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CLASSIFICATION AND IDENTIFICATION OF SOILS FOR GENERAL ENGINEERING PURPOSES

(First Revision)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 19 December 1970, after the draft finalized by the Soil Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Soil survey and soil classification are at present being done by several organizations in this country for different purposes. The engineering departments and research laboratories have done a great deal of work in regard to soil exploration and classification in fields relating to irrigation, buildings, roads, etc. The investigations relating to the field of irrigation have two objectives namely, the suitability of soil for the construction of dams and other kinds of hydraulic structures and the effect on the fertility of soil when it is irrigated. With regard to roads and highways, investigations have been undertaken to classify them from the point of view of their suitability for construction of embankments, sub-grades, and wearing surfaces. In the field of buildings, soil investigation and classification is done to evaluate the soil as regards its bearing power to a certain extent. Soil survey and soil classification are also done by agriculture departments from the point of view of the suitability of the soil for crops and its fertility. Each of these agencies was adopting different systems for soil classification. The adoption of different methods by various agencies led to difficulties in interpreting the results of soils investigated by one agency by the other and quite often results were found to be not easily comparable. This Indian standard was, therefore, published in 1959 to provide a common basis for soil classification.

0.3 Soils seldom exist in nature separately as sand, gravel or any other single component but are usually found as mixture with varying proportions of particles of different sizes. This revision is essentially based on the Unified Soil Classification System with the modification that the fine-grained soils have been subdivided into three subdivisions of low, medium and high compressibility, instead of two subdivisions of the original Unified Soil Classification System. The system is based on those characteristics of the soil which indicate how it will behave as a construction material. This system is not limited to a particular use or geographical location. It does not conflict with other systems; in fact, the use of geologic, pedologic, textural or local terms is encouraged as a supplement to, but not as a substitute for, the definitions, terms and phrases established by this system and which are easy to associate with actual soils.

0.4 In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in this field in this country.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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1. SCOPE

1.1 This standard covers a system for classification and indentification of soils for general engineering purposes. The information given in this standard should be considered as for guidance only for treating the soil for engineering purposes.

2. TERMINOLOGY

2.0 For the purpose of this standard, the definitions given in IS : 2809-1972† and the following shall apply.

2.1 Clay — An aggregate of microscopic and sub-microscopic particles derived from the chemical decomposition and disintegration of rock constituents. It is plastic within a moderate to wide range of water content.

2.2 Silt — A fine-grained soil with little or no plasticity. If shaken in the palm of the hand, a part of saturated inorganic silt expels enough water to make its surface appear glossy. If the pat is pressed or squeezed between the fingers, its surface again becomes dull.

2.3 Sand and Gravel — Cohesionless aggregates of angular, sub-angular, sub-rounded, rounded, flaky or flat fragments of more or less unaltered rocks or minerals.

According to this system, gravel is a fraction of the soil material between 80 mm and the 4·75-mm IS Sieve size and sand is the material between the 4·75-mm IS Sieve size and the 75-micron IS Sieve size.

*Rules for rounding off numerical values (*revised*).

†Glossary of terms and symbols relating to soil engineering (*first revision*).

3. CLASSIFICATION AND IDENTIFICATION

3.1 Division — Soils shall be broadly divided into three divisions as given in **3.1.1** to **3.1.3**.

3.1.1 *Coarse-Grained Soils* — In these soils, more than half the total material by weight is larger than 75-micron IS Sieve size.

3.1.2 *Fine-Grained Soils* — In these soils, more than half of the material by weight is smaller than 75-micron IS Sieve size.

3.1.3 *Highly Organic Soils and Other Miscellaneous Soil Materials* — These soils contain large percentages of fibrous organic matter, such as peat, and particles of decomposed vegetation. In addition, certain soils containing shells, concretions, cinders, and other non-soil materials in sufficient quantities are also grouped in this division.

3.2 Subdivision — The first two divisions (*see* **3.1.1** and **3.1.2**) shall be further divided as given in **3.2.1** and **3.2.2**.

3.2.1 *Coarse-Grained Soils* — The coarse-grained soils shall be divided into two subdivisions, namely:

a) *Gravels* — In these soils, more than half the coarse fraction (+75 micron) is larger than 4·75-mm IS Sieve size. This subdivision includes gravels and gravelly soils.

b) *Sands* — In these soils, more than half the coarse fraction (+75 micron) is smaller than 4·75-mm IS Sieve size. This subdivision includes sands and sandy soils.

3.2.2 *Fine-Grained Soils* — The fine-grained soils shall be further divided into three subdivisions on the basis of the following arbitrarily selected values of liquid limit:

a) *Silts and clays of low compressibility* — having a liquid limit less than 35 (represented by symbol *L*),

b) *Silts and clays of medium compressibility* — having a liquid limit greater than 35 and less than 50 (represented by symbol *I*), and

c) *Silts and clays of high compressibility* — having a liquid limit greater than 50 (represented by symbol *H*).

NOTE — In this system the fine-grained soils are not divided according to particle size but according to plasticity and compressibility. The term 'compressibility' here shall imply volume change, shrinkage during dry periods and swelling during wet periods, as well as, consolidation under load. Soil particles finer than 2-micron may, however, be designated as clay-size particles and the particles between 75-micron and 2-micron as silt-size particles.

3.3 Groups — The coarse-grained soils shall be further divided into eight basic soil groups. The fine-grained soils shall be further divided into nine basic soil groups (*see* Table 2).

3.3.1 Highly organic soils and other miscellaneous soil materials shall be placed in one group. The groups shall be designated by symbols.

NOTE — These groups are broad, based on basic properties of soil; therefore, supplemental detailed word descriptions are required to point out pecularity of a particular soil and differentiate it from others in the same group.

