Chapter 03

Identification and Classification of Soils

3.1 Introduction

Soil classification is the arrangement of soils into different groups such that the soils in a particular group have similar behaviour under given set of physical conditions. Generally soil classification is done on the basis of two criteria, viz.

(a) Grain size distribution
(b) Plasticity of soil

3.2 Field Identification of Soils

Broadly soil can be categorized as coarse grained (cohesionless) and fine grained soils (cohesive).

(a) Coarse Grained Soils

Coarse grained soils can be easily identified by the naked eye on the basis of grain size. The major coarse grained soils are gravel and sand.

- Individual soil particles larger than 4.75 mm and smaller than 80 mm are called 'gravel'.
- Soil particles ranging in size from 0.075 mm to 4.75 mm are called 'sand'.

(b) Fine Grained Soils

Silt and clays are known as fine grained soils. Fine soils can be organic or inorganic.

Inorganic Soils: Field identification of inorganic soils can be done by following tests

(i) Dilatancy test or shaking test
(ii) Dry strength test
(iii) Dispersion test
(iv) Toughness test or Rolling test

(i) Dilatancy Test (Dilatancy → Reaction to Shaking): A part of the material is shaken after placing it on the palm. If it is silt, water comes to the surface and gives it a shining appearance. If it is kneaded, the moisture will re-enter into the soil and the shining disappears.

If it is clay, the water cannot move easily and hence it continues to look dark. If it is a mixture of silt and clay, the relative speed with which the shine appears may give rough indication of the amount of silt present. This test is also known as 'Shaking test'.

(ii) Dry Strength Test (Dry strength → Crushing Resistance): A small ball or briquette of size 3 mm is prepared and kept for drying. If dried ball can be easily broken, the material is silt. If it is clay, it will require effort to break. Also one can dust off loose material form the surface of briquette if it is silt. When moist soil is pressed between fingers, clay gives a soapy touch; it also sticks and dried slowly which cannot be dusted easily.

(iii) Dispersion Test: A spoonful of soil is poured in a jar of water. If it is silt, the particles will settle in about 15 minutes to one hour. If it is clay, it will form a turbid suspension, which will remain as such for hours and even for days.

(iv) Toughness Test or Thread Test (Toughness → Consistency near plastic limit): A thread is attempted to be made out of a moist soil sample with a diameter of about 3 mm. If the material is silt, it is not possible to make such thread without surface cracks and crumbling.

If it is clay, such a thread can be made even to a length of about 30 cm and supported by its own weight when held at the ends.

This test is also called 'Rolling test'.

Organic Soils:

- Fresh, wet organic soils usually have a distinctive odour of decomposed organic matter, which can be more easily detected on heating the wet sample.
- Another distinctive feature of such soils is the dark colour.

3.3 Engineering Classification of Soils

Several classification systems were developed by various organizations for their specific purpose.

Some important classification system are as follows:

- Classification based on grain size
- Textural classification
- Unified soil classification system (USCS)
- American association of state highway and transport officials (AASHTO) system
- Indian standard soil classification system (ISSCS)

3.3.1 Texural Classification (more suitable for coarse grained soils)

- In this system, soil fractions as per the US Bureau of soils and chemistry system are used.
- According to this classification

Gravel	:	> 1.00 mm
Sand	:	0.05 mm - 1.00 mm
Silt	:	0.005 mm - 0.05 mm
Clay	:	< 0.005 mm

- A triangular chart has been developed using grain size distribution. First of all grain size distribution of the soil is found and % fractions are determined with the well known percentages of sand, silt and clay, a point is located in the triangular chart as shown in figure, specified term designated in the chart for the area where the point falls is taken as classification of the soil.

Clay (size)	Silt (size)	Sand				Fine Gravel	Gravel
		Very fine	Fine	Medium	Coarse		
0.005	0.05	0.10	0.25	0.5	1.0	2.0	

- This classification system widely used in Agriculture and Highway engineering
- This classification depends on the grain size distribution only.

3.3.2 The Unified Soil Classification System (USCS)

- This system (USCS), originally developed by A. Casagrande.
- According to USCS, the coarse grained soils are classified on the basis of their grain size distribution and fine grained soils (whose behaviour is controlled by plasticity) on the basis of their plasticity characteristics.
- Soils are classified into four major groups:
  (a) Coarse grained (b) Fine grained
  (c) Organic soils (d) Peat

Note: USCS is adopted by IS classifications with slight modifications.

