the field. The gravel component, if present, will not appreciably influence the plastic displacement characteristics and the strength characteristics of a composite clay-soil, until the proportions of the gravel component exceed about 35 percent, because the larger gravel particles merely float in the combined plastic sand-silt-clay mass, which thus controls the plastic behavior characteristics Hence identifications of composite clay-soils on an overall plasticity basis disclose more significantly the inherent character and qualities of the composite material and the relative dominance of the true clay component. These plasticity concepts also apply to the organic silts. Organic silts, although they possess medium to very high plasticities due to their colloidal organic content, exhibit certain distinguishing fine granular characteristics by which they may be recognized and identified, and distinguished from clay-soils.

Techniques for Identifying Composite Clay-Soils —The proportion and gradation of the gravel component, if present, is identified readily by the techniques of Table 14 The identification of the sand-silt-clay components, as to composition and gradation of the sand component and as to the plasticity, composition and inherent character of the combined sand-silt-clay components is made by the techniques of Table 17.

It must first of all be recognized, as a cardinal principle of identification, that composite clay-soils and composite organic soils cannot be identified properly without the use of water to bring the soil to a characteristic moisture content, as a comparative basis for recognizing and identifying such soils Therefore there is introduced the basic concept of a *characteristic moisture content* and of a *constant consistency condition*, which provide a common basis for identification. This concept states that, if all composite clay-soils and organic silts are brought to a constant consistency or constant shearing strength within the plastic range of moisture content by adjusting the moisture content, then the ease of rolling threads in a plasticity test, expressed in terms of the smallest diameter of thread to which a thread of soil at this characteristic moisture can be rolled when it just crumbles, is a significant and sensitive index of the degree of plasticity, which the soil possesses. This is based upon the significant fact that all plastic soils at the characteristic moisture, termed the "ball moisture," have a constant consistency or shearing strength regardless of the plasticity they possess; whereas soils at the plastic limit, as usually defined by the moisture content at which a thread of soil ⅛ in in diameter just crumbles, have shearing strength, which increase markedly with increase in plasticity, that is, plasticity index. Hence plastic types of soils can be readily differentiated on a plasticity basis at the characteristic moisture by the plasticity test The ball moisture of clay-soils possessing low overall plasticities is at the plastic limit, so that the thread crumbles at ⅛-in in diameter. Feebly plastic soils in the range of slight plasticity, for which it is difficult to determine significant values of the liquid and plastic limits, can be identified readily and significantly on a plasticity basis, because threads can be formed and rolled to only ¼ in. in diameter when they crumble. Non-plastic silts can not be rolled into threads (See Table 17-(4–5–6)-b.

The characteristic or ball moisture, corresponding to a constant consistency or shearing strength, is obtained by adjusting the moisture content of a firmly shaped and compacted ball of plastic clay-soil 1½ in in diameter, so that, when the ball is dropped from a constant height of 2 ft., the constant energy of impact produces by plastic deformation a flattened contact surface 2.2 cm. ± 0.1 cm. (⅞ in.) in diameter, which represents a fixed point on a stress-plastic deformation curve. Research by Deakman (Ref. 5) and by the writer on the ball-drop test, centrifuge and compression tests on balls of plasticene and clay-soils have established approximate force-deformation relations It was found that the area of the flattened contact surface formed by a drop and by static compression is a linear function of the vertical shortening of the ball, and that the external work of the drop and the internal work of deformation may be equated on the basis of equal flattened contact areas. It was also found for a wide range of height of drop that the average pressure on the flattened contact surface was a constant value, which thus represents a yield value condition for plastic deformation of a plastic material. An analysis and correlation of the tests yielded the following approximate relation for the average contact pressure and shearing strength of the material in the ball-drop test.

Average Contact Pressure, p(aver)

$$= \frac{6\,5WH_D}{(D_c)^4} = 2S_{\max} \qquad (2)$$

where W is the weight of the ball in kilograms, H_D is the height of drop in centimeters, D_c is the diameter of the contact surface in centimeters. Substituting a weight of ball of about 50 g. and a height of drop of 2 ft and a contact diameter of 2.2 cm , the shearing strength of all plastic soils in the ball-drop test is a constant value of the order of 0 4 to 0.5 kg. per sq. cm.

Manual identification tests, and the ball-drop and plasticity tests may readily be performed in the field or in the laboratory to identify composite clay-soils accurately and completely. The first few samples of clay-soil from an horizon or stratum should be done with care. Thereafter the principle identification problem for the remainder of a group of similar soils is to detect, recognize and identify significant differences in composition, plasticity and granular characteristics, using the first few samples identified in detail as references for direct comparison.

The Written and Spoken Identification—To illustrate the essential principles of the physical identification of composite clay-soils by the techniques of Tables 14 and 17, and of formulating the identification in accordance with the section on granular soils, the complete identification of a composite clay-soil is given in Figure 3. The physical steps in the identification are noted by the same item numbers as those of Tables 14 and 17 in the work sheet. The grain size curve limits are drawn for the sample identified, and also for the limits for the group of similar soils. It is to be noted that an adjusment has been made in Figure 3, Item 6, to express the proportion of the combined silt-clay components on the basis of the whole soil.

The accurate and complete identification is given in Figure 3, which identifies the plasticity, composition and inherent character of the composite clay-soil, and is also expressed in the three forms previously noted for granular soils, as follows:

Identification Forms

Sample No. N-100

Form-a *"Gray coarse to fine Sand, some Silt & Clay, and coarse+ to fine Gravel"* Low Plasticity, Shale fragments.

