

ICE Core Concepts

Geotechnical Engineering

Second edition



Sanjay Kumar Shukla

ICE Core Concepts: Geotechnical Engineering

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ICE Core Concepts: Geotechnical Engineering

Second Edition

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Preface

Geotechnical engineering involves the analysis, design, construction, maintenance and renovation of geotechnical structures and other ground-related infrastructure. This includes foundations, retaining walls, slopes, embankments, earth dams, pavements, buried structures and landfills. The subject equips students and practising engineers with essential knowledge to tackle field problems related to load-bearing capacity, settlement and ground stability. It plays an important role in ensuring that infrastructure projects remain safe, efficient and sustainable.

Geotechnical engineering is a fundamental subject taught in undergraduate civil engineering programmes around the world. Over the years, many textbooks and reference books have been written to explain both the basic principles and advanced topics of this important field. Each of these books plays a valuable role in supporting the learning needs of students as well as the practical requirements of practising engineers. Together, they help build a strong foundation of knowledge and guide the application of geotechnical principles in real-world engineering projects.

This textbook focuses on the core concepts of geotechnical engineering, as reflected in its title. It includes ten chapters, carefully designed for a one-semester course in undergraduate civil engineering programmes and is also useful for postgraduate students. The content is clearly presented in plain English, with a good balance of text, diagrams, examples and practice questions. Each chapter provides helpful references for further reading. To support real-world learning, the book aims to offer readers a sense of practical experience, which is essential for solving ground engineering problems in the field, particularly in the civil, mining, agricultural, aquacultural and energy sectors.

Chapter 1 introduces the core concepts of soils, rocks and foundations. Chapter 2 covers various techniques used to investigate and assess the surface and subsurface conditions of the ground. Chapter 3 provides a basic overview of different methods for improving unsuitable or weak soil, rock or ground at construction sites. Chapter 4 focuses on the engineering aspects of shallow foundations, while Chapter 5 deals with deep foundations. Chapter 6 discusses retaining structures, including sheet pile walls. Chapter 7 covers key aspects of slopes, embankments and earth dams. Chapter 8 presents the dynamic analysis and design of machine foundations. Chapter 9 introduces the basic concepts of geosynthetics and their use in reinforced and confined geotechnical structures. Chapter 10 explains the principles of specialised topics such as filters and drains, earth anchors, buried structures, pavement infrastructure, landfills and marine structures.

I have written this introductory textbook based on my over 30 years of experience in teaching, research and consultancy in geotechnical engineering, making it a valuable learning resource for students and practising engineers. Students will find this textbook highly useful for understanding the fundamentals of geotechnical engineering on their own, without needing major external support. For lecturers, it serves as a ready reference, reducing the need to prepare separate hand-written lecture notes, as I have used the material in this textbook for classroom teaching over many years. In addition to students and lecturers, this textbook will also be a useful resource for practising engineers, helping them refresh their understanding of core geotechnical concepts when working on relevant projects.

Revised and updated, this second edition offers the following key features.

- A new chapter (Chapter 10) focuses on the principles of special topics, including filters and drains, earth anchors, buried structures, pavement infrastructure, landfills and liner systems, and marine structures.
- Enhancements to existing chapters, with the addition of new sections in Chapters 1, 2, 3, 6 and 7, providing expanded coverage and greater depth.
- Comprehensive updates have been made throughout the book, featuring additional illustrative examples, new and updated illustrations, a fresh set of multiple choice questions, numerical practice problems and conceptual questions. This edition also includes updated test standards, codes of practice and references to ensure relevance and support enhanced learning and practical application.

I would like to express my heartfelt gratitude to the team at Emerald/ICE Publishing, London, especially Michael Fenton, Cathy Sellars, Ryan Molyneux, Benn Linfield, Alison Gilmour, and S. Rajachitra, for their strong support and cooperation throughout the various stages of preparing and producing this textbook. Their dedication and professionalism have been invaluable.