3.3.3 'AASHTO' Soil Classification System

- According to AASHTO system, the soils are classified into eight groups: *A*-1 through *A*-7 with an additional group *A*-8 for peat or muck.
- This system includes several sub groups. Soil within each group are evaluated according to the group index calculated from empirical formula.

$$\text{Group Index, } GI = 0.2a + 0.005ac + 0.01bd$$

where,

a = that part of the percentage passing the 75 μ sieve greater than 35 and not exceeding 75.
b = that part of the percent passing the 75 μ sieve greater than 15 and not exceeding 55.
c = that part of liquid limit greater than 40 and not greater than 60.
d = that part of plasticity index greater than 10 and not exceeding 30.

3.3.4 Indian Standard Soil Classification System (ISSCS)

The Indian soil classification (IS: 1498, 1970) is basically the same as that of USCS with the slight modification that the fine grained soil have been subdivided into three subgroup of low, medium and high compressibility as against only two in the USCS.

- In this system, coarse grain soils are classified on the basis of grain size distribution and fine soils on the basis of plasticity.
- Broadly soils are divided into four major groups
  1. Coarse grained soils : gravel (G) and sand (S)
  2. Fine grained soils : silt (S) and clay (C)
  3. Organic soils (O)
  4. Peat (Pt)

Table 3.1: I.S. Classification (grain size distribution)

		Soils						
Boulder (mm)	Cobble (mm)	Coarse grained soil					Fine Grained Sand	
		Gravel		Sand				
		Coarse (mm)	Fine (mm)	Coarse (mm)	Medium (mm)	Fine (mm)	Silt (mm)	Clay (mm)
> 300	300 - 80	20 - 80	4.75 - 20	2 - 4.75	0.425 - 2.0	0.075 - 0.425	0.002 - 0.075	< 0.002

Table 3.2: Basic Soil Components

Sl. No.	Soil component	Symbol	Particle-size range and description
	Boulders	None	Rounded to angular, bulky, hard, rock particle; average diameter more than 300 mm
	Cobbles	None	Rounded to angular, bulky, hard, rock particle; average diameter smaller than 300 mm but retained on 80 mm IS sieve
(1)	Coarse-grained soils 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 Fine: 20 mm to 4.75 mm
	Sand	S	Rounded to angular, bulky, hard, rock particle; passing 4.75 mm IS sieve but retained on 75 micron Coarse: 4.75 mm to 2.0 mm Medium: 2.0 mm to 425 micron Fine: 425 micron to 75 micron
(2)	Fine-grained soils Silt	M	Particles smaller than 75 micron; 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; 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.
(3)	Organic matter	O	Organic matter in various sizes and stage of decomposition (no specific grain size)
(4)	Peat	Pt	Fibrous, spongy (no specific grain size)

3.4 Classification of Coarse Grained Soil

Classification of coarse grained soil is done on the following basis

(1) Particle size
(2) Gradation characteristics i.e. C_u and C_c
(3) % fineness (% fraction which pass through 75 μ sieve)

- Coarse grained soil are those having 50% or more retained on the 0.075 mm sieve (75 micron).
- Further, the coarse grained soils are designated as gravel (G) if 50% or more of the coarse fraction is retained on the 4.75 mm sieve; otherwise, they are designated as sand (S).

Table 3.3 : Prefix and Suffix of ISSCS

Soil type	Prefix	Subgroup	Suffix
Gravel	G	Well graded	W
Sand	S	Poorly graded	P
Silt	M	Silty	M
Clay	C	Clayey	C
Organic	O	w_L < 35 percent	L
		$35 < w_L < 50$	I
Peat	Pt	$50 < w_L$	H

NOTE

- Well graded soils (W) have wide range of particle size where as poorly graded soil (P) has most of the particle about same size i.e. either excess or a deficiency of certain particle sizes.
- To check, whether a soil is well graded or poorly graded grain size distribution curve is plotted and coefficient of uniformity (C_u) and coefficient of curvature (C_c) are found.

On the basis of % fineness, coarse grained soils can be further classified as:

CASE-1 : When fineness is less than 5% by weight.

Gravels: more than 50% of coarse fraction retained on 4.75 mm sieve

(i) GW ⇒ well graded gravel.