Form-b *"cf Sand, s·Silt & Clay, a c+f Gravel L·PI′.*

Form-c *"cfS, s $\bar{S}$-C, a·c+fG. L·PI′."*

In this case there is no principal component, so that the identification is started with the sand component It is to be noted that the combined silt-clay components are treated as one material through the naming on a plasticity basis, which indicates the relative dominance of the silt component and of the modifying influence of the sand component on plasticity, but with a clay component of a character and proportion sufficient to give the combined sand-silt-clay components a low plasticity. It should be kept in mind in identifying clay-soils and in interpreting identifications that the plasticity and naming of composite clay-soils is based on the overall plasticity of the combined sand-silt-clay components which has a more significant and direct bearing on the actual behavior of the material under different moisture conditions. The designation of the plasticity therefore is always made a part of the identification in any form, as noted above.

INTERPRETATIONS OF SOIL CHARACTER AND RATINGS OF BEHAVIOR CHARACTERISTICS

A thorough knowledge and understanding of the inherent characteristics of soils and insight into the role that they play in determining or influencing the behavior of soils are indispensable as a proper background for identification. The interpretation of soil character and tentative ratings of soils with regard to certain important behavior characteristics listed in Table 2 are considered briefly in order to give point to the principles, techniques and practical purposes of identifications in soil investigations. The interpretation of soil character and the rating of soils with regard to their potential behavior characteristics are fundamental and most important analyses, because they inform the engineer regarding the qualities and behavior characteristics of soils that may dominate in a given situation. The appraisal of the natural situations given in Table 3, will enable the engineer to decide which behavior characteristics are likely to dominate or control in a given situation and how much importance and significance should be given to certain controlling conditions in judging and appraising the propable actual behavior of the soils under a given set of circumstances. The major problem is soil investigations is to recognize and to identify significant differences in soil character, and to recognize, to comprehend and to appraise significant differences in situations that are or may be responsible for differences in actual behavior. The experiences in soil and foundation work, when fully interpreted and comprehended with regard to what was expected, what really happened and why, would become basic information and background for making the interpretations, appraisals and decisions for future works.

Granular Soils—Composition and gradation of the granular soil components and dominating grain shapes are the inherent characteristics of the granular soil material by which soils may be identified, and which determine the behavior characteristics In order adequately to express the dependence of behavior of granular soils on composition and gradation, the significant characteristics of grain size distribution must be defined on an adequate and significant basis The significant characteristics of grain size distribution are fineness, range of grain sizes, and type of grading.[6]

The fineness of a soils may be defined satisfactorily by Hazen's effective size, D_{10}, which is the grain size in millimeters for which 10 percent of material is finer by weight. Experience and research (Ref. 6) on soil behavior have shown that the drainage, capillarity, and frost heaving characteristics of granular soils are influenced most by the fine fractions of the soil, for which D_{10} is a satisfactory index. Hence it is significant to recognize and to identify properly a *trace* of the coarse, medium and fine fractions of the sand and silt components. For the soils of a group of similar soils, which have been identified in detail and for which grain size curve limits have been drawn, as shown in Figures 1 and 2, two values of D_{10} may be obtained as probable representative limits. For the remainder of the soils identified the fineness may be obtained directly from their identifications and expressed as the finest soil fraction. For example, the fineness of the soil in Figure 1 may be expressed as *medium Sand*, and the fineness of the soil in Figure 2 may be expressed as *some fine Silt*. For the purposes of interpreting soil

[6] D M Burmister The Importance and Practical Use of Relative Density in Soil Mechanics *Proc* Amer. Soc for Testing Materials, Vol 48 1948

character and of rating granular soils as to their potential drainage, capillarity and frost heaving characteristics from soil identifications, the tentative criteria for rating granular soils on a fineness basis are given in Table 8. Where a range of effective sizes, D_{10} can be obtained from the grain size curve limits, an approximate range of permeabilities and capillarities may be estimated by the following formulas for the purposes of closer ratings of granular soils in the loose to medium compact states (Ref. 6).

Permeability, cm per sec,

$$k = (1.0 \text{ to } 5.0)(D_{10})^2 \quad (3)$$

Capillarity, rise in feet,

$$H_c = \frac{(0.1 \text{ to } 0.15)}{D_{10}} \quad (4)$$

formation of granular soil deposits. Typical grain size distributions are associated with the different geological processes (Ref. 1 and 6). As a consequence the natural processes tend to deposit each typical grain size distribution in a characteristic state of natural density. The finer soils are always deposited in a loose state. The coarser soils and those containing gravel tend to be deposited in a rather medium compact state. Because grain size distribution controls the packing characteristics of granular soils, their maximum densities are determined by definite gradations laws (Ref. 1 and 6). The maximum densities are important because the higher the value of the maximum density, the higher are the strength characteristics and supporting values associated with a soil compacted to its maximum density. As a basis for tentative ratings of granular

TABLE 8

TENTATIVE CRITERIA FOR RATING GRANULAR SOILS WITH REGARD TO DRAINAGE, CAPILLARITY AND FROST HEAVING CHARACTERISTICS BASED ON FINENESS

Fineness Approx D_{10} *mm.* 1	*trace fine Sand* 0 4–0 2 2	*trace Silt* 0 2–0 7 3	*little Silt* 0 07–0 02 4	*some Silt* 0 05–0 01 5
Drainage Gravity	free drainage excellent	drainable good	fair	drain slowly
Capillarity	negligible	slight	moderate	moderate to high
Approx. rise in feet, H_c	less than 1 0	0 5–2	2–7	5–15
Frost heaving Ground water within 6 ft	non-frost heaving	slight	susceptible	susceptible to objectionable

An appraisal of the controlling conditions in a situation listed in Table 3 with regard to the drainage and seepage conditions, depths to ground water, and probable fluctuations, climatic conditions with respect to precipitation, depth of freezing, etc. will determine how much significance and importance should be given to these potential behavior characteristics in a particular situation.

