Chapter 1 Problem Solutions

1.1 Give examples of three geotechnical problems which can be caused by problematic geomaterials

Solution:

Below are three examples of geotechnical problems caused by problematic geomaterials:

(1) Saturated loose sand liquefies during earthquake.

(2) Expansive soil shrinks to cause pavement cracking during a dry season.

(3) Buildings on soft soil have excessive total and differential settlements to cause cracking of the buildings.

1.2 List five possible geotechnical problems caused by human activities.

Solution:

Below are five possible geotechnical problems caused by human activities:

(1) Dewatering causes ground subsidence.

(2) Excavation causes ground movement.

(3) Excavation of toe causes slope failure.

(4) Pile driving causes ground heave.

(5) Rapid construction of an embankment on soft soil causes bearing failure.

1.3 How can ground improvement methods be classified in terms of their functions?

Solution:

Ground improvement methods can be classified in terms of their functions as follows: (1) replacement, (2) densification, (3) drainage and consolidation, (4) reinforcement, (5) chemical stabilization, and (6) thermal treatment.

1.4 What is the basic principle for soil liquefaction? List five possible ground improvement methods which can be used to mitigate soil liquefaction and explain why.

Solution:

The basic principle for soil liquefaction is: when the excess pore water pressure in a saturated cohesionless soil is equal to the soil total overburden stress, its effective stress becomes zero so that the soil loses its strength (i.e., liquefaction).

Soil liquefaction can be mitigated if the liquefiable soil is replaced with a non-liquefiable soil, the density of the soil is increased, the groundwater is lowered, or the soil bonding strength is introduced. The following five ground improvement methods can be used to mitigate soil liquefaction:

(1) overexcavation and replacement,

(2) dynamic compaction,

(3) vibro-compaction,

(4) dewatering, and

(5) deep mixing.

1.5 List five possible methods for shallow ground improvement.

Solution:

Below are five possible methods for shallow ground improvement:

(1) traditional compaction,

(2) rapid impact compaction,

(3) intelligent compaction,

(4) overexcavation and replacement, and

(5) chemical stabilization of subgrade and base.

1.6. List five possible methods for deep ground improvement.

Solution:

Below are five possible methods for deep ground improvement:

(1) deep compaction,

(2) vibro-compaction,

(3) deep mixing,

(4) jet grouting, and

(5) stone columns.

1.7 A project site has a 5 m thick loose gravel layer near ground surface which needs be improved for foundation support. Which methods may be used for ground improvement? Why?

Solution:

Dynamic compaction or vibro-compaction can be used to improve the 5-m thick loose gravel layer because it can densify this soil layer by impact or vibration.

1.8 Explain why different ground improvement methods are needed for cut and fill walls.

Solution:

For cut walls, ground improvement methods are used to maintain the stability of the walls during excavation by inserting reinforcements into the existing in situ soil. For fill walls, ground improvement methods are used to maintain the stability of the walls during placement of fill by placing reinforcements on the surface of newly placed fill. Due to this construction sequence difference, different ground improvement methods are needed.

1.9 What are the types of construction specifications possibly used in practice?

Solution:

The types of construction specifications possibly used in practice include: (1) method specifications, (2) end-result specifications, (3) quality assurance specifications, (4) performance-related specifications, and (5) performance-based specifications. The method specifications are most commonly used in current practice while performance-based specifications are the trend for future practice.

1.10 Explain why quality control and assurance are so important for ground improvement methods.

Solution:

The performance of ground improvement methods highly depends on the quality of installation, for example, depth and diameter of columns, time of vibration for vibro-compaction, and uniformity of soil-cement mixture by deep mixing. To ensure the quality of installation, quality control and assurance are important.

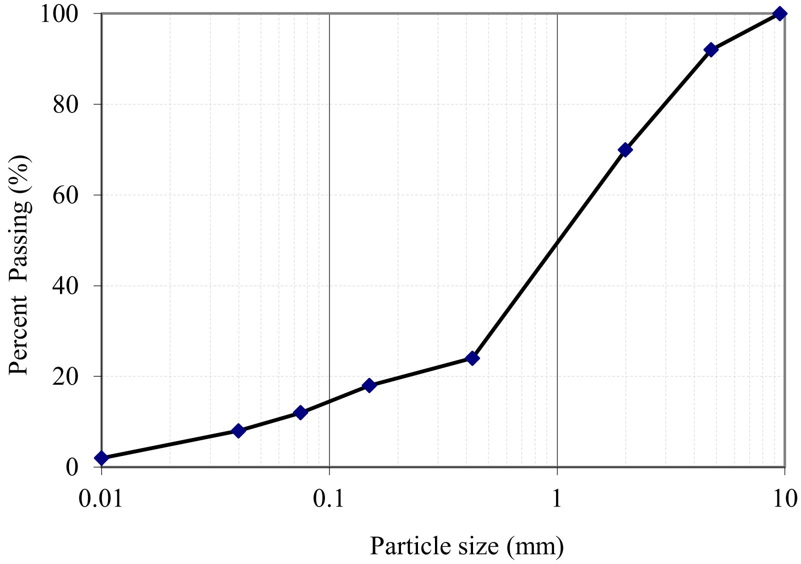
1.11 What are the future trends of ground improvement?