$C_u > 4$, $1 \le C_c \le 3$ and fineness < 5%

(ii) GP ⇒ poorly graded gravel.

Above values of C_u and C_c are not satisfied.

Sand: more than 50% of coarse fraction pass through 4.75 mm sieve

(i) SW ⇒ well graded sand.

$C_u > 6$, $1 \le C_c \le 3$ and fineness < 5%

(ii) SP ⇒ poorly graded sand.

Above values of C_u and C_c are not satisfied

CASE-2 : When fineness is between 5-12%

This is known as borderline case and dual symbols are used. First part of dual symbol represent gradation and second part represents nature of fines i.e. clay or silt.

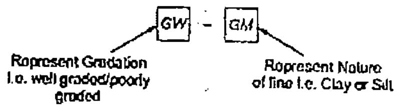


Fig.3.1

Gravel:

(i) GW – GC ⇒ well graded gravel containing clay as fine

$C_u > 4$, $1 \le C_c \le 3$

clay fraction > silt fraction

(ii) GP – GC ⇒ poorly graded gravel containing clay as fine

Above values of C_u and C_c are not satisfied

clay fraction > silt fraction

(iii) GW – GM ⇒ well graded gravel containing silt as fine

$C_u > 4$, $1 \le C_c \le 3$

silt fraction > clay fraction

(iv) GP – GM ⇒ poorly graded gravel containing silt as fine

above values of C_u and C_c are not satisfied

silt fraction > clay fraction

Sand: more than 50% of coarse fraction pass through 4.75 mm sieve

(i) SW – SC ⇒ well graded sand containing clay as fine

$C_u > 6$, $1 \le C_c \le 3$

clay fraction > silt fraction

(ii) SP – SC ⇒ poorly graded sand containing clay as fine

values of C_u and C_c are not satisfied

clay fraction > silt fraction

(iii) SW – SM ⇒ well graded sand containing silt as fine

$C_u > 6$, $1 \le C_c \le 3$

silt fraction > clay fraction

(iv) SP – SM ⇒ poorly graded sand containing silt as fine

values of C_u and C_c are not satisfied

silt fraction > clay fraction

CASE-3 : When fineness is more than 12%

In this case soil is classified according to I.S. plasticity chart ($\%I_P$)

Gravel:

(i) GC ⇒ Clayey gravel

% fineness > 12 and $I_P > 7\%$

clay fraction > silt fraction [$\because I_P > 7\%$]

(ii) GM ⇒ Silty gravel

% fineness > 12 and $I_P < 4\%$

silt fraction > clay fraction [$\because I_P < 4\%$]

Sand:

(i) SC ⇒ Clayey sand

% fineness > 12 and $I_P > 7\%$

clay fraction > silt fraction [$\because I_P > 7\%$]

(ii) SM ⇒ Silty sand

% fineness > 12 and $I_P < 4\%$

silt fraction > clay fraction [$\because I_P < 4\%$]

NOTE: If plasticity index is between 4% - 7% then dual symbols are used.

Example 3.1 From a particle-size distribution curve of a sandy soil, the following data is obtained:

Determine the uniformity coefficient and coefficient of curvature. Is this soil well graded or poorly graded?

Size of particle (mm)	Percentage finer
0.46	60
0.33	30
0.21	10

Solution:

Given $D_{60} = 0.48$ mm, $D_{30} = 0.33$ mm and $D_{10} = 0.21$ mm

Coefficient of curvature, $C_u = \dfrac{D_{60}}{D_{10}}$

⇒ $C_u = \dfrac{0.48}{0.21} = 2.28$

and coefficient of curvature, $C_c = \dfrac{(D_{30})^2}{D_{60} \times D_{10}}$

$C_c = \dfrac{(0.33)^2}{0.48 \times 0.21} = 1.08$

For well graded sand, $C_u > 6$ and $1 \le C_c \le 3$

So it is a poorly graded sand.

Example 3.2

Sieve Size	4.75 mm	75 Micron
% Finer	80	7

For the above soil sample, the size of aggregates vary linearly and it is found that particles finer than 75 micron are non-plastic. According to Indian standard classification system, the soil sample is

(a) *SP–SM* (b) *SW–SM*
(c) *SP–SC* (d) *SW–SC*

Ans. **(b)**

It is a coarse soil, as only 7% are finer than 75 μ sieve. Also it is a sandy soil because more than 50% of the coarse fraction passes through 4.75 mm sieve.