The effective range of grain sizes, designated C_r, and the type of grading (shape of grain size curve) are the second and third important characteristics of grain size distribution of granular soils that determine behavior This is because grain size distribution controls the packing characteristics of granular soils, whether laid down by natural processes, or compacted artificially. The range of grain sizes and the type of grading are determined by the geological processes of deposition and

soil, an approximate value of the effective range of grain sizes can be obtained from the identification by determining the number of fractions from the coarsest to the finest fraction covered by the composition and gradation of the soil, deducting about one-half fraction at both the coarse and fine ends where the tails of the grain size curve taper off However, if the gravel component exceeds 35 percent, no deduction is made at the coarse end of the curve, because of the characteristic shape of the curve in the gravel sizes. For example, the approximate effective range of grain sizes of the soil in Figure 1 from its identification is 3 gravel fractions plus 2 sand fractions and deducting one-half fraction at each end equals 4 fractions, as the effective range of grain sizes (Ref. 6) Tentative ratings of granular soils with regard to grading and maximum density are given in Table 9

TABLE 9

TENTATIVE CRITERIA FOR RATING GRANULAR SOILS WITH REGARD TO GRADING AND MAXIMUM DENSITIES, BASED ON EFFECTIVE RANGE OF GRAIN SIZES

Effective Range of Grain Sizes of Granular Components Expressed in Soil Fractions, C_r 1	Grading 2	Maximum Density 3
		lb per cu ft.
Drainable Less than 10% Silt More than 50% Gravel More than 5 fractions	Well-graded	Greater than 135
No limitation More than 35% Gravel More than 7 fractions	Well-graded	Greater than 135
Less than 7 fractions More than 4 fractions	Good to fair	120–135
Less than 4 fractions	Assorted uniformly graded	105 to 120
More than 1 fraction Less than 1 fraction	Type-S Very uniformly graded Type-S	Less than 105

the coarser soils at the same relative densities have somewhat higher relative supporting values. An experienced soil engineer can learn to identify and to estimate quite reliably by feel or by penetration tests the loose, medium compact and compact density states.

Clay-Soils and Organic Silts—Clay-soils owe their inherent and distinctive character to the true clay mineral content. As the clay component increases, plasticity and clay qualities begin to dominate the character and behavior, and grain size distribution of the granular components plays a less important role. Organic silts owe their inherent and distinctive character to the proportion and character of the colloidal organic matter and to grain size distribution of the granular components. Plasticity and fine granular characteristics dominate the character and behavior of organic silts. The degree of overall plasticity of clay soils and organic silts is indicative of their character and potential behavior characteristics. Accordingly clay-soils may be rated as to their desirable and objectionable characteristics on a plasticity basis in Table 11.

TABLE 10

TENTATIVE CRITERIA FOR RATING GRANULAR SOILS ON A RELATIVE DENSITY BASIS WITH REGARD TO COMPACTNESS AND TO RELATIVE SUPPORTING VALUE IN NATURAL DEPOSITS OR IN A COMPACTED STATE

Relative Density, *Percent RD*	0–40	40–70	70–90	90–100
Compactness	Loose *L*	Medium Compact *MC*	Compact *C*	Very Compact *VC*
Relative Supporting Value				
Composite *Sand-Silt*	Poor to fair	Fair to good	Good to very good	Very good
SAND	Fair	Good	Very good	Excellent
Composite *Sand-Gravel*	Fair to good	Good to very good	Very good to excellent	Very excellent

Note—Designations of the relative compactness in the identification of soils may be written in symbol form as follows, for example—
Low Relative Density, *L RD*
Compact Relative Density, *C·RD*

Experience has shown that the compactness of natural soil deposits and of soils compacted in subgrades of highways and airports and in embankments has a controlling influence on the supporting value of the soils. The compactness of granular soils between the limits of the maximum and minimum densities, as limiting references, is most significantly expressed as relative density (Ref 6), which defines the significant state of the grain structure of granular soils. Granular soils may be rated by the tentative criteria in Table 10 on the basis of relative density with regard to their relative compactness and with regard to their relative supporting values in natural deposits or placed and compacted in embankments. Consideration is given to the fact that

Experience has shown that the compactness and consistency of natural clay-soil deposits and of such soils compacted in subgrades and embankments has a controlling influence on the strength characteristics and relative supporting value of the soils. Natural clay-soils and compacted clay-soils may be rated with regard to their relative supporting value and relative stability in natural slopes and in compacted embankments on the basis of their shearing strengths and of relative consistency in accordance with the tentative criteria in Table 12. An experienced soil engineer can learn to identify and to estimate quite reliably the consistency of natural clay-soils and of compacted clay-soils by feel, by the ball-drop test, or by penetration tests The ball-drop test by Eq. 2 permits estimating the shearing strength of compacted clay-soils, the shearing strength at the ball moisture being about 0.50 tons per sq. ft, as a comparative basis, which moisture is slightly on the wet side of the peak of maximum compacted density.

highest strength after normal capillary saturation has been found by experience to be in the region of the maximum density and optimum moisture content, and probably slightly on the dry side of the peak of the moisture-density compaction curve. Tentative criteria, modified from data given by Kersten[7] in a report of a survey of subgrade moisture conditions, are given in Table 13 for rating clay-soils on an overall plasticity basis with regard

TABLE 11
TENTATIVE CRITERIA FOR RATING CLAY-SOILS WITH REGARD TO POTENTIAL BEHAVIOR CHARACTERISTICS ON A PLASTICITY BASIS

Composite Clay-Soil Type	Degree of Overall Plasticity Composite Sand-Silt-Clay		Potential Behavior Characteristics of Clay-Soils
	Plasticity	PI	
1	2	3	4
Silt	Non-plastic	0	Friable Grain size distribution determines character and behavior
Clayey Silt *Silt & Clay*	Slight Low	1 to 5 5 to 10	Desirable cohesiveness Good compaction characteristics Grain size distribution important with regard to the strength characteristics of the grain structure
CLAY & SILT *Silty CLAY* *CLAY*	Medium High Very high	10 to 20 20 to 40 40 and greater	Increasingly poorer compaction characteristics and low densities. Increasingly objectionable plastic displacement and consolidation characteristics under stress

TABLE 12
TENTATIVE CRITERIA FOR RATING CLAY-SOILS WITH REGARD TO RELATIVE SUPPORTING VALUE AND RELATIVE STABILITY IN SLOPES ON A RELATIVE CONSISTENCY AND SHEARING STRENGTH BASIS

