Chapter 3

Index Properties and Soil Classification

CHAPTER HIGHLIGHTS

- *Introduction*
- *Index properties of soils*
- *Atterberg limits (or consistency limits)*
- *Soil classification*

Introduction

Soil properties are mainly divided into properties and engineering properties. The Index properties are mainly used in the classification and identification of soils. For coarse-grained soil, the main indexed properties are particle size distribution and relative density. For fine-grained soil, the main indexed properties are atterberg limits. These index properties also give the rough assessment of engineering properties. In the present chapter, the various indexed properties are discussed. The classification of soil based on indexed properties is also discussed here.

Index Properties of Soils

Particle Size Analysis

- Also known as mechanical analysis, it is a method of separation of soils into different fractions based on particle size.
- Mechanical analysis is done in two stages:
  (a) Sieve analysis
  (b) Sedimentation analysis
- Sieve analysis is used for coarse-grained soils (size > 75μ).
- Sedimentation analysis or wet analysis is used for fine-grained soils (size < 75μ).
- Sedimentation analysis is based on Stokes' law, which gives the terminal velocity of a sphere settling in a fluid of infinite extent.

Terminal velocity,

$$\boxed{\begin{aligned} V &= \frac{g}{18} d^2 \frac{(\rho_s - \rho_w)}{\mu} \\ V &= \frac{g}{18} d^2 \frac{(G-1)}{\upsilon} \end{aligned}}$$

Where

d = Diameter of the particle.
G = Specific gravity of the material.
g = Acceleration due to gravity.
μ = Dynamic viscosity of water.
υ = Kinematic viscosity of water = μ / ρ_w.

Approximate version of Stokes' law.
If V is expressed in mm/s and 'd' in mm:

$$\boxed{V = 902\, d^2}$$

- A dispersion solution is added to have proper dispersion of soil in preparation of suspension for sedimentation analysis.
- Dispersion solution is obtained after adding 33 g of sodium hexa metaphosphate and 75 g of sodium carbonate in distilled water to make one litre of solution.
- If the soil contains organic matter and calcium compounds, it should be pretreated before adding the dispersing agent.
- Pipette method and hydrometer method are used for the particle size analysis of fine grained soil.

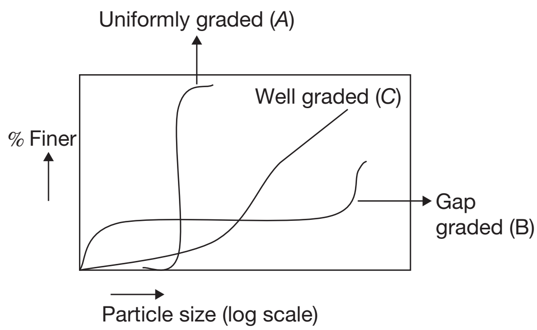
- Pipette method is a standard laboratory method. It is a highly accurate method.
- For quick particle size analysis, hydrometer method is used.
- Hydrometer reading is taken corresponding to the upper level of meniscus. It increased in downward direction towards the centre of the bulb.

The hydrometer readings are corrected as follows:

1. **Meniscus correction:** As the marking on stem increases downward, meniscus correction is positive, constant for a hydrometer.
2. **Temperature correction:** The hydrometer is generally calibrated at 27°C. If temperature is more than 27°C, the suspension is lighter and actual reading will be less than the corrected reading. The temperature correction is positive. If temperature is less than 27°C, the temperature correction is negative.
3. **Dispersion agent correction:** It is always negative.

Particle Size Distribution Curve

- It is also known as gradation curve.
- It represents the distribution of particles of different sizes in the soil mass.



- A curve with a hump, such as curve (*B*), represents the soil in which some of intermediate size particles are missing. Such soils are called 'gap graded' or 'skip graded'.
- A flat S-curve, such as *C*, represents a soil that contains different sized particles in good proportion. Such a soil is called 'graded soil'.
- In curve A, most of the particles are of similar size. Such soils are known as uniformly graded soils.

Coefficient of Uniformity (C_u)

$$\boxed{C_u = \frac{D_{60}}{D_{10}}}$$

Where

D_{60} = Particle size such that 60% of the soil is finer than this size.

D_{10} = Particle size such that 10% of the soil is finer than this size.

- D_{10} is also known as effective size.
- Soil with a value of C_u less than 2 are uniform soils.
- For well-graded gravel, $C_u > 4$ and for well-graded sand, $C_u > 6$.