I extend my sincere appreciation to my wife, Sharmila, for her constant encouragement and support during the preparation of the manuscript. I am equally grateful to my daughter, Sakshi, and my son, Sarthak, for their patience and understanding as I worked on this textbook at home.

Finally, I warmly welcome suggestions from readers and users of this textbook to help improve its content in future editions. Your feedback is highly valued and will contribute to making this resource even more useful and comprehensive.

Sanjay Kumar Shukla
Perth, Australia, 2025

About the author



Dr Sanjay Kumar Shukla is a globally renowned expert in Civil (Geotechnical) Engineering. He is the Founding Editor-in-Chief of the *International Journal of Geosynthetics and Ground Engineering*, published by Springer, Switzerland, and the Founding Leader of the Geotechnical and Geoenvironmental Engineering Research Group at Edith Cowan University, Joondalup, Perth, Australia. He holds distinguished professorships at several universi-

ties, including the prestigious Delhi Technological University, Delhi, India, and Southern Illinois University, Carbondale, USA.

Dr Shukla is a Chartered Professional Engineer in Civil and Geotechnical Engineering, registered with Engineers Australia. He also holds the designation of Asia Pacific Economic Cooperation (APEC) Engineer in Civil Engineering and is recognised as an International Professional Engineer in Civil Engineering by the International Engineering Association.

He is a distinguished Fellow of the American Society of Civil Engineers and Engineers Australia, as well as a Life Fellow of the Institution of Engineers (India) and the Indian Geotechnical Society. His prolific academic contributions include 28 books and over 320 research articles, earning him recognition among the world's top 2% of scientists by Elsevier, and among the top 0.5% globally by ScholarGPS.

Dr Shukla has received numerous accolades, including the 2021 ECU Aspire Award and the prestigious IGS Award 2018 from the International Geosynthetics Society, USA. In 2024, the Consulate General of India in Perth honoured him with the Distinguished Honour for his outstanding academic contributions to geotechnical engineering.

His pioneering works, such as his generalised expressions for seismic active thrust (2015) and passive resistance (2013), along with the innovative Shukla's wraparound reinforcement technique, are widely used in engineering practice and form integral components of engineering education worldwide. His seven research mantras, introduced in 2022, have inspired sustainable research practices and influenced researchers globally.

A highly regarded speaker, Dr Shukla frequently delivers keynote talks and short courses internationally. He is also widely consulted by researchers and practising engineers for his expertise in advancing practical engineering solutions.

Sanjay Kumar Shukla

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Chapter 1

Introduction

Learning aims

This chapter explores the core concepts of the following topics

- geotechnical engineering and its areas of application
- soil and soil mechanics
- rock, engineering geology and rock mechanics
- foundations and their major types
- role of the geotechnical engineer
- geotechnical design approach
- sustainability, health and safety considerations.

1.1. Geotechnical engineering

Geotechnical engineering deals with the analysis, design, construction, maintenance and renovation of geotechnical structures, typically classified into the following seven basic types: foundation, retaining wall, slope, embankment, earth dam, tunnel and pavement. Any geotechnical structure not explicitly covered by these seven basic types may be considered a variation or a combination of them. Soil or rock problems associated with landfills, waste containment facilities and contaminated ground are also studied within geotechnical engineering, under the subfield of geoenvironmental engineering. The core concepts of geotechnical engineering are primarily derived from three subjects: engineering geology, soil mechanics and rock mechanics. Geotechnical engineering includes the area of foundation engineering, which addresses various aspects of foundations for engineering structures or systems, focusing on the safe and economical transfer of structural loads to the ground. Other geotechnical structures, such as retaining walls and slopes, are also addressed within foundation engineering. In brief, geotechnical engineering provides solutions to various types of soil or rock problems. It is important to note that practical solutions to these problems require engineering judgement and experience, which are gained through regular professional practice and self-directed study.