Relative Consistency, *RC*		Maximum Shearing Strength	Relative Supporting Value and Relative Stability in Slopes
1		2	3
		tons per sq ft	
Liquid limit	*LL*	0 03 (approx)	
Very soft	*VS*	less than 0 05	None
Soft	*S*	0 05 to 0 10	Practically none
Medium soft	*MS*	0 01 to 0 50	Poor to fair
Ball moisture	*BM*	0 50	
Firm or stiff	*F*	0 50 to 1 0	Fair to good
Medium hard	*MH*	1 0 to 2 0	Good to very good
Hard	*H*	2 0 to 4 0	Very good to excellent
Very hard	*VH*	4 0 and greater	Excellent

Note—Designations of the relative consistency in the identification of soils may be written in symbol form as follows, for example—
Soft Relative Consistency, *S RC*
Firm Relative Consistency, *F RC*

The permanence of the strength characteristics of natural deposits of clay-soils and of compacted clay-soils in embankments and subgrades is affected by capillary saturation Certain absorptive types of clay-soils, which possess objectionable water absorption and swelling characteristics, have a tendency to soften in the presence of excess water and to lose their supporting value. For compacted soils the most permanent condition with the to normal expected capillary saturation and tendency for swelling for subgrades beneath pavements

These few examples illustrate the possibilities for establishing significant and practically useful ratings of soils with regard to their potential behavior characteristics. When the

[7] M S Kersten Survey of Subgrade Moisture Conditions. *Proc* Highway Research Board, Vol 24. 1944, p 497

actual behavior of different types of soils under different kinds of situations have been observed in sufficient detail in the field, have been compared with what was expected, and have been properly interpreted and correlated with significant soil characteristics and soil properties, and when the controlling conditions in the different situations have been appra sed and comprehended properly, then the id'entifications of soils will become or can be made more significant in disclosing the inherent characteristics that control behavior. The tentative criteria and the tentative ratings as to potential behavior can then be corrected and can be made more reliable, significant and practicay useful.

The interplretative ratings of soils with regard to qualitlies and potential behavior, however, should not be taken as a substitute for factual identifications but may be added to identifications. A rating is an interpretative expression of experience or of the results of research. It must be constantly checked against experience and brought up to date with the growth in knowledge and experience, in order to make it more significant, reliable and practically useful. The interpretative rating of soils and the appraisal of natural situations, and the correlations of expected behavior with the actual observed behavior under a given set of circumstances, can inform the engineer regarding what characteristics and qualities of soils are significant, which should be accurately and completely identified, whether the ones now recognized or others that are not yet suspected to be of controlling importance. The factual identification of soils can then be expanded to cover these qualities and characteristics of the soil material and of the natural structure of soils, which are found by experience and correlations to be significant. This paper has been concerned principally with the factual information identifying the character and qualities of the soil material But the factual information concerning the natural structure of the soil en mass may be equally or even more important But both are essential The following will illustrate the possibilities in this direction.

The important qualities and characteristics of the granular soil mass are: natural compactness, natural coherence due to deposition of silt in small amounts at the grain contacts capable of holding capillary moisture films permanently, the influence of composition and gradation on the grain structure and density in the natural state or in the compacted state and on the strength characteristics of the soil (Ref. 6), and the layering and anisotropic character of a deposit in detail and en mass. These qualities and characteristics should be made a part of the factual soil identification Thus to identify a granular soil as: *medium to fine SAND, trace fine Silt, Medium Compact, Moderate Coherence* or *fine SILT with ⅛-in. thin layers of medium to fine SAND at ⅜ to ½ in.* would give more accurate and complete information on the inherent character and probable behavior of the soil

The important qualities and characteristics of the clay-soil mass are: natural consistency and shearing strength, natural structure, natural state of aggregation of the clay-soil particles, the relation of the natural moisture content to the liquid or plastic limits, and the thin layering and anisotropic character of a

TABLE 13

TENTATIVE CRITERIA FOR RATING CLAY-SOILS ON AN OVERALL PLASTICITY BASIS WITH REGARD TO NORMAL CAPILLARY SATURATION AND SWELLING. MODIFIED AFTER KERSTEN (REF 7)

Composite Clay-Soil Type	Degree of Overall Plasticity Sand-Silt-Clay Components		Approx Normal Capillary Saturation. Per cent of Optimum Moisture	Approx Swelling Percent of Original Volume
	Plasticity	PI		
1	2	3	4	5
Silt	Non-plastic	0	70 to 100	none
Clayey Silt	Slight	1-5	100	0 to 1
Silt & Clay	Low	5-10	to	1 to 3
CLAY & SILT	Medium	10-20		3 to 7
Silty CLAY	High	20-40	110	7 to 10
CLAY	Very high	40 and greater	110 plus	10 and greater

deposit. Thus to identify a clay-soil as: '*medium to fine SAND, some Clayey Silt, Slight plasticity, Very Hard and Compact* or *CLAY & SILT, little medium to fine Sand, Medium Plasticity, Stiff Consistency, Fragmentary Fissured Structure* would give more accurate and complete information on the inherent character and probable behavior of the clay-soil.

These more accurate and complete identifications would become significant and of great practical value, when it was learned by experience what this factual information meant in terms of relative supporting value, relative stability of slopes, excavation and unwatering practices, permanence of strength characteristics, etc. under any given circumstances and controlling conditions. But to make this last step possible, the basic concept and requirements of the scientific method must be satisfied, namely, that of adequately and reliably knowing and identifying the soils and the controlling conditions with which we are dealing Thus identification must be a constantly growing and expanding technique, which is capable of discovering possible unsuspected qualities and characteristics of soils and of disclosing accurately and completely the inherent characteristics and qualities, which may be responsible for the actual behavior of soils under the varied controlling conditions encountered in engineering practice.