Since size of aggregates varies linearly.

D_{60}: $$\frac{80-7}{4.75-0.075} = \frac{80-60}{4.75-D_{60}}$$

⇒ $$D_{60} = 3.47 \text{ mm}$$

D_{30}: $$\frac{80-7}{4.75-0.075} = \frac{80-60}{4.75-D_{30}}$$

⇒ $$D_{30} = 1.548 \text{ mm}$$

similarly, $$D_{10} = 0.267 \text{ mm}$$

∴ $$C_u = \frac{D_{60}}{D_{10}} = 12.99 > 6$$

and $$C_c = \frac{D_{30}^2}{D_{60} \times D_{10}} = 2.59$$

It means, $1 \le C_c \le 3$

Thus soil is well graded, also the finer particles are non-plastic, so it is silt.
Hence option (b) is correct.

Example 3.3 Laboratory sieve analysis was carried out on a soil sample using a complete set of standard IS-Sieves. Out of 500 g of soil used in the test, 200 g was retained on IS 600 μ sieve, 250 g was retained on IS 500 μ sieve and the remaining 50 g was retaining on IS 425 μ sieve. Find the coefficient of uniformity. Also classify the soil.

Solution:

S.N.	Sieve size	Weight retained (g)	Cum-weight retaining (g)	Cum. % Retained	% Finer % N
1	600 μ	200	200	40	60
2	500 μ	250	450	90	10
3	425 μ	50	500	100	0

∴ $D_{60} = 600\,\mu$ and $D_{10} = 500\,\mu$

Coefficient of uniformity, $$C_u = \frac{D_{60}}{D_{10}}$$

⇒ $$C_u = \frac{600\,\mu}{500\,\mu} = 1.2$$

More than 50% of the soil pass through 600 μ sieve, it means that greater percentage of the soil will pass through 4.75 mm sieve. Hence the soil is definitely sandy soil.

For well graded sand

$C_u > 6$ and $1 \le C_c \le 3$

Here, $C_u = 1.2$ thus the soil is poorly graded sand.

Example 3.4 Classify the soil for data given:

Sieve size (mm)	Weight retained (g)
4.75	20
0.075	730

1000 g of soil was used.
Liquid Limit = 40%
Plastic Limit = 18%
The soil classification is

(a) GM (b) SM
(c) GC (d) ML-MI

Ans. (a)

S.N.	Sieve size (mm)	Weight retained (g)	Cum-weight retained (g)	Cum. % retained	% Finer % N
1	4.75	20	20	2	98
2	0.075	730	750	75	25

Since 98% of soil pass through 4.75 mm IS sieve, and 75% are retained on 75 μ, given soil is sand.
Also, 25% soil is pass through 0.75 mm sieve.

∴ fineness = 25%

$W_L = 40\%,\ W_P = 18\%$

∴ $I_P = 22\% > 7\%$

here fineness > 12% and $I_P > 7\%$

∴ soil is clayey sand (SC)

3.5 Classification of Fine Grained Soil

- In ISSCS, fine grained soils are classified on the basic of plasticity chart (I_P) and compressibility (w_L)
- Generally soils are considered as fine soils, when 50% or more of the total material by weight pass 75 μ sieve.
- LL (w_L) and PL (w_P) are determined for 425 μ sieve fraction and corresponding plasticity index is found out.

$$I_P = w_L - w_P$$

CASE-1: Low Plastic Soil (Low Compressibility) (LL < 3.5%)

CL → Low plastic inorganic clay
ML → Low plastic silt
OL → Low plastic organic clay

CASE-2: Medium Plastic Soil (Medium Compressibility) (35% < LL< 50%)

$CI \rightarrow$ Medium plastic inorganic clay

$MI \rightarrow$ Medium plastic silt

$OI \rightarrow$ Medium plastic organic clay

CASE-3: Highly Plastic Soils (High compressibility) (LL > 50%)

$CH \rightarrow$ High plastic inorganic clay

$MH \rightarrow$ High plastic silt

OH $\rightarrow$ High plastic organic

NOTE: Organic and inorganic soils are plotted in same zone in plasticity chart which are distinguished by odour and colour or liquid limit test on oven dry sample. If LL of oven dry sample is less than the three fourth of in-situ soil sample then soil is organic otherwise inorganic.