The core principles of engineering geology, rock mechanics and soil mechanics can be refreshed by referring to textbooks specifically dedicated to these subjects (Shukla, 2025; Sivakugan *et al.*, 2013). In addition to these three core geotechnical subjects, several specialised areas, such as site investigation, soil dynamics, ground engineering, geosynthetic engineering, environmental geotechnics, soil–structure interaction, pavement geotechnics and tunnelling, also significantly contribute to geotechnical engineering. This book presents the fundamental concepts of geotechnical engineering, focusing on basic geotechnical structures that are routinely handled by civil/geotechnical engineers. To facilitate the learning process, this chapter provides a brief introduction

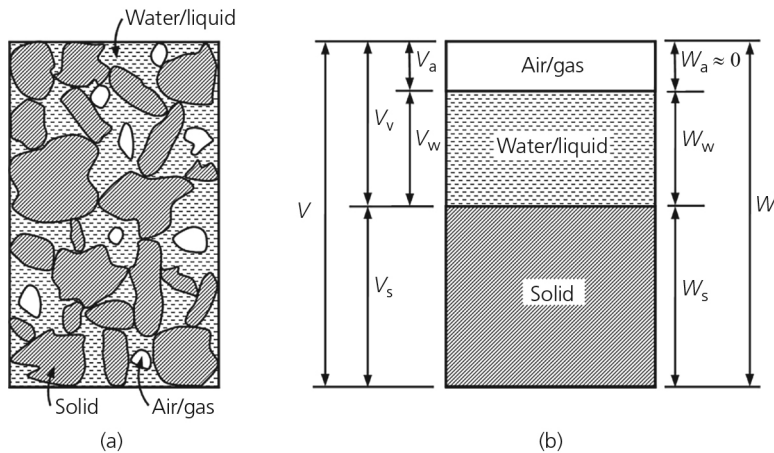
to the core concepts of soils, rocks and foundations. Further details on basic and certain specialised geotechnical structures, including foundations, are presented in Chapters 4 to 10.

1.2. Soils

Soil consists of all materials in the Earth's crust that are loose enough to be excavated by a spade or shovel. According to Karl Terzaghi, soil is a natural aggregate of mineral particles that can be separated by such gentle means as agitation in water (Terzaghi *et al.*, 1996). Soil supports structural foundations and is used as a construction material in various civil/geotechnical engineering projects.

Soil is a particulate, multiphase system, generally consisting of three phases: solid, liquid and gas (Figure 1.1). The space in a soil mass occupied by liquid and/or gas is known as the void. A dry soil contains only air in its voids, whereas a saturated soil contains only water. There are several phase relationships and interrelationships. The most common ones are given below, where V and W refer to volume and weight, respectively, and subscripts a, w, s and v denote air, water, solid and void, respectively.

Figure 1.1 (a) A soil element with its phases in the natural state; (b) a soil element separated into its three phases



$$n = \frac{V_v}{V} \quad (1.1)$$

$$e = \frac{V_v}{V_s} \quad (1.2)$$

$$S = \frac{V_w}{V_v} \quad (1.3)$$

$$w = \frac{W_w}{W_s} \quad (1.4)$$

$$\gamma = \frac{W}{V} \quad (1.5)$$

$$\gamma_d = \frac{W_s}{V} \quad (1.6)$$

$$\gamma_s = \frac{W_s}{V_s} \quad (1.7)$$

$$\gamma_{\text{sat}} = \frac{W_{\text{sat}}}{V} \quad (1.8)$$

$$\gamma' = \gamma_{\text{sat}} - \gamma_w \quad (1.9)$$

$$G = \frac{\gamma_s}{\gamma_w} \quad (1.10)$$

$$n = \frac{e}{1+e} \quad (1.11)$$

$$Se = wG \quad (1.12)$$

$$\gamma = \left(\frac{G + Se}{1+e} \right) \gamma_w \quad (1.13)$$

$$\gamma_d = \left(\frac{G\gamma_w}{1+e} \right) = \left(\frac{\gamma}{1+w} \right) \quad (1.14)$$