3.3.2 The basic soil components are given in Table 1.

3.3.3 The various subdivisions, groups and group symbols are given in Table 2.

3.4 Field Identification and Classification Procedure — The field method is used primarily in the field to classify and describe soils. Visual observations are employed in place of precise laboratory tests to define the basic soil properties. The procedure is, in fact, a process of elimination beginning on the left side of the classification chart (Table 2) and working to the right until the proper group name is obtained. The group name should be supplemented by detailed word descriptions, including the description of the in-place conditions for soils to be used in place as foundations. A representative sample of the soil is selected which is spread on a flat surface or in the palm of the hand. All particles larger than 80 mm are removed from the sample. Only the fraction of the sample smaller than 80 mm is classified. The sample is classified as coarse-grained or fine-grained by estimating the percentage by weight of individual particles which can be seen by the unaided eye. Soils containing more than 50 percent visible particles are coarse-grained soils, soils containing less than 50 percent visible particles are fine-grained soils.

If it has been determined that the soil is coarse grained, it is further identified by estimating and recording the percentage of: (a) gravel sized particle, size range from 80 mm to 4·75-mm IS Sieve size (or approximately 5 mm size); (b) sand size particles, size range from 4·75 to 75-micron IS Sieve size; and (c) silt and clay size particles, size range smaller than 75-micron IS Sieve.

NOTE — The fraction of soil smaller than 75-micron IS Sieve, that is, the clay and silt fraction is referred to as fines.

3.4.1 *Gravelly Soils* — If the percentage of gravel is greater than that of sand, the soil is a gravel. Gravels are further identified as being clean (containing little or no fines, that is less than 5 per cent) or dirty (containing appreciable fines, that is more than 12 per cent) depending upon the percentage of particles not visible to the unaided eye. Gravels containing 5 to 12 percent fines are given boundary classification. If the soil is obviously clean, the classification shall be either: (a) well graded gravel (GW), if there is good representation of all particle sizes; or (b) poorly graded gravel (GP), if there is an excess or absence of intermediate particle sizes. A well-graded soil has a reasonably large spread between the largest and the finest particles and has no marked deficiency in any size. If the soil obviously is dirty, the classification will be either (c) silty gravel (GM), if the fines have little or no plasticity; or (d) clayey gravel (GC), if the fines are of low to medium or high plasticity (*see* **3.2.2**).

3.4.2 *Sandy Soils* — If the percentage of sand is greater than gravel, the soil is a sand. The same procedure is applied as for gravels except that the word sand replaces gravel and the symbol S replaces G. The group classification for the clean sands will be either: (a) well-graded sand (SW) or (b) poorly-graded sand (SP), and the dirty sands shall be classified as (c) silty sand (SM), if the fines have little or no plasticity; or (d) clayey sand (SC), if the fines are of low to medium or high plasticity (*see* **3.2.2**).

3.4.3 *Boundary Classification for Coarse-Grained Soils* — When a soil possesses characteristics of two groups, either in particle size distribution or in plasticity, it is designated by combinations of group symbols. For example, a well-graded coarse-grained soil with clay binder is designated by GWGC.

3.4.3.1 Boundary classifications can occur within the coarse-grained soil division, between soils within the gravel or sand grouping, and between gravelly and sandy soils. The procedure is to assume the coarser soil, when there is a choice, and complete the classification and assign the proper group symbol; then, beginning where the choice was made, assume a finer soil and complete the classification, assigning the second group symbol.

3.4.3.2 Boundary classifications within gravel or sand groups can occur. Symbols such as GW-GP, GM-GC, GW-GM, GW-GC, SW-SP, SM-SC, SW-SM and SW-SC are common.

3.4.3.3 Boundary classifications can occur between the gravel and sand groups. Symbols such as GW-SW, GP-SP, GM-SM and GC-SC are common.

3.4.3.4 Boundary classifications can also occur between coarse and fine grained soils. Classifications such as SM-ML and SC-CL are common.

3.4.4 *Descriptive Information for Coarse-Grained Soils* — The following descriptive information shall be recorded for coarse-grained soils:

a) Typical name;
b) Maximum size, and fraction larger than 80 mm in the total material;
c) Percentage of gravel, sand and fines in the soil or fraction of soil smaller than 80 mm;
d) Description of average size of sand of gravel;

e) Shape of the particles — angular, subangular, subrounded, rounded;
f) The surface coatings, cementation and hardness of the particles and possible breakdown, when compacted;
g) The colour and organic content;
h) Plasticity of fines;
j) Local or geologic name, if known; and
k) Group symbol.

3.4.5 *Fine-Grained Soils* — If it has been determined that the soil is fine-grained, it is further identified by estimating the percentage of gravel, sand, silt and clay size particles and performing the manual identification tests for dry strength, dilatancy, and toughness. By comparing the results of these tests with the requirements given for the nine fine-grained soil groups, the appropriate group name and symbol is assigned. The same procedure is used to identify the fine-grained fraction of coarse-grained soil to determine whether they are silty or clayey.

3.4.6 *Manual Identification Tests* — The following tests for identifying the fine-grained soils shall be performed on the fraction of the soil finer than the 425-micron IS Sieve:

a) *Dilatancy (reaction to shaking)* — Take a small representative sample in the form of a soil pat of the size of about 5 cubic centimetres and add enough water to nearly saturate it. Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. Squeeze the pat between the fingers. The appearance and disappearance of the water with shaking and squeezing is referred to as a reaction. This reaction is called quick, if water appears and disappears rapidly; slow, if water appears and disappears slowly; and no reaction, if the water condition does not appear to change. Observe and record type of reaction as descriptive information.

b) *Toughness (consistency near plastic limit)* — Dry the pat used in the dilatancy test by working and moulding, until it has the consistency of putty. The time required to dry the pat is the indication of its plasticity. Roll the pat on a smooth surface or between the palms into a thread about 3 mm in diameter. Fold and reroll the thread repeatedly to 3 mm in diameter so that its moisture content is gradually reduced until the 3 mm thread just crumbles. The moisture content at this time is called the plastic limit and the resistance to moulding at the plastic limit is called the toughness. After the thread crumbles, lump the pieces together and continue the slight kneading action until the lump crumbles. If the lump can still be moulded slightly drier than the plastic limit and if high pressure is required to role the thread between the palms of the hand, the soil is described as having high toughness. Medium toughness is indicated by a medium thread and a lump formed of the threads slightly below the plastic limit will crumble; while low toughness is indicated by a weak thread that breaks easily and cannot be lumped together when drier than the plastic limit. Highly organic clays have very weak and spongy feel at the plastic limit. Non-plastic soils cannot be rolled into thread of 3 mm in diameter at any moisture content. Observe and record the toughness as descriptive information.

c) *Dry strength (crushing resistance)* — Completely dry the prepared soil pat. Then measure its resistance to crumbling and powdering between fingers. This resistance, called dry strength, is a measure of the plasticity of the soil and is influenced largely by the colloidal fraction content. The dry strength is designated as low, if the dry pat can be easily powdered; medium, if considerable finger pressure is required and high, if it cannot be powdered at all. Observe and record the dry strength as descriptive information.