Coefficient of Curvature (C_c)

- It is also known as coefficient of gradation.
- C_c describes the general shape of particle size distribution curve.

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

D_{30}: Particle size corresponding to 30% finer.

- For well-graded soils, C_c lies between 1 and 3.

Relative Density/Density Index (I_D)

- Most important index property of cohesion less soil:

$$\boxed{I_D = \frac{e_{\max} - e}{e_{\max} - e_{\min}} \times 100}$$

Where

$e_{\max}$ = Maximum void ratio of the soil in the loosest condition.

$e_{\min}$ = Minimum void ratio of the soil in the densest condition.

e = Void ratio in the natural state.

- It indicates denseness of soil.

Denseness	Very Loose	Loose	Medium Dense	Dense	Very Dense
D_r(%)	< 15	15 to 35	35 to 65	65 to 85	85 to 100

SOLVED EXAMPLES

Example 1

The void ratio at the densest, loosest and the natural state of a sand deposit are 0.2, 0.6 and 0.4. respectively. The relative density of the deposit is

(A) 100% (B) 75%
(C) 50% (D) 25%

[GATE, 2002]

Solution

Given:

$$e_{\min} = 0.2; e_{\max} = 0.6, e = 0.4$$

$$\text{Relative density } (I_D) = \frac{e_{\max} - e}{e_{\max} - e_{\min}} \times 100$$

$$= \frac{0.6 - 0.4}{0.6 - 0.2} \times 100$$

$$I_D = 50\%$$

Hence, the correct answer is option (c).

Atterberg Limits (or Consistency Limits)

Plasticity of Soils

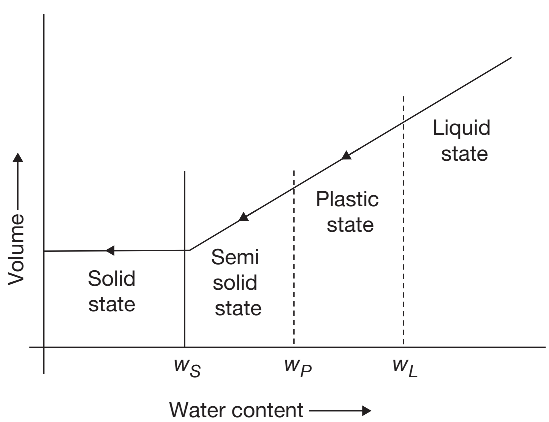
- Plasticity of soil is defined as its ability to undergo deformation without cracking or fracturing.
- Plasticity of soil is due to adsorbed water.
- Plasticity is not observed when it is mixed with non-polarizing liquid, such as kerosene or paraffin oil and, also if the soil contains non-clay minerals, such as quartz, feldspar, mica, and calcite.

Consistency Limits

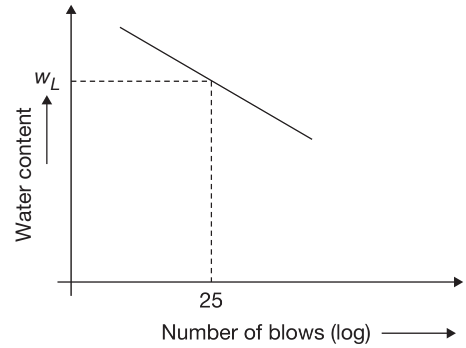
- As per Atterberg, a fine-grained soil can exist in four states, namely, liquid, plastic, semi-solid or solid state.
- The water contents at which soil changes from one state to another are known as consistency limits or Atterberg limits.
- It is important to note that the soils with same consistency limits behave in a similar manner.

Liquid Limit

- The water content at which soils changes from liquid to plastic state is known as liquid limit.
- At liquid limit, soil ceases to be liquid.



- The liquid limit is determined in the laboratory by Casagrande's apparatus.
- Drop of cup on hard base is 1 cm.
- About 120 gm of soil passing through 425μ sieve is taken.
- The moisture content corresponding to 25 blows from the flow curve is taken as the liquid limit of the soil.
- Flow curve is a graph plotted between water content on Y-axis and number of blows (log scale) on X-axis.