where n is the porosity of soil; e is the void ratio of soil; S is the degree of saturation of soil; w is the water content of soil; γ is the total/bulk/wet/moist unit weight of soil; γ_d is the dry unit weight of soil; γ_s is the unit weight of soil solids; γ_{sat} is the saturated unit weight of soil; γ_w is the unit weight of water ($= 9.81 \text{ kN/m}^3$); γ' is the submerged/buoyant unit weight of soil; G is the specific gravity of soil solids; W_{sat} is the saturated weight of soil.

Volume, V , and weight, W , with different subscripts have their usual meanings, as indicated in [Figure 1.1](#). Mass, M , and weight, W , of a soil (or rock) element are related as $W = Mg$, where g is the acceleration due to gravity, which is taken as approximately 9.81 m/s^2 , or sometimes as 10 m/s^2 for simplicity. The unit weight, γ , and density, ρ ($= M/V$), of a soil (or rock) element are related as $\gamma = \rho g$.

The important properties of soils are listed below.

- Index/basic properties. Total unit weight, γ ; void ratio, e ; specific gravity of soil solids, G ; water content, w ; degree of saturation, S ; particle size distribution; consistency limits (liquid limit, w_L ; plastic limit, w_p ; shrinkage limit, w_s) for cohesive soils; relative density, D_r , for cohesionless soils.
- Compaction characteristics. Maximum dry unit weight, γ_{dmax} ; optimum water content, w_{opt} .
- Permeability. Coefficient of permeability or hydraulic conductivity, k .
- Compressibility. Compression index, C_c ; recompression index, C_r ; swelling index, C_s ; coefficient of volume change, m_v ; coefficient of consolidation, c_v ; secondary compression index, C_α .

- Shear strength. Total stress–strength parameters such as the cohesion intercept, c , and angle of shearing resistance, ϕ ; effective stress–strength parameters such as the effective cohesion intercept, c' , and effective angle of shearing resistance, ϕ' .
- Stiffness. Elastic constants such as Young’s modulus of elasticity, E , bulk modulus of elasticity, K , shear modulus of elasticity, G , and Poisson’s ratio, μ .

The properties of soils are highly variable from one site to another, and even at a single site they can vary with location. The air content of a soil has little engineering significance, while the water content influences the engineering properties of soil significantly. The design and stability of geotechnical structures are significantly influenced by soil properties, primarily permeability, compressibility and shear strength. The subject that deals with the physical properties of soil and the behaviour of soil masses in relation to their practical applications is known as soil mechanics.

Example 1.1

A soil sample in its natural condition weighs 1.852 kg and has a volume of 0.001 m³. After being completely dried in an oven, the sample weighs 1.635 kg. If the specific gravity of soil solids is 2.70, determine the following.

- (a) total unit weight
- (b) water content
- (c) dry unit weight
- (d) void ratio
- (e) degree of saturation.

Solution

Given: $W = 1.852 \times 9.81 = 18.17$ N, $V = 0.001$ m³, $W_s = 1.635 \times 9.81 = 16.04$ N and $G = 2.70$.

- (a) From Equation 1.5, the total unit weight

$$\gamma = \frac{W}{V} = \frac{18.17}{0.001} = 18170 \text{ N/m}^3 \text{ or } 18.17 \text{ kN/m}^3$$

- (b) From Equation 1.4, the water content

$$w = \frac{W_w}{W_s} = \frac{W - W_s}{W_s} = \frac{18.17 - 16.04}{16.04} = 0.133 \text{ or } 13.3\%$$

Note that water content, w , can be calculated using the wet mass, M ($= 1.852$ kg), and dry mass, M_s ($= 1.635$ g), as follows

$$w = \frac{M_w}{M_s} = \frac{M - M_s}{M_s} = \frac{1.852 - 1.635}{1.635} = 0.133 \text{ or } 13.3\%$$