IDENTIFICATION TECHNIQUES

TABLE 14—Gravel Component
TABLE 15—Sand and Silt Components of Granular Soils with less than Five Percent Silt.
TABLE 16—Sand and Silt Components of Granular Soils with more than Five Percent Silt
TABLE 17—Composite Clay-Soils and Composite Organic Silts.

TABLE 14

IDENTIFICATION TECHNIQUES FOR THE GRAVEL COMPONENT

GRAVEL—Material passing the 3-in. sieve and retained on No 10 sieve (2 mm) (about $\frac{1}{16}$ in). Fractions—coarse, 3 in. to 1 in.; medium, 1 in to $\frac{3}{8}$ in ; fine, $\frac{3}{8}$ in to $\frac{1}{16}$ in

Select a representative sample of soil of at least one pint in volume, if appreciable gravel is present. Use the method of quartering for bulk samples

(1) *Soil Characteristics*—Identify visually.

(a) General color of the whole soil, preferably moist
(b) Maximum particle size of gravel
(c) Predominating grain shape—waterworn, sub-angular, angular, etc
(d) Kind of rock or mineral
(e) Hardness, soundness or friable condition.
(f) Constituents—mica. shells, roots and humus, foreign matter, etc

(2) *Proportion of Gravel Component*—Identify the proportion of gravel visually referred to the whole soil, in accordance with the definitions of identifying terms in Table 5 Pick the gravel particles out from the air-dried or moist soil by hand to at least $\frac{1}{4}$ in size and place them in a pile at one side in the pan Compare the volumes of the gravel component and the material finer (moist or dry) to determine whether the gravel is a principal component or a minor component Some allowance, which can be learned by experience, can be made for the effect of the larger gravel sizes and for bulking effects in moist materials The identification of proportions of the gravel referred to the whole soil can be made as follows Divide the larger pile of soil, whether gravel or the material finer, into two equal parts. It will then be relatively easy to estimate whether the smaller undivided pile falls within the range of *and* (35 to 50%) If gravel is the principal component, the designation would be *GRAVEL and*, (50 to 65%), or if a minor component, the designation would be, *and Gravel* If the smaller undivided pile is less 35 percent, divide the larger pile now into three equal parts and then subdivide one of these parts again into three equal parts It will then be relatively easy to estimate whether the smaller undivided pile is more than two of these parts and falls within the range of *some* (20 to 35%), or is more than one of these parts and falls within the range of *little* (10 to 20%), or is less than one of these parts and falls within the range of *trace* (1 to 10%) In many cases it will not be difficult, if considered significant with regard to soil behavior, to estimate closer proportions designated by plus and minus signs, as noted in Table 5 With experience the proportion of the gravel component can be identified readily within these ranges of proportions visually and by running the fingers through the soil

(3) *Gradation of the Gravel Component*—Identify the gradation of the gravel component in accordance with the definitions of the identifying terms in Table 5 The identification of the gradation of the gravel component involves recognizing visually whether or not the coarse, medium and fine fractions are present in amounts exceeding 10 percent, as a percentage of the component itself, and also involves

identifying which fraction predominates The gravel component can be readily separated into fraction, if desired for identification, because the 1-in. and ⅜-in sizes are easily recognized In many composite sand-gravel soils the coarser gravel fractions predominate Because of the influence on behavior closer designations should be made by using the plus sign, as noted in Table 5

TABLE 15

IDENTIFICATION TECHNIQUES FOR THE SAND AND SILT COMPONENTS OF COMPOSITE GRANULAR SOILS WITH LESS THAN FIVE PERCENT SILT

SAND—Material passing the No. 10 sieve (about $\frac{1}{16}$ in.) and retained on the No 200 sieve

SILT—Material passing the No 200 sieve, which is non-plastic at any moisture content, and has little or no strength in air-dried lumps. The individual particles can not be readily distinguished by the unaided eye.

If gravel is present, follow the techniques of Table 14 to identify the gravel and continue with Item 2 below. If gravel is not present, select a representative sample and continue with Item 1. Check Item 5 to identify the silt content as being less than 5 percent.

(1) *Soil Characteristics*—Identify visually
(a) General color of the soil, preferably moist
(d) Kind of rock or soil mineral
(e) Constituents—mica, shells, roots and humus, foreign matter, etc.

(2) *Proportion of Combined Sand-Silt Components*—The proportion of the combined sand-silt components is equal to 100 percent minus the proportion of gravel identified by the range of percentages in Col. 4, Table 5.

(4) *Gradation of Sand Component*—Identify the gradation of the sand component according to the definitions of terms in Table 5 The identification of the gradation of the sand component involves only recognizing whether or not the coarse, medium and fine fractions are present in amounts exceeding 10 percent, as a percentage of the component itself Identify the presence of more or less than 10 percent of coarse sand in the dry or moist condition visually or by feel by picking up a pinch of thoroughly mixed soil between the thumb and forefinger and by rubbing the soil rather lightly between them The coarse sand particles ($\frac{1}{16}$ to $\frac{1}{32}$ in) separate the thumb and forefinger sufficiently to allow the fine sand and most of the medium sand to fall out. If three or four or more coarse sand particles remain, when the residue is spread in the palm of the hand, there is more than 10 percent coarse sand Identify the presence of more or less than 10 percent of fine sand in the dry state visually by spreading a small pinch of well mixed soil lightly and evenly in a white evaporating dish or on a piece of white paper by rubbing the soil lightly between the thumb and forefinger about one inch above the bottom of the dish until a light even sprinkling of sand particles is made with individual particles sufficiently separated to recognize the fine sand The fine sand can be readily recognized by comparing with a light sprinkling of the fine sand fraction from the standard set of identification samples of Table 6 If 3 to 5 or more fine sand particles are present for each medium sand particle, there is more than 10 percent fine sand When the fine sand fraction exceeds about 30 per cent of the component (about 10 particles of fine to one medium sand) the sand appears to be all fine sand However the presence of the medium sand can be recognized by feel, or by the use of a hand lens. Since natural processes seldom deposit a single fraction with less than 10 percent of the fractions coarser or finer, the identification would be *medium to fine+ Sand*, if the use of the plus sign was considered significant.