Flow curve

- Slope of flow curve is known as flow index.

$$\boxed{I_f = \frac{w_2 - w_1}{\log_{10}\left(\frac{N_1}{N_2}\right)}}$$

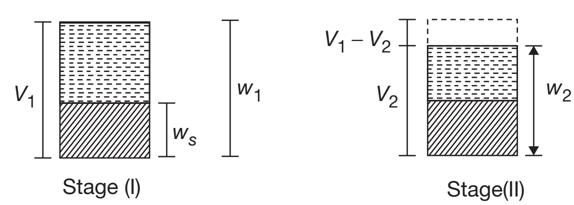
- The shear strength of soil at liquid limit is about 2.7 kN/m^2.

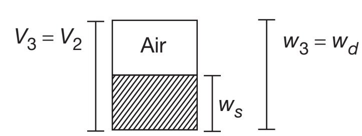
Plastic Limit

- Plastic limit is the water content at which soil just fails to behave plastically.
- The water content at which soil can be rolled into a thread of 3 mm in diameter without crumbling is known as plastic limit.
- Shear strength at plastic limit is about 100 times that at the liquid limit.

Shrinkage Limit

- Shrinkage limit is defined as the maximum water content at which a reduction of water content does not cause a decrease in volume of soil.
- Shrinkage limit is the least water content at which soil is still saturated.





Determination of Shrinkage Limit

1. $$\boxed{w_s = w_1 - \frac{(V_1 - V_2)\gamma_w}{w_d} \times 100}$$

$$w_1 = \frac{(w_1 - w_d)}{w_d} \times 100$$

2. $$\boxed{w_s = \frac{(V_2 - V_s)\gamma_w}{w_d} \times 100}$$

3. $$\boxed{w_s = \left(\frac{\gamma_w}{\gamma_d} - \frac{1}{G}\right) \times 100}$$

4. $$\boxed{w_s = \frac{e}{G}}$$

Where

w_1 = Weight of soil in stage (1)
w_d = Weight of solids or weight of dry soil
V_1 = Volume of soil in stage (1)
V_2 = Volume of soil in stage (2)
V_s = Volume of solids
e = Void ratio at its minimum (dry) condition

Shrinkage Parameters

1. **Shrinkage index (I_s):** It is the difference between the plastic limit and the shrinkage limit (w_s).

$$\boxed{I_s = w_P - w_s}$$

2. **Shrinkage ratio:** It is defined as the ratio of a given volume change expressed as a percentage of dry volume to the corresponding change in the water content.

$$\boxed{SR = \frac{\left[\dfrac{V_1 - V_2}{V_d} \times 100\right]}{(w_1 - w_2)}}$$

When volume V_2 is at shrinkage limit,

$$\boxed{SR = \frac{\left[\dfrac{V_1 - V_d}{V_d} \times 100\right]}{(w_1 - w_3)}}$$

- Shrinkage ratio is equal to the mass-specific gravity of the soil in dry state (G_m).

$$\boxed{SR = \frac{\gamma_d}{\gamma_w}(G_m)_{\text{dry}}}$$

3. **Volumetric shrinkage:** It is defined as the change in volume expressed as a percentage of dry volume when the water content is reduced from a given value to the shrinkage limit.

$$\boxed{\begin{aligned} VS &= \left(\frac{V_1 - V_d}{V_d}\right) \times 100 \\ VS &= (SR)(w_1 - w_s) \end{aligned}}$$

4. **Linear shrinkage:** It is defined as the change in length divided by the initial length when the water content is reduced to shrinkage limit.

$$\boxed{\text{LS} = \left(\frac{\text{Initial length} - \text{Final length}}{\text{Initial length}}\right) \times 100}$$

Important Indexes

1. **Plasticity index:** It is equal to the difference between the liquid limit and the plastic limit.

$$\boxed{I_P = w_1 - w_p}$$

- When w_P is greater than w_l, the plasticity index is responded as zero, and not negative.
- Burmister classified plastic properties of soils, according to their plasticity index, are as follows.

Plasticity Index	Plasticity
0	Non–plastic
1–5	Slight
5–10	Low
10–20	Medium
20–40	High
> 40	Very high

2. **Consistency index or relative consistency:** It is defined as the ratio of the difference between liquid limit and the natural water content to the plasticity index of soil.

$$\boxed{I_C = \frac{w_L - w}{I_P}}$$

If $I_C = 0$, w = LL
$I_C = 1$, w = PL
$I_C > 1$, the soil is in semi-solid state and stiff.
$I_C < 0$, the natural water content is greater than LL and the soil behaves like a liquid.