NOTE — The presence of high-strength water soluble cementing materials, such as calcium carbonates or iron oxides may cause high dry strength. Non-plastic soils, such as caliche, coral, crushed lime stone or soils containing carbonaceous cementing agents may have high dry strength, but this can be detected by the effervescence caused by the application of diluted hydrochloric acid.

d) *Organic content and colour* — Fresh wet organic soils usually have a distinctive odour of decomposed organic matter. This odour can be made more noticeable by heating the wet sample. Another indication of the organic matter is the distinctive dark colour. In tropical soils, the dark colour may be or may not be due to organic matter; when not due to organic matter, it is associated with poor drainage. Dry organic clays develop an earthy odour upon moistening, which is distinctive from that of decomposed organic matter.

e) *Other identification tests*

1) *Acid test* — Acid test using dilute hydrochloric acid (HCl) is primarily a test for the presence of calcium carbonate. For soils with high dry strength, a strong reaction indicates that the strength may be due to calcium carbonate as cementing agent rather than colloidal clay. The results of this test should be included in the soil description, if pertinent.

2) *Shine test* — This is a quick supplementary procedure for determining the presence of clay. The test is performed by cutting a lump of dry or slightly moist soil with a knife. The shiny surface imparted to the soil indicates highly plastic clay, while a dull surface indicates silt or clay of low plasticity.

3) *Miscellaneous test* — Other criteria undoubtedly may be developed by the individual as he gains experience in classifying

the soils. For example, differentiation between some of the fine-grained soils depends largely upon the experience in the feel of the soils. Also wet clay sticks to the fingers and dries slowly but silt dries fairly quickly and can be dusted off the fingers leaving only a stain. Frequent checking by laboratory tests is necessary to gain this experience.

3.4.7 *Boundary Classification for Fine-Grained Soils* — Boundary classifications can occur within the fine-grained soil divisions, between low and medium or between medium and high liquid limits and between silty and clayey soils. The procedure is comparable to that given for coarse-grained soils (*see* **3.4.3**), that is, first assume a coarse soil, when there is a choice, and then a finer soil and assign dual group symbols. Boundary classifications which are common are as follows:

ML-MI, CL-CI, OL-OI, MI-MH, CI-CH, OI-OH, CL-ML, ML-OL, CL-OL, CI-MI, MI-OI, CI-OI, MH-CH, MH-OH, and CH-OH.

3.4.8 *Very Highly Organic Soils* — Peat or very highly organic soils may be readily identified by colour, sponginess or fibrous texture.

3.4.9 *Descriptive Information for Fine-Grained Soils* — The following descriptive information shall be recorded for fine-grained soils:

a) Typical name;

b) Percentage of gravel, sand and fines;

c) Colour in moist condition and organic content;

d) Plasticity characteristics;

e) Local or geologic name, if known; and

f) Group symbol.

3.4.10 *Description of Foundation Soils* — The following information shall be recorded to define the in-place condition of soils which are to be utilized as foundation for hydraulic or other structures:

a) *For coarse-grained soils*:
   1) Natural moisture content (as dry, moist, wet and saturated);
   2) Perviousness or drainage properties in the natural condition;
   3) Structure (as stratified, uniform, uncemented, lensed; and attitude, that is, strike and dip);
   4) Type and degree of cementation; and
   5) Degree of compactness (as loose or dense).

b) *For fine-grained soils*:
   1) Natural moisture content (as dry, moist, wet and saturated);
   2) Perviousness or drainage properties;

3) Structures (as stratified, homogenous, varved, honeycomb, root-holes, blocky, fissured, lensed; and attitude, that is, strike and dip). The thickness of lenses, fissures, etc, shall be noted;

4) Type and degree of cementation; and

5) Consistency (very soft, soft, firm, hard, very hard, sticky, brittle, friable and spongy).

NOTE — The consistency and the compactness of undisturbed soil should be defined clearly from the consistency of the soil when disturbed and manipulated. For example, a very thick stratum of hard, dense shale or pre-consolidated clay of high bearing capacity, not requiring piling, may be correctly classified as a fat clay (CH) of high plasticity. Obviously the classification without description of undisturbed condition might cause the interpreter to erroneously conclude that it is soft and plastic in its natural state.

3.5 Laboratory Identification and Classification Procedure — The laboratory method is intended for precise delineation of the soil groups by using results of laboratory tests, for gradation and moisture limits, rather than visual estimates. Classification by these tests alone does not fulfil the requirements for complete classification, as it does not provide an adequate description of the soil. Therefore, the descriptive information required for the field method should also be included in the laboratory classification.

3.5.1 *Classification Criteria for Coarse-Grained Soils* — The laboratory classification criteria for classifying the coarse-grained soils are given in Tables 3 and 4.

3.5.2 *Boundary Classification for Coarse-Grained Soils* — The coarse-grained soils containing between 5 and 12 percent of fines are classified as border-line cases between the clean and the dirty gravels or sands as for example, GW-GC, or SP-SM. Similarly border-line cases might occur in dirty gravels and dirty sands, where the I_p is between 4 and 7 as, for example, GM-GC or SM-SC. It is possible, therefore, to have a border line case of a border line case. The rule for correct classification in this case is to favour the non-plastic classification. For example, a gravel with 10 percent fines, a Cu of 20, a Cc of 2·0 and I_p of 6 would be classified GW-GM rather than GW-GC (I_p is the plasticity index of the soil).

3.5.3 *Classification Criteria for Fine-Grained Soils* — The laboratory classification criteria for classifying the fine-grained soils are given in the plasticity chart shown in Fig. 1 and Table 4. The '*A*' line has the following linear equation between the liquid limit and the plasticity index:

$$I_p = 0{\cdot}73\ (w_L - 20)$$

where

I_p = plasticity index, and

w_L = liquid limit.