(5) *Proportion of Silt Component*—Identify the proportion of silt, as a percentage of the combined sand-silt components to be less than 5 percent If more than 5 percent, proceed to Table 16 Less than one percent silt is identified by the absence of dust in the dry state, when a handfull of soil is dropped from a height of about one foot into a pan The appearance of a slight amount of dust indicates about 1 to 2 percent silt. If the individual sand grains in the dry or moist state visually appear to be somewhat indistinct, due to adhering silt, the silt content is between 2 and 5 percent As a check, silt can be identified in a washing test by mixing a pinch of soil in an evaporating dish with just enough water to cover the soil about ⅛ in deep A slight discoloration indicates at least one percent silt A discoloration so turbid that the sand cannot be seen through the water indicates that the silt content exceeds 5 percent This test can be done readily in the palm of the hand

TABLE 16

IDENTIFICATION TECHNIQUES FOR THE SAND AND SILT COMPONENTS OF COMPOSITE SOILS WITH MORE THAN FIVE PERCENT SILT

If gravel is present, follow the techniques of Table 14 to identify the gravel component. Check the silt content to be greater than 5 percent by Item 5 of Table 15 and continue with

Item 1 below in the identification of the sand and silt components

(1) *Soil Character*—Identify visually.

(a) General color of the whole soil, preferably moist

(d) Kind of soil mineral

(e) Constituents—mica, shells, roots and humus, foreign matter, etc

(2) *Proportion of Combined Sand-Silt Components*—The proportion of the combined sand-silt components is equal to 100 percent minus the proportion of gravel identified by the range of percentages given in Col 4, Table 5

(4)-(5) *Proportions and Gradations of the Sand and Silt Components*—Identify the proportions of the sand and silt components as a percentage of the combined sand-silt components by the following techniques If gravel is present adjust the proportion to percentages of the whole soil Identify the gradation of the sand and the silt components at the appropriate stage in the identification

(a) *Characteristic Moisture*—Adjust the moisture content of a portion of the combined sand-silt components to the characteristic moisture, as a comparative basis for identification If the soil is too dry, increase the moisture content a little at a time by small increments with thorough mixing with one hand Check the moisture content with the dry hand by rubbing the moist soil with considerable pressure between the thumb and fingers The characteristic moisture is indicated by the moist soil sticking to and dirtying the fingers, so that a little rubbing only is required to remove the moist soil If the soil is too wet, mix and stir the soil lightly with the fingers until it dries out to the characteristic moisture Soils wetter or drier than the characteristic moisture are less sensitive in the manual identification tests as a comparative basis

(b) *Plasticity*—Check whether a small piece of the moist soil exhibits appreciable plasticity by trying to form a thread and to roll it to a smaller diameter, also at slightly higher moisture contents by applying a drop of water to a pinch of moist soil. If the soil exhibits appreciable plasticity, proceed to Table 17

(c) *Washing Test*—This test is used to more accurately identify the proportion and gradation of the sand in the combined sand-silt components for the first few samples of a similar group of soils identified in detail Compact moist soil lightly level full into a measuring spoon (for example, the ¼ teaspoon of a set of measuring spoons) Thoroughly stir the soil specimen in an evaporating dish with one-half inch depth of water Allow the dish to stand quiet for 5 sec and pour off one-half of the turbid water into a second empty dish Fill the dish again to a depth of one-half inch and repeat until the water is clear enough to see the sand through the water Pour off all of the water Identify the gradation of the sand residue according to the identifying terms of Table 5 Identify the proportion of sand by carefully scraping the sand residue into the measuring spoon and comparing the final volume with the original volume of the spoon full, in accordance with the proportions defined in Table 5 The proportion of silt of the combined sand-silt components is equal to 100 percent minus the proportion of sand This test can also be made in a 25 cc graduate by successive shakings and washings until the water is clear enough to measure the volume If gravel is present, adjust the silt content of the combined sand-silt components to a proportion of the whole soil, as indicated in Item 5 of Figure 2 by multiplying the two larger and the two smaller percentages together in the expression —(proportion of combined sand-silt of whole soil, Item 2) × (proportion of silt, Item 4c) equals (proportion of silt of whole soil) The gradation of the silt is determined by stirring the wash water in the second dish, and allowing it to settle for 5 minutes If the wash water is practically clear the gradation is ***coarse Silt***, if it is not clear, and there is a considerable residue of coarse silt,the gradation is ***coarse to fine Silt***.

(d) *Smear or Rubbing Test*—This test may be used on the remainder of a group of similar soils to recognize and to identify significant difference in the proportion and gradation of the sand, using the first few carefully identified samples as references for direct comparison, and also for selecting and forming the soils into groups of similar character and composition for identification Differences in the degree of grittiness, roughness or smoothness can be readily recognized with experience on a small portion of the soil brought to the characteristic moisture A pinch of the moist soils is pressed firmly between the thumb and forefinger and is then smeared under pressure by a single motion forward of the thumb A very gritty smear (sand grains rubbing directly on sand grains) is an indication of less than 10 percent coarse or fine silt The sand grains, however, are not distinctly visible For increasing proportions of coarse silt the soil becomes less gritty, but is always slightly gritty When the fine silt content exceeds 10 percent, individual sand grains are no longer distinguishable The soil in the smear test now exhibits a feeling of roughness rather than grittiness, which is quite distinctive because the silt gives a bedding to the sand grains The piece of soil also scuffs up and cracks in the smear test. As the fine silt content increases the smear becomes noticeably less rough When the silt content exceeds 65 percent, the soil feels quite smooth in the smear test With a few carefully identified samples for direct comparison and with experience a soil engineer can readily recognize differences in roughness of soil containing fine silt, for example, between ***little, some,*** and ***and,*** or differences in grittiness of soils containing coarse silt In judging the degree of roughness or grittiness consideration should be given to the gradation of the sand. A ***coarse to fine Sand*** will feel rougher than a ***medium to fine*** or ***fine Sand*** for the same fine silt content