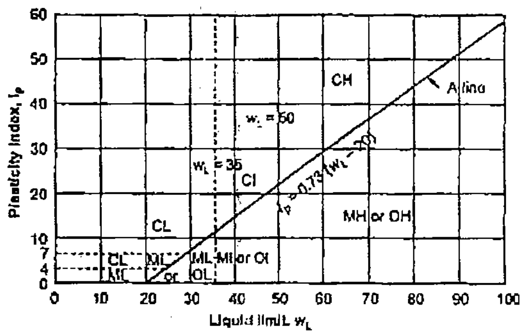


Fig.3.2 Plasticity chart as per Indian Standard Soil Classification System

The above soil classification is based on a line called A-line, which is a boundary representing relationship between plasticity index (I_P) and LL (W_L).

- If I_P of soil > I_P of A-line
  the soil will lie above A-line and it will be clay(C)
- If I_P of soil < I_P of A-line
  the soil will lie below A-line and it may be either silt (M) or organic clay (OI)
- The I_P of A-line is given by

$$I_P = 0.73\,(W_L - 20)$$

where W_L = liquid limit

- U-line represent upper boundary beyond which no soil will lie. If results are found above U-line then test must be repeated.

$$I_P \text{ of } U\text{-line} = 0.9\,(W_L - 8)$$

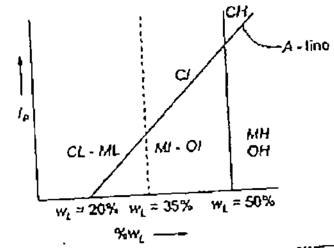
where W_L = liquid limit

- Highly organic soils (eg. Peat) are classified as Pt.

Example 3.5 As per the Indian standard soil classification system, a soil sample of silty clay with liquid limit 40% and plasticity of 28% is classified as

(a) CP (b) CI
(c) CL (d) $CL - ML$

Solution:



$$I_P \text{ of soil} = 28\%$$
$$I_P \text{ of A-line} = 0.73\,(W_L - 20) = 0.73\,(40 - 28) = 8.76$$

$\because$ I_P of soil > I_P of A-line

$\therefore$ It will lie above A-line

Also $35 < W_L < 50$

So soil is CI.

Example 3.6 A soil has following properties:

LL = 40%; PL = 30%;

% passing through 4.75 mm sieve = 65% and % passing through 75 μ sieve = 58%.

The soil can be classified as

(a) SC (b) CL
(c) MI (d) MH

Ans. (c)

Gravel fraction = % retained on 4.75 mm sieve = 65%

Coarse fraction = % retained on 75 μ sieve = 58%

Sand fraction = 65 − 58 = 7%

Since more than 50% soil pass through 75 μ sieve, soil is fine grained.

$$I_P \text{ of A-line} = 0.73(W_L - 20)$$
$$I_{P,A} = 0.73(40 - 20) = 14.6\%$$
$$PI \text{ of soil} = W_L - W_P = 40 - 30$$

$\because$ PI = 10% is less than $I_{P,A}$

Thus silty soil, since $35 < W_L < 50$

$\therefore$ Soil may be MI or OI

Example 3.7 A soil has following characteristics

% passing 75 μ sieve = 62%; Liquid limit = 40%

Plasticity index, I_P = 10%; Liquid limit of oven dry sample = 25%

Classify the soil according to ISSCS system.

(a) MI (b) OI
(c) CH (d) CI

Ans. (b)

More than 50% of soil pass through 75 μ sieve. So soil is fine grained.

$$I_P \text{ of A-line} = 0.73(W_L - 20) = 0.73\,(40 - 20) = 14.6\%$$
$$I_P \text{ of soil} = 10\%$$

I_P of soil < I_P of A-line. Hence soil will lie below A-line

Also, $35 < W_L < 50$, so may be *MI* or *OI*

Since liquid limit of oven dry soil is 25% which is less than $\frac{3}{4}$ of *LL* of soil.

Therefore soil is *OI* (medium plastic organic clay)

Example 3.8 A soil has the following characteristics:

1. Percentage of soil passing 75 µm sieve = 20
2. Percentage of fraction retained by 4.75 mm sieve = 60
3. Liquid limit = 35
4. Plastic limit = 20

Classify the given soil as per IS-soil classification system.

Solution:

% of soil retained on the 75 µ sieve = 80

It is greater than 50% hence it is a coarse grained soil.