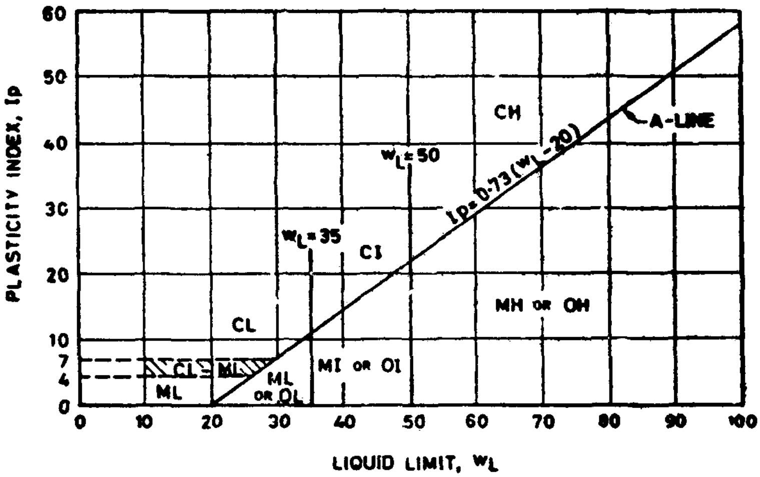

FIG. 1 PLASTICITY CHART

3.5.3.1 Organic silts and clays are usually distinguished from inorganic silts which have the same position on the plasticity chart, by odour and colour. However, when the organic content is doubtful, the material can be oven dried, remixed with water, and retested for liquid limit. The plasticity of fine-grained organic soils is greatly reduced on oven drying, owing to irreversible changes in the properties of the organic material. Oven drying also affects the liquid limit of inorganic soils, but only to a small degree. A reduction in liquid limit after oven drying to a value less than three-fourth of the liquid limit before oven drying is positive identification of organic soils.

3.5.4 *Boundary Classification for Fine-Grained Soils* — The fine-grained soils whose plot on the plasticity chart falls on, or practically on:

a) 'A' line

b) '$w_L = 35$' line

c) '$w_L = 50$' line

shall be assigned the proper boundary classification. Soils which plot above the 'A' line, or practically on it, and which have plasticity index between 4 and 7 are classified ML-CL.

3.6 Black Cotton Soils — Black cotton soils are inorganic clays of medium to high compressibility and form a major soil group in India. They are predominantly montmorillonitic in structure and black or blackish grey in colour. They are characterized by high shrinkage and swelling properties. The majority of the soils, when plotted on the plasticity chart, lie along a band above the '*A*' line. The plot of some of the black cotton soils is also found to lie below the '*A*' line. Care should therefore be taken in classifying such soils.

3.7 Some other inorganic clays, such as kaolin, behave as inorganic silts and usually lie below the '*A*' line and shall be classified as such (ML, MI, MH), although they are clays from mineralogical stand-point.

3.8 Relative Suitability for General Engineering Purposes — Table 5 gives the characteristics of the various soil groups pertinent to roads and airfields. Table 6 gives the characteristics pertinent to embankments and foundations. Table 7 gives the characteristics pertinent to suitability for canal sections, compressibility, workability as a construction material and shear strength. The information given in these tables should be considered as a guidance only for treating a soil for a particular engineering purpose.

TABLE 1 BASIC SOIL COMPONENTS

(*Clause* 3.3.2)

SL No.	SOIL	SOIL COMPONENT	SYMBOL	PARTICLE-SIZE RANGE AND DESCRIPTION
(1)	(2)	(3)	(4)	(5)
i)	Coarse-grained components	Boulder	None	Rounded to angular, bulky, hard, rock particle; average diameter more than 300 mm
		Cobble	None	Rounded to angular, bulky, hard, rock particle; average diameter smaller than 300 mm but retained on 80-mm IS Sieve
		Gravel	G	Rounded to angular, bulky, hard, rock particle; passing 80-mm IS Sieve but retained on 4·75-mm IS Sieve Coarse: 80-mm to 20-mm IS Sieve Fine: 20-mm to 4·75-mm IS Sieve
		Sand	S	Rounded to angular, bulky, hard, rock particle; passing 4·75-mm IS Sieve but retained on 75-micron IS Sieve Coarse : 4·75-mm to 2·0-mm IS Sieve Medium: 2·0-mm to 425-micron IS Sieve Fine : 425-micron to 75-micron IS Sieve
ii)	Fine-grained components	Silt	M	Particles smaller than 75-micron IS Sieve; identified by behaviour, that is, slightly plastic or non-plastic regardless of moisture and exhibits little or no strength when air dried
		Clay	C	Particles smaller than 75-micron IS Sieve; identified by behaviour, that is, it can be made to exhibit plastic properties within a certain range of moisture and exhibits considerable strength when air dried
		Organic matter	O	Organic matter in various sizes and stages of decomposition

NOTE — A comparison between the size classifications of IS : 1498-1959 ‘ Classification and identification of soils for general engineering purposes ’ and the present revision is shown in Appendix A.

TABLE 2 SOIL CLASSIFICATION (INCLUDING FIELD IDENTIFICATION AND DESCRIPTION)

(*Clauses* 3.3, 3.3.3 *and* 3.4)