Solution:

The future trends of ground improvement include: (1) use of combined technologies to create more technically and cost-effective solutions, (2) use of intelligent construction technologies with sensors and computer monitoring to improve efficiency and quality of ground improvement, (3) use of recycled materials and other alternative materials to make ground improvement methods more sustainable, (4) use of end-result or performance-based specifications, and (5) application of biological treatment in field.

Chapter 2 Problem Solutions

2.1Determine D_{10}, D_{15}, D_{30}, D_{50}, D_{60}, and D_{85} from the following gradation curve.



Solution:

From the above gradation, the following parameters can be determined:

D_{10} = 0.057 mm, D_{15} = 0.1, D_{30} = 0.51 mm, D_{50} = 1.0 mm, D_{60} = 1.5 mm, D_{85} = 3.5 mm.

2.2 Determine void ratio, porosity, and degree of saturation of a soil sample with the following known information: moist weight of soil sample = 1000 g, volume of soil sample = 580000 mm^3, specific gravity = 2.70, and dry weight of soil = 910 g.

Solution:

The volume of solid is

$$V_s = \frac{M_s}{\rho_w G_s} = \frac{910}{1 \times 2.70} = 337.037\ \text{cm}^3 = 337037\ \text{mm}^3$$

The volume of water is

$$V_w = \frac{M_w}{\rho_w} = \frac{1000-910}{1} = 90\ \text{cm}^3 = 90000\ \text{mm}^3$$

The volume of voids is

$$V_v = V - V_s - V_w = 580000 - 337037 - 90000 = 152963\,\text{mm}^3$$

The void ratio is

$$e = \frac{V_v}{V_s} = \frac{152963}{337037} = 0.45$$

The porosity is

$$n = \frac{V_v}{V} = \frac{152963}{580000} = 0.26$$

The degree of saturation is

$$S_r = \frac{V_w}{V_v} \times 100\% = \frac{90000}{152963} \times 100\% = 59\%$$

2.3 The maximum and minimum void ratios of sand are 0.82 and 0.42, respectively. What is the void ratio of the sand corresponding to a relative density of 70%?

Solution:

Known parameters: e_{max}= 0.82 and e_{min}= 0.42.

Relative density is defined as $D_r = (e_{max} - e)/(e_{max} - e_{min})$ and the void ratio corresponding to a relative density of 70% is

$$e = (e_{max} - D_r\,(e_{max} - e_{min})) = (0.82 - 70\% \times (0.82 - 0.42)) = 0.54.$$

2.4 A soil sample has 30% particles retained on the US No. 200 sieve. The plastic limit and liquid limit of this soil are 20 and 60, respectively. Classify this soil according to the USCS method.

Solution:

This soil has 30% particles retained on the US No. 200 sieve, in other words, more than 50% particles pass the US No. 200 sieve. Therefore, it is a fine-grained soil.

The plasticity index of this soil is $PI = 60 - 20 = 40$. Based on the ASTM plasticity chart with $LL = 60$ and $PI = 40$, this soil can be classified as a high-plasticity clay (CH) or organic soil (OH).

2.5 Laboratory gradation analyses and Atterberg Limit tests are performed on a soil sample. Results are summarized below. No organic odor or materials are noted in the sample.

U.S. sieve size	percent passing
9.8 mm	100
No. 4	95
No. 10	90
No. 40	82
No. 100	75
No. 200	68

Liquid limit (LL) = 51% and plastic limit (PL) =21%.
Classify this soil according to the USCS system.