Liquidity Index

- It is also known as water-plasticity ratio.
- It is defined as the ratio of the difference between the natural water content and the plastic limit to the plasticity index.

$$\boxed{I_L = \frac{w - w_p}{I_P}}$$

- $I_C + I_L = 1$

Toughness index (I_t): Toughness index of a soil is defined as the ratio of the plasticity index (I_P) to the flow index (I_f).

$$\boxed{I_t = \frac{I_P}{I_f}}$$

- It is a measure of shearing strength of soil at the plastic limit.

Activity (A): Activity (A) of a soil is the ratio of the plasticity index and the percentage of clay fraction (-2μ Size).

$$\boxed{A = \frac{I_P}{F}}$$

- It is a measure of water holding capacity of a soil.
- During swelling and shrinkage, the changes in the volume of a soil depend upon activity.

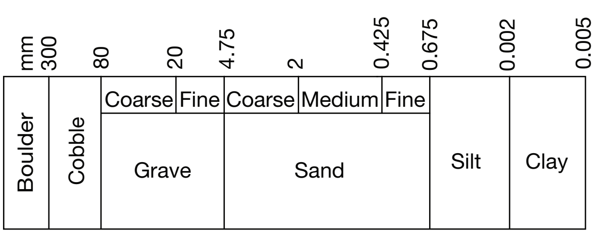
Activity	Soil Type
$A < 0.75$	Inactive
A: 0.75–1.25	Normal
$A > 1.25$	Active

- The soil containing the mineral kaolinite are least active ($A < 1$), and montomorillonite have very high activity ($A > 4$).
- For a soil of specific origin, the activity is constant.

Soil Classification

Indian Standard Particle Size Classification (IS: 1498–1970)

- Soils are designated according to grain size or particle size.
- Terms, such as 'gravel', 'sand', 'silt' and 'clay' are used to indicate certain range of grain sizes.



Unified Soil Classification System

- Developed by A. Casagrande and adopted by US Army Corps of Engineers as airfield classification.

Criteria:

1. Grain size distribution
2. Plasticity characteristics
3. Compressibility

Indian Standard Classification System (ISC System)

- It is similar to the unified soil classification system.
- Soils are divided into three categories. These are:
  1. Coarse-grained soil
  2. Fine-grained soil
  3. High organic soil (e.g., peat, Pt)

Coarse-grained soil: A soil is classified as coarse-grained soil when more than 50% of the total material, by weight, is retained on 75μ Sieve.

Fine-grained soil: A soil is classified as fine-grained soil. When more than 50% of the total material passes 75μ IS sieve.

Coarse grained soils are subdivided into gravel and sand.

Gravel (G): The soil is termed as gravel when more than 50% of coarse fraction (more than 75μ) is retained on 4.75 mm IS sieve.

Sand (S): If more than 50% of coarse fraction is smaller than 4.75 mm IS sieve, then it is termed as sand. Gravel and sands are further subdivided as:

1. **Well-graded gravel (GW):** Clean gravels, i.e., fines < 5% and $C_u > 4$ and C_c between 1 and 3.
2. **Poorly-graded Gravels (GP):** Clean gravels, i.e., fines < 5% and not meeting all gradation requirement as above.
3. **Silty gravels (GM):** Gravels with appreciable amount of fines, i.e., fines > 12% and Atterberg limits below A-line or I_P less than 4.
4. **Clayey gravels (G_C):** Gravels with appreciable amount of fines, i.e., fines more than 12% and Atterberg limits above A-line and I_P greater than 7.
   (a) **Well-graded sand (SW):** Clean sands, i.e., fines < 5% and $C_u > 6$, and C_c between 1 and 3.
   (b) **Poorly-graded sands (SP):** Clean sands, i.e., fines < 5% and not meeting all gradation requirement as stated above.
   (c) **Silty sands (SM):** When fines more than 12% and atterberg limits below A-line or I_P less than 4.
   (d) **Clayey sands (SC):** When fines > 12% and atterberg limits above A-line with $I_P > 7$.

NOTES

1. When fines lies between 5–12% border line, cases requiring dual symbols, such as GW-GM, GP-GM, SW-SM, etc. are used.
2. When I_P lies between 4 and 7, border line cases requiring double symbols, such as SM-SC, etc. are used.