Division	Sub-Division		Group Letter Symbol	Hatching	Mapping Colour	Typical Names	Field Identification Procedures (Excluding particles larger than 80 mm and basing fractions on estimated weights)	Information Required for Describing Soils
1	2		3	4	5	6	7	8
COARSE-GRAINED SOILS More than half of material is larger than 75-micron IS Sieve size The smallest particle visible to the naked eye	*Gravels* More than half of coarse fraction is larger than 4·75-mm IS Sieve size (For visual classification the 5-mm size may be used as equivalent to the 4·75-mm IS Sieve size)	Clean gravels (Little or no fines)	GW		Red	Well graded gravels, gravel-sand mixtures; little or no fines	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	For undisturbed soils add information on stratification; degree of compactness, cementation, moisture conditions and drainage characteristics Give typical name; indicate approximate percentages of sand and gravel; maximum size, angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses *Example* : Silty sand, gravelly; about 20 percent hard angular gravel particles, 10 mm maximum size; rounded and subangular sand grains; about 15 percent non-plastic fines with low dry strength; well compacted and moist; inplace; alluvial sand (SM)
			GP		Red	Poorly graded gravels or gravel-sand mixtures; little or no fines	Predominantly one size or a range of sizes with some intermediate sizes missing	
		Gravels with fines (Appreciable amount of fines)	GM		Yellow	Silty gravels, poorly graded gravel-sand-silt mixtures	Non-plastic fines or fines with low plasticity (for identification procedures, *see* ML and MI below)	
			GC		Yellow	Clayey gravels, poorly graded gravel-sand-clay mixtures	Plastic fines (for identification procedures, *see* CL and CI below)	
	Sands More than half of coarse fraction is smaller than 4·75-mm IS Sieve size	Clean sands (Little or no fines)	SW		Red	Well graded sands, gravelly sands; little or no fines	Wide range in grain size and substantial amounts of all intermediate particle sizes	
			SP		Red	Poorly graded sands or gravelly sands; little or no fines	Predominantly one size or a range of sizes with some intermediate sizes missing	
		Sands with fines (Appreciable amount of fines)	SM		Yellow	Silty sands, poorly graded sand-silt mixtures	Non-plastic fines or fines with low plasticity (for intermediate procedures, *see* ML and MI below)	
			SC		Yellow	Clayey sands, poorly graded sand-clay mixtures	Plastic fines (for identification procedures, *see* CL and CI below)	

Division	Sub-Division	Group Letter Symbol	Hatching	Mapping Colour	Typical Names	Identification Procedures (on Fraction Smaller than 425-Micron IS Sieve Size): Dry Strength	Dilatancy	Toughness	Information Required for Describing Soils
FINE-GRAINED SOILS More than half of material is smaller than 75-micron IS Sieve size The 75-micron IS Sieve size is about the smallest particle visible to the naked eye	Silts and clays with low compressibility and liquid limit less than 35	ML		Blue	Inorganic silts and very fine sands rock flour, silty or clayey fine sands or clayey silts with none to low plasticity	None to low	Quick	None	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition; odour, if any, local or geologic name and other pertinent descriptive information and symbol in parentheses *Example*: Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place: loess (ML)
		CL		Green	Inorganic clays, gravelly clays, sandy clays, silty clays, lean clays of low plasticity	Medium	None to very slow	Medium	
		OL		Brown	Organic silts and organic silty clays of low plasticity	Low	Slow	Low	
	Silts and clays with medium compressibility and liquid limit greater than 35 and less than 50	MI		Blue	Inorganic silts, silty or clayey fine sands or clayey silts of medium plasticity	Low	Quick to slow	None	
		CI		Green	Inorganic clays, gravelly clays, sandy clays, silty clays, lean clays of medium plasticity	Medium to high	None	Medium	
		OI		Brown	Organic silts and organic silty clays of medium plasticity	Low to medium	Slow	Low	
	Silts and clays with high compressibility and liquid limit greater than 50	MH		Blue	Inorganic silts of high compressibility, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Low to medium	Slow to none	Low to medium	
		CH		Green	Inorganic clays of high plasticity, fat clays	High to very high	None	High	
		OH		Brown	Organic clays of medium to high plasticity	Medium to high	None to very slow	Low to medium	
Highly Organic Soils		Pt		Orange	Peat and other highly organic soils with very high compressibility	Readily identified by colour, odour, spongy feel and frequently by fibrous texture			

NOTE — *Boundary classification*: Soil possessing characteristics of two groups are designated by combinations of group symbols, for example, GW-GC, Well-graded, gravel-sand mixture with clay binder.

specification.

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TABLE 3 CLASSIFICATION OF COARSE-GRAINED SOILS (LABORATORY CLASSIFICATION CRITERIA)

(*Clause* 3.5.1)

Group Symbols	Laboratory Classification Criteria		
GW	C_u Greater than 4 C_c Between 1 and 3		Determine percentages of gravel and sand from grain-size curve. Depending on percentage of fines (fraction smaller than 75-micron IS Sieve) coarse-grained soils are classified as follows: Less than 5% GW, GP, SW, SP More than 12% GM, GC, SM, SC 5% to 12% Border-line cases requiring use of dual symbols Uniformity coefficient, $C_u = \frac{D_{60}}{D_{10}}$ Coefficient of curvature $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ where D_{60} = 60 percent finer than size D_{30} = 30 percent finer than size D_{10} = 10 percent finer than size
GP	Not meeting all gradation requirements for GW		
GM	Atterberg limits below 'A' line or I_p less than 4	Limits plotting above 'A' line with I_p between 4 and 7 are border-line cases requiring use of dual symbol	
GC	Atterberg limits above 'A' line with I_p greater than 7		
SW	C_u greater than 6 C_c between 1 and 3		
SP	Not meeting all gradation requirements for SW		
SM	Atterberg limits below 'A' line or I_p less than 4	Limits plotting above 'A' line with I_p between 4 and 7 are border-line cases requiring use of dual symbols	
SC	Atterberg limits above 'A' line with I_p greater than 7		

I_p = plasticity index.