- (c) From Equation 1.14, the dry unit weight

$$\gamma_d = \frac{\gamma}{1 + w} = \frac{18.17}{1 + 0.133} = 16.04 \text{ kN/m}^3$$

(d) From Equation 1.14, the void ratio

$$e = \frac{G\gamma_w}{\gamma_d} - 1 = \frac{(2.70)(9.81)}{16.04} - 1 = 0.651$$

(e) From Equation 1.12, the degree of saturation

$$S = \frac{wG}{e} = \frac{(0.133)(2.70)}{(0.651)} = 0.552 \text{ or } 55.2\%$$

The following points regarding soils and the fundamental principles of soil mechanics are noteworthy.

- The term ‘ground’ refers to soil, rock and/or fill in its natural or existing state before the commencement of a construction project. Based on their mode of formation, soils are classified as residual soils, sedimentary soils, organic soils and fills (also known as human-made soils).
- The smallest particle size that can be seen with the naked eye is typically 0.075 mm. Clay (< 0.002 mm), silt (0.002–0.075 mm), sand (0.075–4.75 mm), gravel (4.75–80 mm), cobble (80–300 mm) and boulder (> 300 mm) are the names of particle sizes, and they are also used to describe soils. The dividing lines between the size limits are arbitrary and vary across different classification systems. Silt-sized and clay-sized particles are collectively called fines. A fine-grained soil contains $\geq 50\%$ fines (by dry weight), whereas a coarse-grained soil contains < 50% fines (by dry weight).
- The classification of a soil requires particle size distribution based on sieve analysis and consistency limits (liquid and plastic limits). If a soil is described as silty clay, its clay content is greater than its silt content.
- A soil is called ‘well graded’ if its particle sizes are distributed over a wide range. Soil consisting of particles of nearly the same size is called a ‘uniformly graded’ soil. If a soil has an excess of certain particle sizes and a deficiency of others, it is called a ‘poorly graded’ soil.
- Soil particles and water are nearly incompressible, so any volume change in saturated soil equals the volume of water that drains in or out.
- For a dry soil, the degree of saturation, $S = 0\%$, while for a fully saturated soil, $S = 100\%$. For a partially saturated soil, S lies between 0% and 100%. The natural water content, w , of soils can exceed 100%, although it is well under 100% for most soils.
- The typical values of the saturated unit weight of some common soils are as follows: 19–24 kN/m³ for sands and gravels; 14–21 kN/m³ for silts and clays; and 10–11 kN/m³ for peats.
- In the absence of measured values, it is common practice to assume $G = 2.65$ for a sand and $G = 2.70$ for a clay.
- The difference $w_L - w_p$ is called the plasticity index, I_p , which is used in strength correlations and for estimating certain compressibility parameters.

- If the natural water content, w , of a soil is close to its liquid limit, w_L , the soil is normally consolidated, while for a medium to heavily overconsolidated soil, w is close to its plastic limit, w_p (Bowles, 1996).
- The consistency of a cohesionless (granular) soil is typically described in terms of its relative density, which is defined as

$$D_r = \left(\frac{e_{\max} - e}{e_{\max} - e_{\min}} \right) \times 100\% \quad (1.15)$$

or

$$D_r = \left(\frac{\gamma_d - \gamma_{d\min}}{\gamma_{d\max} - \gamma_{d\min}} \right) \left(\frac{\gamma_{d\max}}{\gamma_d} \right) \times 100\% \quad (1.16)$$

where e is the in situ (or in-place) void ratio of soil; e_{\min} is the minimum void ratio (i.e. the void ratio in the densest possible state of soil); e_{\max} is the maximum void ratio (i.e. the void ratio in the loosest possible state of soil); γ_d is the in situ (or in-place) dry unit weight of soil; $\gamma_{d\min}$ is the minimum dry unit weight (i.e. the dry unit weight in the loosest possible state of soil); $\gamma_{d\max}$ is the maximum dry unit weight (i.e. the dry unit weight in the densest possible state of soil).