- Fine-grained soils, depending upon the values of the liquid limit, are further divided into three sub-divisions:

(i) Low compressibility (L): These soils have a liquid limit less than 35%.

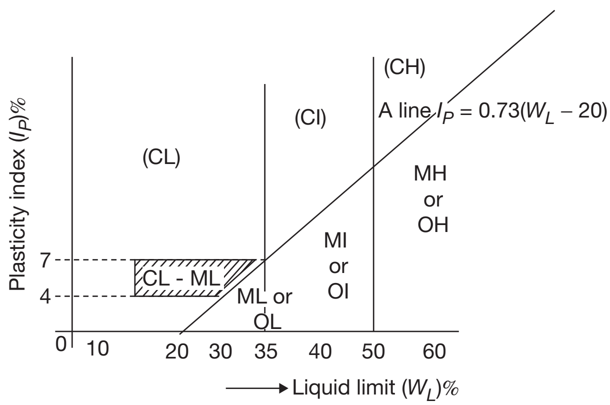
(ii) Medium compressibility (M): These soils have a liquid limit greater than 35% and less than 50.

(iii) High compressibility: These soils have a liquid limit greater than 50%. Fine-grained soils are further subdivided into three groups as follows:

- Inorganic silts (M)
  - Inorganic silts of low compressibility (ML)
  - Inorganic silts of intermediate compressibility (MI)
  - Inorganic silts of high compressibility (MH)
- Inorganic clays (C)
  - Inorganic clays of low compressibility (CL)
  - Inorganic clays of intermediate compressibility (CI)
  - Inorganic clays of high compressibility (CH)
- Organic silts and Clays (O)
  - Organic silts and clays of low compressibility (OL)
  - Organic silts and clays of intermediate compressibility (OI)
  - Organic silts and clays of high compressibility (OH)

Based on plasticity chart developed by casagrande, these fine-grained soils are classified in the laboratory.

Equation of A-line, $\boxed{I_P = 0.73(W_L - 20)}$



Plasticity chart

- Inorganic clays are plotted above A-line.
- Inorganic silts and organic silts and clays are plotted below A-line.

NOTES

1. Atterberg limits plotting above A-line with I_P between 4–7 are classified as ML-CL.
2. Organic and Inorganic soils plotted in the same zone, in the plasticity chart, are distinguished by their odour and colour or liquid limit even after oven drying.
3. In case of organic soils, liquid limit after oven drying decreases by 25% when compared to the liquid limit before oven drying.
4. Highly organic soils can be readily identified by their colour, odour, spongy feel and fibrous texture.

Field Identification of the Fine-Grained Soils

1. Dialatancy (reaction to shaking) test
2. Dispersion test
3. Toughness test
4. Dry strength test

Direction for questions 2 and 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 600μ sieve, 250 g was retained on IS 500μ sieve, and the remaining 50 g and retained on IS 425μ sieve. **[GATE, 2006]**

Example 2

The coefficient of uniformity of the soil is:

(A) 0.9 (B) 1.0
(C) 1.1 (D) 1.2

Solution

The correct answer is option (D).

Example 3

The classification of the soil is

(A) SP (B) SW
(C) GP (D) GW

Solution

The correct answer is option (A).

Total weight of soil (w) = 500 gm

Sieve Size	Weight Retained	Weight Retained (%)	Cumulative Weight Retained (%)	Finer (%)
600 ∝	200 gm	$\frac{200}{500}\times 100 = 40$	40	60
500 ∝	250 gm	$\frac{250}{500}\times 100 = 50$	90	10
425 ∝	50 gm	$\frac{50}{500}\times 100 = 10$	100	0

$$C_U = \frac{D_{60}}{D_{10}}$$

D_{60} = Diameter corresponding to 60% finer = 600μ
D_{10} = Diameter corresponding to 10% finer = 500μ

$$C_u = \frac{D_{60}}{D_{10}} = \frac{600}{500}$$

$C_U = 1.2$

Total weight of soil is retained on 75μ sieve $\Rightarrow$ Coarse-grained soil and, also it is passing through 4.75 mm $\Rightarrow$ sand

Since, $C_U \not> 6 \Rightarrow$ poorly graded

$\therefore$ The given soil can be classified as poorly-graded sand (SP).