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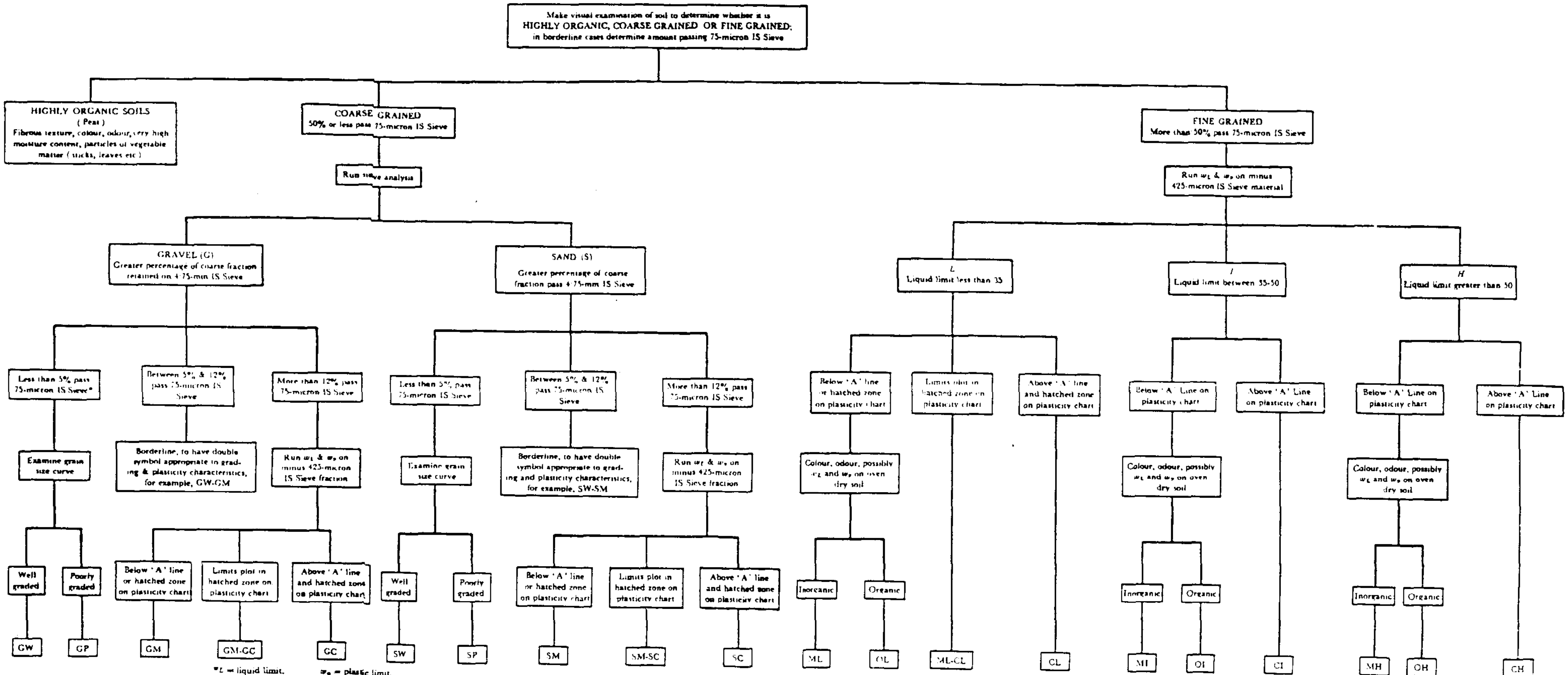
TABLE 4 AUXILIARY LABORATORY IDENTIFICATION PROCEDURE

(*Clauses* 3.5.1 *and* 3.5.3)



*w_L = liquid limit. w_P = plastic limit.

*If fines interfere with free drainage properties use double symbol, such as GW-GM.

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TABLE 5 CHARACTERISTICS PERTINENT TO ROADS AND AIRFIELDS

(*Clause* 3.8)

Soil Group	Value as Sub-Grade when not Subject to Frost Action	Value as Sub-Base when not Subject to Frost Action	Value as Base when not Subject to Frost Action	Potential Frost Action	Compressibility and Expansion	Drainage Characteristics	Compaction Equipment	Unit Dry Weight g/cm³	CBR Value Percent	Sub-Grade Modulus (*k*) kg/cm³
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
GW	Excellent	Excellent	Good	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tyred roller, steel-wheeled roller	2·00-2·24	40-80	8·3-13·84
GP	Good to excellent	Good	Fair to good	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tyred roller, steel-wheeled roller	1·76-2·24	30-60	8·3-13·84
GM d	Good to excellent	Good	Fair to good	Slight to medium	Very slight	Fair to poor	Rubber-tyred roller, sheeps-foot roller, close control of moisture	2·00-2·32	40-60	8·3-13·84
GM u	Good	Fair	Poor to not suitable	Slight to medium	Slight	Poor to practically impervious	Rubber-tyred roller, sheeps-foot roller	1·84-2·16	20-30	5·53-8·3
GC	Good	Fair	Poor to not suitable	Slight to medium	Slight	Poor to practically impervious	Rubber-tyred roller, sheeps-foot roller	2·08-2·32	20-40	5·53-8·3
SW	Good	Fair to good	Poor	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tyred roller	1·76-2·08	20-40	5·53-11·07
SP	Fair to good	Fair	Poor to not suitable	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tyred roller	1·68-2·16	10-40	4·15-11·07
SM d	Fair to good	Fair to good	Poor	Slight to high	Very light	Fair to poor	Rubber-tyred roller, sheeps-foot roller, close control of moisture	1·92-2·16	15-40	4·15-11·07
SM u	Fair	Poor to fair	Not suitable	Slight to high	Slight to medium	Poor to practically impervious	Rubber-tyred roller, sheeps-foot roller	1·60-2·08	10-20	2·77-8·3
SC	Poor to fair	Poor	Not suitable	Slight to high	Slight to medium	Poor to practically impervious	Rubber-tyred roller sheeps-foot roller	1·60-2·16	5-20	2·77-8·3
ML, MI	Poor to fair	Not suitable	Not suitable	Medium to very high	Slight to medium	Fair to poor	Rubber-tyred roller, sheeps-foot roller, close control of moisture	1·44-2·08	15 or less	2·77-5·53
CL, CI	Poor to fair	Not suitable	Not suitable	Medium to high	Medium	Practically impervious	Rubber-tyred roller, sheeps-foot roller	1·44-2·08	15 or less	1·38-4·15
OL, OI	Poor	Not suitable	Not suitable	Medium to high	Medium to high	Poor	Rubber-tyred roller, sheeps-foot roller	1·44-1·68	5 or less	1·38-2·77
MH	Poor	Not suitable	Not suitable	Medium to very high	High	Fair to poor	Sheeps-foot roller, rubber-tyred roller	1·28-1·68	10 or less	1·38-2·77
CH	Poor to fair	Not suitable	Not suitable	Medium	High	Practically impervious	Sheeps-foot roller, rubber-tyred roller	1·44-1·84	15 or less	1·38-4·15
OH	Poor to very poor	Not suitable	Not suitable	Medium	High	Practically impervious	Sheeps-foot roller, rubber-tyred roller	1·28-1·76	5 or less	0·69-2·77
Pt	Not suitable	Not suitable	Not suitable	Slight	Very high	Fair to poor	Compaction not practical	—	—	—

NOTE 1 — Column 1: Division of GM and SM groups into sub-division of d and u are for roads and airfields only; sub-division is on basis of Atterberg limits; suffix *d* (for example GM d) will be used when the liquid limit is 25 or less and the plasticity index is 5 or less; the suffix *u* will be used otherwise.