- The total vertical stress at a depth, z , from the ground surface can be computed as

$$\sigma_v = \gamma z \quad (1.17)$$

where γ is the total unit weight of the soil.

- Within a saturated soil mass, the effective vertical stress, σ'_v , at any depth, z , is equal to the total vertical stress, σ_v , minus the pore water pressure, $u = \gamma_w z$, at that depth. Thus, Equation 1.18 states the effective stress principle

$$\sigma'_v = \sigma_v - u \quad (1.18)$$

- When the water table is below the ground surface, its rise reduces the effective stress at any point within the soil. However, if the water table is above the ground surface, fluctuations in its level do not affect the effective stress within the soil.
- The permeability of a soil depends on the characteristics of both the permeant and the soil. The flow through a soil mass may be estimated using Darcy's law, which is stated as

$$v = ki \quad (1.19)$$

where v is the flow or discharge velocity of water through an element of the soil mass; $i = \Delta h/L$ is the hydraulic gradient causing the flow (Δh is the hydraulic head causing the flow; L is the length of the soil element in the direction of the flow); k is the coefficient of permeability or hydraulic conductivity of soil). Equation 1.19 is valid for most soils, particularly those finer than coarse sands. The permeability of sands ranges from 10^{-2} to 10^{-5} m/s, whereas that of clays is $\leq 10^{-9}$ m/s.

- Above the water table within a soil mass, pore water pressure is negative due to surface tension, creating suction, which can reach up to 6 kPa in fine sand and 600 kPa in clay.
- The seepage force per unit volume of soil is called the seepage pressure, $i\gamma_w$. In isotropic soil, it acts in the direction of flow.

- Compaction is the reduction in volume of an unsaturated soil mass due to the expulsion of air from its voids or pores under an applied external compressive load or stress. Compaction differs from consolidation, which is a time-dependent process of volume reduction in a primarily saturated soil mass due to the expulsion of water from its voids or pores.
- Within a soil mass, the ratio of the effective horizontal stress, σ'_h , to the effective vertical stress, σ'_v , is called the lateral stress ratio, K . It is typically in the range 0.2–0.5.
- The compressibility of a soil is a function of the soil type/composition, effective stress and stress history. The compression index, C_c , determines the magnitude of primary consolidation settlement in a normally consolidated soil, while the coefficient of consolidation, c_v , governs the rate of settlement during primary consolidation.
- The ratio of the maximum past effective vertical stress, σ'_{vmax} , to the present effective vertical stress, σ'_{v0} , is called the overconsolidation ratio (OCR); this is used to express the degree of overconsolidation or stress history of soil. Thus

$$\text{OCR} = \frac{\sigma'_{vmax}}{\sigma'_{v0}} \quad (1.20)$$

For normally consolidated soils, $\text{OCR} = 1$, whereas for overconsolidated soils, $\text{OCR} > 1$.

- Soil rarely resists tension and typically fails in shear, even under compressive loading. Therefore, analysing soil strength is fundamentally a shear strength problem. The shear strength, τ_f , appears as the shear stress on the failure plane within the soil mass at failure, and its SI unit is newtons per square metre (N/m^2) or pascal (Pa). It is commonly expressed as the Mohr–Coulomb failure criterion, which is stated as

$$\tau_f = c' + \sigma'_f \tan \phi' \quad (1.21)$$

where σ'_f is the effective normal stress on the failure plane at failure; c' is the effective cohesion (also referred to as the effective cohesion intercept); ϕ' is the effective angle of internal friction (also known as the effective angle of shearing resistance or simply the effective friction angle). Since coarse-grained soil has little to no cohesion, its shear strength primarily depends on internal friction between particles. Such soils are referred to as cohesionless, granular, frictional or free-draining soils. A fine-grained soil contains a significant amount of silt-sized and clay-sized particles, so its shear strength depends on both cohesion and internal friction between particles. Such soils are classified as cohesive or cohesive-frictional, depending on the relative significance of cohesion and internal friction.