Exercises

1. Consistency index for a clayey soil is

[LL = Liquid limit, PI = Plasticity index, w = natural moisture content]

(A) $\dfrac{\text{LL}-w}{\text{PI}}$ (B) $\dfrac{w-\text{PL}}{\text{PI}}$

(C) LL – PL (D) 0.5W

2. If soil is dried beyond its shrinkage limit, it will show
(A) large volume change.
(B) moderate volume change.
(C) low volume change.
(D) no volume change.

3. The toughness index of clayey soils is given by
(A) plasticity index/flow index
(B) liquid limit/plastic limit
(C) liquidity index/plastic limit
(D) plastic limit/liquidity index

4. The following data were obtained from a liquid limit test conducted on a soil sample:

Number of Blows	17	22	25	28	34
Water Content (%)	63.8	63.1	61.9	60.6	60.5

The liquid limit of the soil is:
(A) 63.1% (B) 62.8%
(C) 61.9% (D) 60.6%

5. The void ratios at the densest, loosest and the natural states of a sand deposit are 0.2, 0.6 and 0.4 respectively. The relative density of the deposit is
(A) 100% (B) 75%
(C) 50% (D) 25%

6. The liquid limit and plastic limit of sample are 65% and 29% respectively. The percentage of the soil fraction with grain size finer than 0.002 mm is 24. The activity ratio of the soil sample is
(A) 0.50 (B) 1.00
(C) 1.50 (D) 2.00

7. The moisture content of a clayey soil is gradually decreased from a large value. What will be the correct sequence of the occurrence of the following limits?
I. Shrinkage limit
II. Plastic limit
III. Liquid limit

Select the correct answer using the codes given below:
(A) I, II, III (B) I, III, II
(C) III, II, I (D) III, I, II

8. A clay sample has a void ratio 0.54 in dry state. The specific gravity of soil solids is 2.7. What is the shrinkage limit of the soil?
(A) 8.5% (B) 10.0%
(C) 17.0% (D) 20.0%

9. A specimen of clayey silt contains 70% silt size particles. Its liquid limit = 40 and plastic limit = 20. In liquid limit test, at moisture content of 30%, required number of blows was 50. Its plasticity index, activity and consistency index will respectively be
(A) 20, 0.67 and 0.5
(B) 20, 1.5 and 2.0
(C) 30, 1.5 and 0.72
(D) 20, 0.286 and 0.38

10. Consider the following statements:
I. Activity is a property typical of clay soils.
II. An activity value of 7 in a clay soil is indicative of the presence of montmorillonite mineral.
III. An activity value of 7 in a clay soil is indicative of the presence of illite mineral.

Which of these statements are correct?
(A) I, II and III (B) I and II only
(C) 1 and III only (D) II and III only

11. A saturated specimen of clay was immersed in mercury and displaced volume was 21.8 cc. The weight of the sample was 32.2 gm. After oven drying for 48 hours, weight reduced to 20.2 gm while volume came down to 11.6 cc. The shrinkage limit of the soil is
(A) 7.9% (B) 8.0%
(C) 8.9% (D) 9.8%

12. Consider the following statements:
A well-graded sand should have
I. Uniformity coefficient greater than 6
II. Coefficient of curvature between 1 and 3
III. Effective size greater than 1 mm

Which of these statements are correct?
(A) I, II and III (B) I and II
(C) I and III (D) II and III

13. Given that coefficient of curvature = 1.4,

$D_{30} = 3$ mm, $D_{10} = 0.6$ mm.

Based on this information of particle size distribution for use as sub grade, this soil will be taken to be
(A) uniformly-graded sand.
(B) well-graded sand.
(C) very fine sand.
(D) poorly-graded sand.

14. 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.	Pt	3.	Inorganic silt with small compressibility
d.	MH	4.	Soil with high organic content with high compressibility

Codes:

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

15. Data from a sieve analysis conducted on a given sample of soil showed that 67% of the particles passed through 75 micron IS sieve. The liquid limit and plastic limit of the finer fraction was found to be 45 and 33 per cent respectively. The group symbol of the given soil as per IS:1498–1970 is
(A) SC (B) MI
(C) CH (D) MH

16. 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.

17. The symbol 'SM' indicates
(A) sandy silt.
(B) medium silt.
(C) silty sand.
(D) medium sand.

18. For a particular soil sample, if D_{10}, D_{30} and D_{60} is given as 425μ, 2.36 mm and 4.75 mm respectively. Then match the following.