Since gravel fraction (i.e. 60%) is greater than 50. Hence large proportion of the coarse grained soil is gravel, the soil is gravel.

Fineness = % fraction which pass through 75 µ sieve
= 20% (which is greater than 12%)

In this case, soil is classified according to IS-plasticity chart

$$I_P = W_L - W_P = 35 - 20 = 15 > 7\%$$

It means clay fraction > silt fraction

Hence the soil is classified as GC.

Example 3.9 The following test results were obtained on a soil sample:

Percentage passing through 4.75 mm IS sieve = 98.5%

Percentage passing through 75 µ IS sieve = 35%

$D_{60} = 0.22$, $D_{30} = 0.19$, $D_{10} = 0.16$

Liquid limit = 22%

Plasticity limit = 19%

Classify the soil by IS classification.

Solution:

Percentage of soil retained on the 75 µ sieve = 65

It is greater than 50%. Hence it is a coarse grained soil.

Since gravel fraction (i.e. 1.5%) is less than 50, large proportion of the coarse grained soil is sand

Fineness = % fraction which pass through 75 µ sieve
= 35%

It means fines is greater than 12%

In this case, soil is classified as per IS-classification

$$I_P = W_L - W_P = 22 - 19 = 3\%$$

which is less than 4%

It means silt fraction > clay fraction

Also,

Coefficient of uniformity, $C_u = \frac{D_{60}}{D_{10}} = \frac{0.22}{0.16} = 1.39 < 6$

and coefficient of curvature, $C_c = \frac{D_{30}^2}{D_{60} \times D_{10}} = \frac{(0.19)^2}{0.22 \times 0.16} = 1.03$

For the soil to be well graded,

$C_u > 6$ and $1 < C_c < 3$

Hence the given soil is classified as poorly graded silty sand i.e. SM

Summary

- Broadly soils are classified as coarse grained (cohessionless) and fine grained (cohesive) soils.
- Gravel and sand are put in the category of coarse soil whereas silt and clays are put in the category of fine soils.
- Generally soil classification is done on the basis of two criteria, viz
  (a) Grain size distribution
  (b) Plasticity of soil
- The Indian soil classification system is basically the some as the unified soil classification system but for a slight modification in the plasticity chart.
- For classification of fine soils, organic and inorganic soils are plotted in same zone in plasticity chart, which are distinguished by odour, colour or liquid limit on oven dry sample. If LL of oven dry sample is less then of three fourth of in-situ soil sample, then soil is called organic soil, otherwise inorganic.

Objective Brain Teasers

Q.1 The properties of soil A and soil B are given below:

A	B
LL = 60%	LL = 55%
PL = 35%	PL = 20%
w = 40%	w = 25%
G = 2.65	G = 2.7
S = 80%	S = 100%

Which of the following statements are correct?

(a) A has more clay particles and more dry density than B.
(b) A has more clay particles but less dry density than B.
(c) B has more clay particles and more dry density than A.
(d) B has more clay particles but less dry density than A.

Q.2 Match List-I (Symbol) with List-II (Soil) and select the correct answer using the codes given below the lists:

List-I	List-II
A. ML	1. Silty sand
B. SM	2. Inorganic silt with large compressibility
C. PI	3. Inorganic silt with small compressibility
D. MH	4. Soil with high organic content with high compressibility

Codes:

	A	B	C	D
(a)	3	2	4	1
(b)	4	1	3	2
(c)	3	1	4	2
(d)	4	2	3	1

Q.3 Match List-I (Soil classification symbol) with List-II (Soil property) and select the correct answer using the codes given below the lists:

List-I	List-II
A. GW	1. Soil having uniformity coefficient > 6

B. SW	2. Soil having uniformity coefficient > 4	
C. ML	3. Soil have low plasticity	
D. CL	4. Soil have low compressibility	

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	2	1	3	4
(c)	2	1	4	3
(d)	1	2	3	4

Q.4 Match List-I (Soils) with List-II (Group symbols) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Clayey gravel	1. SM
B. Clayey sand	2. OH
C. Organic clay	3. SC
D. Silty sand	4. GC

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	1	2
(c)	4	3	2	1
(d)	3	4	1	2

Q.5 A soil mass contains 40% gravel, 50% sand and 10% silt. This soil can be classified as

(a) silty sandy gravel having coefficient of uniformity less than 60.