Identify the gradation of the sand component, if the smear is rough or gritty, by rubbing a pinch of the moist soil lightly between the thumb and forefinger sufficiently to dry the soil up a bit and to allow most of the finer material to drop out If an examination of the residue in the palm of the hand shows 3 to 4 or more coarse sand grains, the sand contains more than 10 percent coarse sand, and it is identified as, ***coarse to fine Sand;*** if not, it is identified as ***medium to fine Sand,*** since with a silt content greater than 10 percent both medium and fine sand are present

If the soil in the smear test exhibits only a slightly rough or gritty to smooth feel, identify the proportion and gradation of the sand by the washing test of Item 4c above, or by washing a small pinch of the moist soil in the palm of the hand, and by examining the residue as to the gradation and proportion of sand.

(f) *Shaking-Squeezing Test* —Identify the gradation of the silt component by forming a small ball of the moist soil about one-half inch in diameter and by applying a few drops of water until the ball exhibits a wet surface appearance when shaken or bounced lightly in the palm of the hand If too wet, add a little more soil The test involves observing in sequence the reaction and speed of response of the soil, first to shaking or lightly bouncing the ball, second to lightly squeezing the ball between the thumb and forefinger, and third to releasing the seueezing pressure alternately. Predominantly medium sand cannot be formed into a ball for the test Predominantly fine sand can be formed into a ball, but the ball is very weak The presence of coarse silt (with less-than 10 percent fine silt) is identified by a pronounced and rapid response to shaking with a very wet surface appearance, to squeezing with a very rapid drying out of the surface, and to releasing the ball with a slumping down and again a very wet surface The response becomes only slightly less pronounced with increasing coarse silt content, and is an index of essentially open system conditions and relatively good drainage characteristics in soils containing coarse silt only

The response to the shaking-squeezing test on composite sand-fine silt soils becomes noticeably less pronounced and much less rapid, as the silt content increases, or as the fineness of the silt increases The presence of a very small amount of clay is sufficient to materially weaken and to slow up the response, especially the squeezing, but is not sufficient to give appreciable plasticity to the soil

The shaking-squeeze test is unsatisfactory on composite sand-silt soils with a rough smear. The fine character of the silt can be identified by forming a rather wet ball about one-half inch in diameter and by placing the ball firmly on some of the moist or dry soil If the wet ball dries out rather rapidly, the gradation of the silt is *coarse Silt* If the ball dries out rather slowly, the gradation of the silt is *coarse to fine Silt* or *fine Silt*, depending upon the slowness The presence of a very small amount of clay in the silt, sufficient to form hard lumps, but not sufficient to give the soil appreciable plasticity, is indicated by the surface of the ball remaining wet in appearance The test is an index of the relative capillarity of the wet ball and of the drier soil on which the ball was placed, and of the relatively poorer drainage characteristics of the soil in a puddled condition.

(g) *Capillary Strength or Ball-Drop Test*—The ball test may be used on soils exhibiting a gritty or rough smear to identify the first few samples more carefully Check the soil for the characteristic moisture content and adjust, if necessary Form a ball 1½ in in diameter by firmly pressing and compacting the moist soil at the characteristic moisture into shape with the thumb and fingers in the cup of the other hand, turning the ball after each pressure application The diameter of the ball should be checked by a 1½ in. ring Compact the soil rather lightly at first to form it into shape. Clean the hands of loose material frequently, and gradually increase the pressure to whatever the soil will take without cracking or shearing the ball Take care to apply the pressure as nearly uniformly all-around as possible with the thumb and fingers in the cup of the other hand

Medium to fine Sand will form a very weak ball, which cannot be picked up between the thumb and forefinger without crushing The soil can be formed and compacted into a ball with difficulty As the silt content increases the ball can be formed more readily and exhibits considerable strength When the ball exhibits sufficient strength to resist a drop greater than one-half inch, the height of drop, as discussed under *Techniques for Identification of Granular*

Soils, can be used to estimate the proportion of silt in composite sand-silt soils. Determine the bracketing heights of drop in inches within which only two or three very slight vertical tension cracks are caused under the impact around the flattened surface of contact at the lower limit and a cracking open of the ball at the upper limit, for purpose of identifying the proportion of silt in accordance with the following tentative criteria

Tentative Criteria for Identifying Composite Sand-Silt Soils, Based on the Height of Drop in the Ball-Drop Test, as an Index of Capillarity

Identification Proportion of Silt	Compacting of Ball		Bracketing Heights of Drop Inches	
	coarse Silt	*fine Silt*	*coarse Silt*	*fine Silt*
1	2	3	4	5
trace+ Silt		very difficult can pick ball up	none	0 5–2
little Silt	very difficult, can pick ball up	difficult	none 0 5–1	2–6
some Silt	difficult	readily	1–2	6–15
and Silt	quite readily	very readily	2–5	18 plus
SILT and	readily	" "	5 plus	

Note—The findings of Item f above will identify the character of the silt component and will indicate which column to use, 4 or 5

Adjust the proportions of silt obtained above to the basis of the whole soil, is gravel is present, in accordance with Item 4c, above, and as shown in Figure 2, Item 5.

TABLE 17

IDENTIFICATION TECHNIQUES FOR COMPOSITE CLAY-SOILS AND COMPOSITE ORGANIC SILTS

CLAY-SOIL—Material passing the No 200 sieve, which exhibits plastic properties and clay qualities within a certain range of moisture content and has considerable strength when air-dried

ORGANIC SILT—Material passing the No 200 sieve which exhibits plastic properties within a certain range of moisture content and exhibits fine granular and organic characteristics

If gravel is present, identify the gravel component by the techniques of Table 14, check the plasticity by the plasticity test, and continue with Item 2 below If gravel is not present, select a representative sample, check the plasticity, and continue with Item 1

(1) *Soil Characteristics*—Identify visually.
(a) General Color of the soil, preferably moist
(d) Kind of soil minerals.
(e) Constituents—mica, shells, root and humus, muck, foreign matter.