- The triaxial compression test is the most versatile method for studying the strength and stiffness (stress–strain relationship) properties of soil. There are three types of triaxial tests, selected based on the loading conditions required to simulate field conditions: consolidated–drained (CD), consolidated–undrained (CU) and unconsolidated–undrained (UU). The stress–strain behaviour of loose sand is similar to that of normally consolidated clay, whereas dense sand behaves similarly to overconsolidated clay. A clay subjected to undrained/quick loading or unloading with a constant volume behaves as a purely cohesive material, which has angle of shearing resistance equal to zero. Therefore, the shear strength, called the undrained shear strength, is

$$\tau_f = c_u = \frac{q_u}{2} \quad (1.22)$$

where c_u is the undrained cohesion and q_u is the unconfined compressive strength of the soil.

- The shear strength of a cohesive soil increases with time from $\tau_f = c_u$ under undrained loading to $\tau_f = c' + \sigma'_f \tan \phi'$ under drained loading as the pore water escapes from the voids, resulting in a decrease in pore water pressure. A decrease in soil shear strength may occur due to unloading from excavation, increased pore water pressure from changes in groundwater conditions or seepage pressure, or the softening of fissures and cracks in stiff clays. Shear strength is typically calculated for the most critical condition, which usually occurs immediately on load application or immediately after construction as an undrained loading condition (Teng, 1962).
- Granular soil is generally an excellent foundation material and the preferred choice for embankments and backfill, whereas clayey soil is typically unsuitable for foundations, embankments and backfill. Clay is nearly watertight due to its low permeability, making it the ideal soil material for constructing impervious layers, liners and barriers for ponds and landfills.
- A cohesive soil generally loses some of its shear strength when remoulded or disturbed. If an unconfined compression test is performed on both undisturbed and remoulded specimens of the same cohesive soil at the same water content, the effect of remoulding or disturbance (i.e. the degree of strength loss) can be quantified in terms of sensitivity, S_t , defined as

$$S_t = \frac{q_{u(\text{undisturbed})}}{q_{u(\text{remoulded})}} = \frac{c_{u(\text{undisturbed})}}{c_{u(\text{remoulded})}} \quad (1.23)$$

Based on the sensitivity, clays are classified as insensitive ($S_t = 1$), low sensitive ($S_t = 1$ to 2), medium sensitive ($S_t = 2$ to 4), highly sensitive ($S_t = 4$ to 8), extra sensitive ($S_t = 8$ to 16) or quick ($S_t > 16$).

- Swelling and shrinkage characteristics of highly plastic clays due to the presence of mainly montmorillonite minerals cause damage to foundations, pavements and other structures.
- Organic soil has a spongy structure, low shear strength, high compressibility and acidity, making it unsuitable as a foundation material due to its potentially harmful effects on construction materials. It also undergoes creep (continued compression under constant effective stress), which significantly contributes to long-term settlement.
- An unsaturated soil derives part of its strength from capillary water suction within its voids. However, when the soil becomes saturated, this strength is lost, leading to the collapse of the soil structure and significant deformation or settlement.

Example 1.2

At an embankment construction site, the soil deposit is homogeneous with a level ground surface, and the water table coincides with the ground surface. If the total unit weight of the soil is 18.94 kN/m^3 , determine the total vertical stress, pore water pressure and effective vertical stress at a depth of 10 m from the ground surface. What is the submerged unit weight of soil? Establish a relationship between the effective vertical stress and the submerged unit weight of soil.

Solution

Given: $\gamma = 18.94 \text{ kN/m}^3$

At $z = 10 \text{ m}$ depth:

Total vertical stress (Equation 1.17), $\sigma_v = \gamma z = (18.94)(10) = 189.4 \text{ kPa}$