(b) silty gravelly sand having coefficient of uniformity equal to 10.

(c) gravelly silty sand having coefficient of uniformity greater than 60.

(d) gravelly silty sand and its coefficient of uniformity cannot be determined.

Q.6. In a soil specimen, 70% of particles are passing through 4.75 mm IS sieve and 40% of particles are passing through 75 μ IS sieve. Its uniformity coefficient is 8 and coefficient of curvature is 2. AS per IS classification, this soil is classified as

(a) SP (b) GP
(c) SW (d) GW

Q.7 In a particular soil sample, laboratory analysis has yielded the following result:

1. Sand – 20%
2. Silt – 30%
3. Clay – 50%

Without using the textural chart, the correct textural classification of the soil would be

(a) loam (b) sandy clay
(c) silty loam (d) clay

Q.8 Sieve analysis on a dry soil sample of mass 1000 g showed that 980 g and 270 g of soil pass through 4.75 mm and 0.075 mm sieve, respectively. The liquid limit and plastic limits of the soil fraction passing through 425 m sieves are 40% and 18%, respectively. The soil may be classified as

(a) SC (b) MI
(c) CI (d) SM

Q.9 Consider the following statements:

1. Coarse-grained soil having fines (<75μ in size) between 5% and 12%, have a dual symbol according to IS code for soil classification
2. At liquid limit, all soils have the same shearing strength.
3. Lower the shrinkage limit, greater is the volume change in a soil with change in water content.

Which of these statements are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

Answers

1. (c) 2. (c) 3. (b) 4. (c) 5. (c)
6. (c) 7. (d) 8. (a) 9. (d)

Hints and Explanations:

1. (c)

A	B
$PI = LL - PL$	$60 - 35 = 25$
$55 - 20 = 35$	

$$e = \frac{wG}{S} \qquad \frac{0.4 \times 2.65}{0.8} = 1.325$$

$$\frac{0.25 \times 2.7}{1} = 0.675$$

$$\gamma_d = \frac{G\gamma_w}{1+e} \qquad \frac{2.65 \times 1}{1+1.325} = 1.14 \text{ g/ml}$$

$$\frac{2.7 \times 1}{1+0.675} = 1.61 \text{ g/ml}$$

PI of *B* is more hence it has more clay particles.

3. (b)
GW is well graded gravel for which coefficient of uniformity (C_u) > 4.
SW is well graded sand for which coefficient of uniformity (C_u) > 6
ML is silt with low plasticity (< 35%)
CL is clay with low plasticity (< 35%). It also possess low compressibility.

5. (c)

Particle Size	% Retained	% Cumulative	% N = 100-cum. %
Gravel retained 4.75 mm	40%	40%	60%
Sand retained 0.075 mm	50%	90%	10%
Silt retained 0.002 mm	10%	100%	0%

$\therefore$ $D_{60} = 4.75$ mm
$D_{10} = 0.075$ mm

$$\therefore \quad C_u = \frac{D_{60}}{D_{10}} = \frac{4.75}{0.075} = 63.33 > 60$$

So correct answer is '*c*'.

6. (c)
Since more than 50% of particles are passing through 4.75 mm sieve while less than 50% are passing through 75μ sieve, the soil is sand.

$$C_u = 8 > 6$$
$$1 < C_c = 2 < 3$$

Therefore its well graded sand (SW)

7. (d)
As 50% of soil is clay. So it will be classified as clay.

9. (d)
Lower the shrinkage limit greater is the volume change.
For coarse-grained soil with fines < 5% classification will be GP, GW, SP, and SW. for fines > 12% classification will be based on plasticity chart as GM, GC, SM and SC. For fines 5 – 12% dual classification like GP – GM; GP – GC etc., will be used.
At liquid limit the soils possess a certain shear strength which is the smallest value that can be measured in a standard procedure. From direct shear tests on different types of clays it is found that liquid limit corresponds to a shearing strength of about 2.7 kN/m^2.

The shrinkage ratio $SR = \frac{(V_1 - V_2)/V_d}{W_1 - W_2} \times 100$

$$\frac{(V_1 - V_2)}{W_1 - W_2} \times 100 = SRV_d = \frac{1}{\left(w_s + \frac{1}{G}\right)}$$

If shrinkage limit is less the volume change with change in water content will be more.