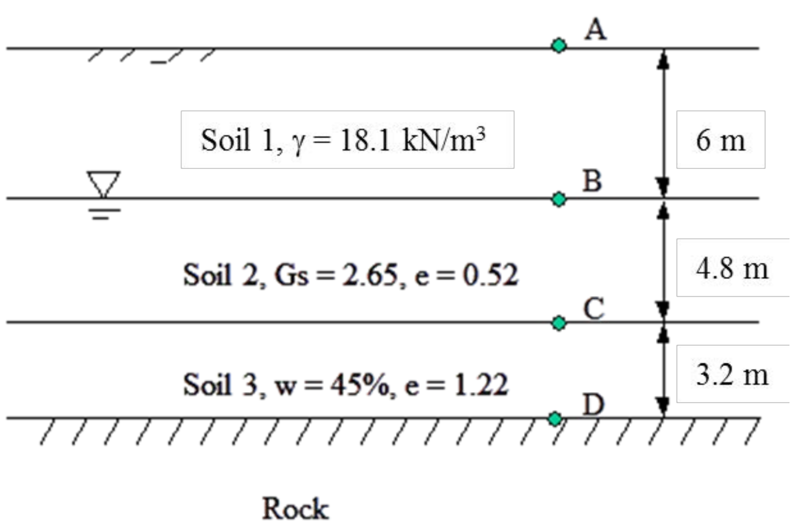
Solution:

The above gradation shows that more than 50% particles pass the US No. 200 sieve; therefore, this is a fine-grained soil.

The plasticity index of this soil is PI = 51 – 21 = 30. Based on the ASTM plasticity chart with LL = 51 and PI = 30, this soil can be classified as a high-plasticity clay (CH) or organic soil (OH). Since there is no organic odor or material in this soil, it is a fat clay (CH).

Since this soil has more than 30% particles retained on the No. 200 sieve, % sand > % gravel, and <15% gravel, this soil can be further classified as a sandy fat clay.

2.6 Calculate the total vertical stress σ_z, pore water pressure u and effective vertical stress σ_z' at A, B, C, and D in the following figure.



Solution:

Unit weights are needed to calculate vertical stresses in soil.

For Soil 2, its saturated unit weight is

$$\gamma_{sat} = \frac{(G_s + e)\gamma_w}{1+e} = \frac{(2.65+0.52)\times 9.81}{1+0.52} = 20.5\ \text{kN/m}^3.$$

For Soil 3, its saturated unit weight is

$$\gamma_{sat} = \frac{e}{w}\left(\frac{1+w}{1+e}\right)\gamma_w = \frac{1.22}{0.45}\times\left(\frac{1+0.45}{1+1.22}\right)\times 9.81 = 17.4\ \text{kN/m}^3.$$

The total vertical stresses σ_z, pore water pressures u, and effective vertical stresses σ_z' at A, B, C, and D are

Point A: $\sigma_z = 0$, $u = 0$, $\sigma_z' = 0$.

Point B: $\sigma_z = \gamma z = 18.1\times 6 = 109\ \text{kPa}$, $u = 0$, $\sigma_z' = \sigma_z - u = 109 - 0 = 109\ \text{kPa}$

Point C: $\sigma_z = 18.1\times 6 + 20.5\times 4.8 = 207\ \text{kPa}$, $u = 9.81\times 4.8 = 47\ \text{kPa}$, $\sigma_z' = 207 - 47 = 160\ \text{kPa}$

Point D: $\sigma_z = 18.1\times 6 + 20.5\times 4.8 + 17.4\times 3.2 = 262\ \text{kPa}$, $u = 9.81\times(4.8+3.2) = 78\ \text{kPa}$,
$\sigma_z' = 262 - 78 = 184\ \text{kPa}$

2.7 Consolidation test results of a soil sample taken at a depth of 2.5 m from field with a groundwater table at the ground surface are shown below:

Stress (kPa)	10	20	40	80	160	320
Void ratio	0.910	0.851	0.760	0.629	0.490	0.352

The saturated unit weight and permeability of the soil sample are 19.0 kN/m^3 and 6.5 x 10^{-7} m/s. Calculate: (1) effective overburden stress in field; (2) pre-consolidation stress; (3) over-consolidation ratio (OCR); (4) coefficient of recompression; (5) coefficient of compression; (6) coefficient of volumetric compressibility in the stress range between 100 to 200 kPa; (7) coefficient of consolidation.

Solution:

(1) The effective overburden stress in the field is

$$\sigma'_{z0} = 2.5\times(19 - 9.81) = 23.0\ \text{kPa}$$

(2) Using the Casagrande method, the preconsolidation stress can be determined as shown in the following figure as $\sigma'_p = 33\ \text{kPa}$.