NOTE 2 — The equipment listed in col 8, will usually produce the required densities with a reasonable number of passes when moisture condition and thickness of layer are properly controlled. In some instances, several types of equipment are listed because variable soil characteristics within a given soil group may require different equipment. In some instances, a combination of two types may be necessary.

a) *Processed base materials; other angular materials* — Steel-wheeled and rubber-tyred rollers are recommended for hard, angular materials with limited fines or screenings. Rubber-tyred equipment is recommended for softer materials subject to degradation.

b) *Finishing* — Rubber-tyred equipment is recommended for rolling during final shaping operations for most soils and processed materials.

c) *Equipment Size* — The following sizes of equipment are necessary to assure the high densities required for airfield construction: Crawler-type tractor: Total weight in excess of 13 600 kg. Rubber-tyred equipment: Wheel load in excess of 6 800 kg, wheel loads as high as 18 100 kg may be necessary to obtain the required densities for some materials (based on contact pressure of approximately 4·57 to 10·5 kg/cm²). Sheeps-foot roller: Unit pressure (on 38·7 to 77·4 cm²) to be in excess of 17·5 kg/cm² and unit pressure as high as 46 kg/cm² may be necessary to obtain the required densities for some materials. The area of the feet should be at least 5 percent of the total peripheral area of the drums using the diameter measured to the face of the feet.

NOTE 3 — Unit dry weights in column 9 are for compacted soil at optimum moisture content for Indian Standard heavy compaction effort [*see* IS : 2720 (Part VIII)-1965*].

NOTE 4 — Column 10: The maximum value that can be used in design of airfields, is in some cases, limited by gradation and plasticity requirements. The values are representative of saturated or nearly saturated conditions.

*Methods of test for soils: Part VIII Determination of moisture content-dry density relationship using heavy compaction.

TABLE 6 CHARACTERISTICS PERTINENT TO EMBANKMENTS AND FOUNDATIONS

(*Clause* 3.8)

SOIL GROUP	VALUE OF EMBANKMENT	PERMEABILITY cm/s	COMPACTION CHARACTERISTICS	UNIT DRY WEIGHT g/cm³	VALUE OF FOUNDATION	REQUIREMENTS FOR SEEPAGE CONTROL
(1)	(2)	(3)	(4)	(5)	(6)	(7)
GW	Very stable; pervious shells of dikes and dams	$K > 10^{-2}$	Good; tractor, rubber tyred, steel-wheeled roller	2·00-2·16	Good bearing value	Positive cutoff
GP	Reasonably stable, pervious shells of dikes and dams	$K > 10^{-2}$	do	1·84-2·00	do	do
GM	Reasonably stable; not particularly suited to shells, but may be used for impervious cores or blankets	$K = 10^{-3}$ to 10^{-6}	Good; with close control, rubber-tyred, sheeps-foot roller	1·92-2·16	do	Toe trench to none
GC	Fairly stable; may be used for impervious core	$K = 10$ to 10^{-8}	Fair; rubber-tyred, sheeps-foot roller	1·84-2·08	do	None
SW	Very stable; pervious sections, slope protection required	$K > 10^{-3}$	Good; tractor	1·76-2·08	do	Upstream blanket and toe drainage or wells
SP	Reasonably stable; may be used in dike section with flat slopes	$K > 10^{-3}$	Good; tractor	1·60-1·92	Good to poor bearing value depending on density	do
SM	Fairly stable; not particularly suited to shells, but may be used for impervious cores or dikes	$K = 10^{-3}$ to 10^{-6}	Good; with close control, rubber-tyred, sheeps-foot roller	1·76-2·00	do	do
SC	Fairly stable; use for impervious core for flood control structures	$K = 10^{-6}$ to 10^{-8}	Fair; sheeps-foot roller, rubber tyred	1·68-2·00	Good to poor bearing value	None
ML, MI	Poor stability; may be used for embankments with proper control	$K = 10^{-3}$ to 10^{-6}	Good to poor, close control essential; rubber-tyred roller, sheeps-foot roller	1·52-1·92	Very poor, susceptible to liquefaction	Toe trench to none
CL, CI	Stable; impervious cores and blankets	$K = 10^{-6}$ to 10^{-8}	Fair to good; sheeps-foot roller, rubber-tyred	1·52-1·92	Good to poor bearing	None
OL, OI	Not suitable for embankments	$K = 10^{-4}$ to 10^{-6}	Fair to poor; sheeps-foot roller	1·28-1·60	Fair to poor bearing, may have excessive settlements	do
MH	Poor stability; core of hydraulic fill dams not desirable in rolled fill construction	$K = 10^{-4}$ to 10^{-6}	Poor to very poor; sheeps-foot roller	1·12-1·52	Poor bearing	do
CH	Fair stability with flat slopes; thin cores, blankets and dike sections	$K = 10^{-6}$ to 10^{-8}	Fair to poor; sheeps-foot roller	1·20-1·68	Fair to poor bearing	do
OH	Not suitable for embankments	$K = 10^{-6}$ to 10^{-8}	Poor to very poor; sheeps-foot roller	1·04-1·60	Very poor bearing	do
Pt	Not used for construction	—	Compaction not practical	—	Remove from foundation	—

NOTE 1 — Values in Column 2 and 6 are for guidance only. Design should be based on test results.

NOTE 2 — The equipment listed in Column 4 will usually produce densities with a reasonable number of passes when moisture conditions and thickness of lift are properly controlled.

NOTE 3 — Unit dry weights in column 5 are for compacted soil at optimum moisture content for Indian Standard light compaction effort [*see* IS : 2720 (Part VII)-1965*].