	Group I		Group II
1.	Coefficient of curvature	**a.**	1.81
2.	Coefficient of uniformity	**b.**	2.76
3.	Permeability	**c.**	11.2

(A) 1 – a, 2 – b, 3 – c
(B) 1 – c, 2 – b, 3 – a
(C) 1 – a, 2 – c, 3 – b
(D) 1 – b, 2 – c, 3 – a

19. The relationship between water content (w%) and number of blows (N) in soils, as obtained from Casgrande's liquid limit device, is given by $w = 15 - \log_{10} N$. The liquid limit of soil is
(A) 15.6% (B) 14.6%
(C) 13.6% (D) 16.6%

20. At shrinkage limit, the degree of saturation is _______.
(A) 100% (B) 75%
(C) 50% (D) 0%

21. 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 75 μ sieve, respectively. The liquid limit and plastic limits of the soil fraction passing through 425 μ sieves are 55% and 25% respectively. The soil may be classified as _______.
(A) GC (B) SM
(C) GM (D) SC

22. A clay sample has a void ratio 0.35 in dry state. The specific gravity of soil solids is 2.68. What is the shrinkage limit of the soil?
(A) 10.5% (B) 13.06%
(C) 12.2% (D) 15%

PREVIOUS YEARS' QUESTIONS

1. 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 425μ sieves are 40% and 18% respectively. The soil may be classified as **[GATE, 2007]**
(A) SC (B) MI
(C) CI (D) SM

2. The Liquid Limit (LL), Plastic Limit (PL) and Shrinkage Limit (SL) of a cohesive soil satisfy the relation **[GATE, 2008]**
(A) LL > PL < SL
(B) LL > PL > SL
(C) LL < PL < SL
(D) LL < PL > SL

3. Group symbols assigned to silty sand and clayey sand are respectively **[GATE, 2008]**
(A) SS and CS (B) SM and CS
(C) SM and SC (D) MS and CS

4. The laboratory test results of a soil sample are given below:
Percentage finer than 4.75 mm = 60
Percentage finer than 0.075 mm = 30
Liquid limit = 35%
Plastic limit = 27%
The soil classification is **[GATE, 2009]**
(A) GM (B) SM
(C) GC (D) ML – MI

5. A fine grained soil has liquid limit of 60 and plastic limit of 20. As per the plasticity chart, according to IS classification, the soil is represented by letter symbols **[GATE, 2010]**
(A) CL (B) CI
(C) CH (D) CL – ML

6. As per the Indian Standard soil classification system, a sample of silty clay with liquid limit of 40% and plastics index of 28% is classified as **[GATE, 2012]**
(A) CH (B) CI
(C) CL (D) CL – ML

7. A given cohesion less soil has e_{max} = 0.85 and e_{min} = 0.50. In the field, the soil is compacted to a mass density of 1800 kg/m^3 at a water content of 8%. Take the mass density of water as 1000 kg/m^3 and G_s as 2.7. The relative density (in %) of the soil is **[GATE, 2014]**

(A) 56.43 (B) 60.25
(C) 62.87 (D) 65.7

8. As per Indian Standard soil classification system (IS:1498–1970) an expression for A-line is **[GATE, 2014]**

(A) $I_P = 0.73(w_L - 20)$ (B) $I_P = 0.70(w_L - 20)$
(C) $I_P = 0.73(w_L - 10)$ (D) $I_P = 0.70(w_L - 10)$

9. A fine-grained soil has 60% (by weight) silt content. The soil behaves as *semi-solid* when water content is between 15% and 28%. The soil behaves *fluid-like* when the water content is more than 40%. The *'Activity'* of the soil is **[GATE, 2015]**

(A) 3.33 (B) 0.42
(C) 0.30 (D) 0.20

10. A fine grained soil is found to be plastic in the water content range of 26–48%. As per Indian Standard Classification System, the soil is classified as **[GATE, 2016]**

(A) CL (B) CH
(C) CL-ML (D) CI

Answer Keys

Exercises

1. A	**2.** D	**3.** A	**4.** C	**5.** C	**6.** C	**7.** C	**8.** D	**9.** A	**10.** B
11. C	**12.** B	**13.** B	**14.** C	**15.** B	**16.** C	**17.** C	**18.** D	**19.** C	**20.** A
21. D	**22.** B								

Previous Years' Questions

1. A	**2.** B	**3.** C	**4.** A	**5.** C	**6.** B	**7.** D	**8.** A	**9.** C	**10.** D