(2) Proportion of Composite Sand-Silt-Clay Components—The proportion of the combined sand-silt-clay components is equal to 100 percent minus the proportion of gravel identified by the range of percentages given in Table 5

(4-5-6) *Character and Proportions of the Sand and Combined Silt-Clay*—Identify the combined silt-clay components on the basis of overall plasticity, and identify the proportion of sand and combined silt-clay components. Adjust the proportion to the basis of the whole soil if gravel is present.

(a) *Ball Moisture and Characteristic Consistency*—Bring a portion of the soil to the characteristic constant consistency by adjusting the moisture as follows If the soil is too dry, add moisture to the soil a few drops at a time with thorough mixing and kneading until the soil has sufficient coherence to form a ball Thereafter break the ball in half and apply a few drops of water to the broken surfaces Put the moistened surfaces back together and distribute the moisture by thorough kneading Build the ball up to the required size by adding more soil at each addition of moisture Form a ball 1½ in in diameter by firmly shaping and pressing the moist soil with the thumb and fingers with a final shaping by rolling the ball between the palms of the hands to an approximately spherical shape Test the size of the ball with a ring 1½ in in diameter Adjust the moisture content by adding water a few drops at a time, as above, or if too wet by additional kneading to dry the soil sufficiently until the ball exhibits a flattened contact surface 2 2 cm (±0 1) in diameter, when dropped from a height of 2 ft The ball should not show a hard crusty surface with fine cracks and a softer interior, which is usually due to too much working of the surface of the ball and rolling between the palms of the hand This can be prevented by frequently breaking the ball in half, joining the exterior surfaces, and thoroughly kneading the material in the hands.

(b) *Plasticity Test*—Identify the overall plasticity of the combined sand-silt-clay components by the plasticity test on the basis of the following tentative criteria

Tentative Criteria for Identifying the Overall Plasticity of the Combined Sand-Silt-Clay Components at the characteristic Ball Moisture by the Plasticity Tests

Form and press a small piece of soil from the interior of the ball into a thread not larger than ⅛ in in diameter and about ½ in long, and shape by rolling lightly between the thumb and forefinger. Pick out any fine gravel particles that remain, which are between ¼ and $\frac{1}{16}$ in in size, because they interfere with the plasticity test Roll this thread on a hard surface with a gentle pressure of the forefinger until it breaks

Degree of Overall Plasticity 1	Feel and Smear Appearance 2	Ease of Rolling Threads of Soil 3	Smallest Diameter of Threads in Inches 4
Non-plastic.	gritty or rough	no threads can be rolled	ball cracks
Slight	rough to smooth	difficult	$\frac{1}{4}$
Low	rough to smooth	less difficult	$\frac{1}{8}$
Medium	smooth and dull	readily	$\frac{1}{16}$
High	shiny	very readily	$\frac{1}{32}$
Very high	very shiny and waxy	very readily	$\frac{1}{64}$

or crumbles, in order to determine the smallest diameter to which the thread of soil can be rolled at the ball moisture The rolling should be performed by rolling gradually toward one end of the thread only, allowing the larger end to break off. Check the final thread size by forming a second thread of soil from the ball only very slightly larger than the final size of the first thread when it crumbled, and by rolling this thread to the smallest diameter until it crumbles or breaks under the finger pressure. Identify the plasticity of the soil on the basis of the tentative criteria given above This plasticity test at the ball moisture is a sensitive index of overall plasticity.

(c) *Identification of Clay-Soils*—Identify the combined silt-clay components on the basis of the overall plasticity of the sand-silt-clay material determined above in the plasticity test on soil at the characteristic ball moisture in accordance with the definitions of identifying terms for the identification of composite clay-soils given in Table 7, considering the combined silt-clay components as one material

(d) *Washing Test*—Identify the proportion and gradation of the sand component in the combined sand-silt-clay components by washing a small piece of the moist clay soil in an evaporation dish or in the palm of the hand The gradation is identified visually by examination of the residue The porportion of the sand is identified by comparing the volume of the sand residue with the original volume of The piece of moist soil. A small measuring spoon (¼ teaspoon, for example) can be used or this purpose, filling the spoon level full, and estimating the proportion of the residue after washing. The proportions of the sand and clay-soil are identified in accordance with the definitions of proportions in Table 5 If gravel is present, these proportions are adjusted to the basis of the whole soil, in accordance with Item 4c of Table 16 and as shown in Figure 3

(e) *Smear Test*—This test may be used to identify the proportion and gradation of the sand component, using the first few carefully identified samples as references for direct comparison. A piece of the moist soil at the ball moisture is smeared between the thumb and forefinger under considerable pressure. A very rough smear for soils with slight and low plasticities is an indication of more than 65 percent sand of coarse to fine gradation With experience and by using the first few carefully identified samples, a person can judge proportions quite reliably. When the soil forms a thin cake with a relatively smooth smear and no breaks on the surface, the silt-clay components probably exceed 65 percent. For clay-soils of medium- and high plasticities the appearance of the smeared surface is an index of the dominance of the silt or of the clay Clay-soils of medium plasticity exhibit a dull to slightly shiny smeared surface. Clay-soils of high plasticity exhibit a smeared surface having a shiny to waxy appearance.

(f) *Identification of Organic Silts*—Identify the overall plasticity of the combined sand-organic silt at the ball moisture by the plasticity test of Item-b above. In the smear test of Item-e above the smear will be smooth, but will exhibit a characteristic dull silty appearance. When the ball at the ball moisture is broken in half, the surfaces will exhibit a characteristic fine granular silty texture The dark gray to black color and the characteristic odor of fresh material, together with these other characteristics will definitely identify the material as organic silt.