*Methods of test for soils : Part VII Determination of moisture content-dry density relation using light compaction.

TABLE 7 SUITABILITY FOR CANAL SECTIONS, COMPRESSIBILITY, WORKABILITY AS A CONSTRUCTION MATERIAL AND SHEAR STRENGTH

(*Clause* 3.8)

Soil Group	Relative Suitability for Canal Sections*		Compressibility when Compacted and Saturated	Workability as a Construction Material	Shearing Strength when Compacted and Saturated
	Erosion Resistance	Compacted Earth Lining			
GW	1	—	Negligible	Excellent	Excellent
GP	2	—	Negligible	Good	Good
GM	4	4	Negligible	Good	Good
GC	3	1	Very low	Good	Good to Fair
SW	6	—	Negligible	Excellent	Excellent
SP	7, if gravelly	—	Very low	Fair	Good
SM	8, if gravelly	5 (Erosion critical)	Low	Fair	Good
SC	5	2	Low	Good	Good to Fair
ML, MI	—	6 (Erosion critial)	Medium	Fair	Fair
CL, CI	9	3	Medium	Good to Fair	Fair
OL, OI	—	7 (Erosion critical)	Medium	Fair	Poor
MH	—	—	High	Poor	Fair to Poor
CH	10	8 (Volume change critical)	High	Poor	Poor
OH	—	—	High	Poor	Poor
Pt	—	—	—		

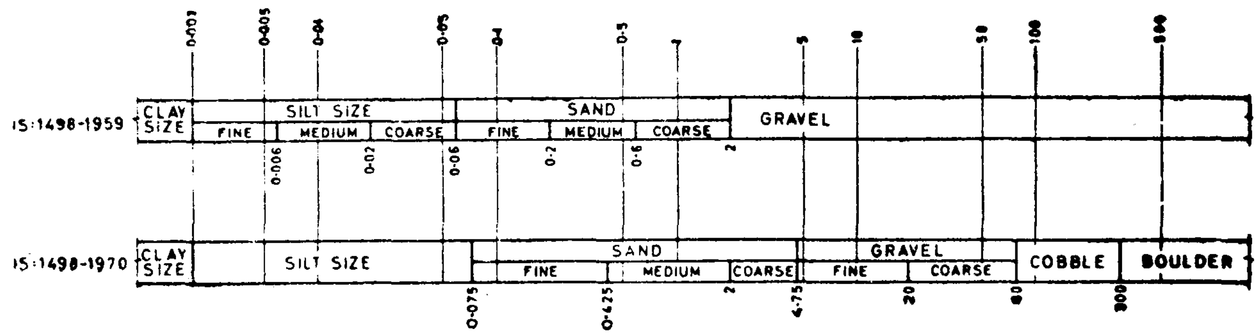
*Number 1 is the best.

APPENDIX A

(Table 1)

COMPARISON BETWEEN SIZE CLASSIFICATIONS OF IS:1498-1959 AND IS:1498-1970

Particle size in millimetres.



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53/5 Ward No. 29, R.G. Barua Road, 5th By-lane, GUWAHATI 781003	54 11 37
5-8-56C, L.N. Gupta Marg, Nampally Station Road, HYDERABAD 500001	20 10 83
E-52, Chitaranjan Marg, C-Scheme, JAIPUR 302001	37 29 25
117/418 B, Sarvodaya Nagar, KANPUR 208005	21 68 76
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AMENDMENT NO. 1 AUGUST 1982
TO
IS : 1498-1970 CLASSIFICATION AND IDENTIFICATION OF SOILS FOR GENERAL ENGINEERING PURPOSES

(First Revision)

Addenda

(*Page* 13, *clause* **3.8**) — Add the following new clause after **3.8**:

'**3.9 Degree of Expansion** — Fine grained soils depending upon the presence of clay mineral exhibit low to very high degree of expansion. Based upon Atterberg's limits and free swell of the soils the degree of expansion and degree of severity for soils is shown in Table 8.'

[*Page* 14, *col* 5 *against Sl No.* (ii)] — Add the following new matter at the end:

'Coarse: 75 micron to 7·5 micron

Fine: 7·5 micron to 2 micron'

(*Page* 21, *Table* 5, *Note* 4) — Add the following new note after note 4:

'NOTE 5 — In most of the expansive soils, the CBR values after soaking are often found to be less than 2. The thickness of the pavements for such small values turn out to extremely high and impracticable. A minimum CBR value of 2 is recommended for use for design purposes in such soil.'

(*Page* 23, *Table* 7) — Add the following new table after Table 7:

TABLE 8 SHOWING THE DEGREE OF EXPANSION OF FINE GRADED SOILS

(*Clause* 3.9)

LIQUID LIMIT (W_L)	PLASTICITY INDEX (I_P)	SHRINKAGE INDEX (I_S)	FREE SWELL (PERCENT)	DEGREE OF EXPANSION	DEGREE OF SEVERITY
20-35	< 12	< 15	< 50	Low	Non-critical
35-50	12-23	15-30	50-100	Medium	Marginal
50-70	23-32	30-60	100-200	High	Critical
70-90	> 32	> 60	> 200	Very High	Severe

(BDC 23)

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TO

IS:1498-1970 CLASSIFICATION AND IDENTIFICATION OF SOILS FOR GENERAL ENGINEERING PURPOSES

(*First Revision*)

(*Page* 4, *clause* 2.3, *line* 5):

(*Page* 6, *clause* 3.4, *para* 1, *lines* 10 *and* 12 *and para* 2, *line* 3):

[*Page* 7, *clause* 3.4.4(b) and (c)]:

(*Page* 14, *Table* 1, *col* 5, *lines* 6 *and* 8):

(*Page* 24, *Appendix* A, *matter against* IS:1498-1970):

Substitute '75 mm' *for* '80 mm' wherever existing.

(*Page* 21, *Table* 5, *Note* 3) - Substitute 'IS:2720(Part 8)-1983' *for* 'IS:2720(Part 8)-1965'.

(*Page* 21, *footnote with '*' mark*) - Substitute the following for the existing footnote:

> '*Method of test for soils: Part 8 Determination of water content - Dry density relation using heavy compaction (*second revision*).'

(BDC 23)

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