

Review Article: Soil Mechanics and Soil in Civil Engineering: Principles, Applications, Scientific techniques

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Abstract:

Soil mechanics is an important discipline in geotechnical engineering sciences, especially civil engineering. Soil is a naturally occurring multiphase material composed of solids, water, and air and has complex system of mechanical and hydraulic properties when under loading. Such behavior also accounts for designing safe and affordable foundations, slopes, embankments, as well as the earth retaining systems. This article provides the reader a comprehensive and readily applicable description of the core principles of soil mechanics including phase relationships, effective stress theory, shear strength, consolidation and bearing capacity. It is also supplemented with discussions about unsaturated soil mechanics, numerical modeling on soil dynamics while incorporating new ground improvement techniques. This article incorporates classical theory and fresh approaches, therefore providing a unified reference for scholarly theory and practice for research, teaching and work in a student and expert domain.

Keywords — Soil mechanics, effective stress, consolidation, shear strength, bearing capacity, unsaturated soils, ground improvement

I. INTRODUCTION

Soil Mechanics emerged in the early 20th century as a science from the work of Karl Terzaghi, whose very first works to develop the effective stress principle in foundation engineering. It has proven important for the further study into consolidation behaviour of clay layers when a pore pressure response is taken. Whereas soil is not part of construction materials, as opposed to solid materials, its properties are spatial, subject to strong influences on the environment and stress. The materials' behaviour consists of matter-based interactions and therefore requires both physical, mechanical physics as well as pore physics, hydraulics and the material science as well as chemistry.

The phase relationships and structures of the soil.

Soil is usually described as a three-phase system of solids, water, and air. This simple representation is to give the core relationship between volume and gravimetric (Figure 1 in [14]).

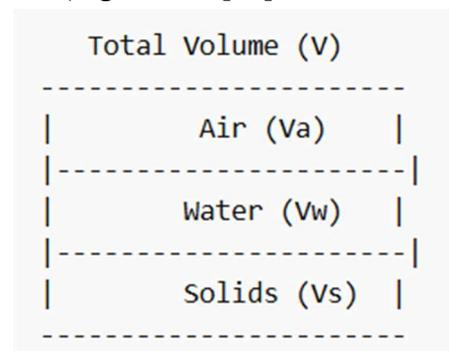


Figure 1: Idealized representation for soil as 3 phases system.

This includes void ratio $e = V_v / V_s$, porosity $n = V_v / V$, saturation $S = V_w / V_v$.

These things are related to compressibility, permeability and strength and the way soil reacts to an applied load. They are considered extensively in [5] and [2]. Critical state soil mechanics was useful to understand soil structure and stress path later, through Schofield & Wroth (1968; Wood, 1990).

2.EFFECTIVE STRESS PRINCIPLE

The effective stress principle is the backbone of soil mechanics and is stated as $\sigma' = \sigma - u$ (where σ' is the effective stress, σ is total stress and u is pore water pressure). It describes the soil strength, deformation and volumes as well as settlement, slope and bearing capacity analyses from this equation. [21]. It is still at the center of settlement, slope and bearing capacity analytical studies [22]; [11]. (Skempton's effective stress was translated into pore pressure parameters and the properties of clays in figure 2).

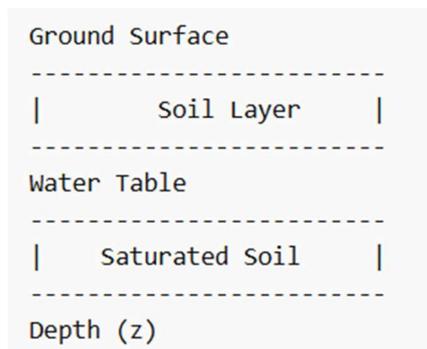


Figure 2: Vertical Stress Distribution

[19] extended this concept of effective stress to dynamic loading cases, especially in earthquake geotechnics, where soil behavior under cyclic and seismic forces has become crucial.

3.SHEAR STRENGTH AND CONSTITUTIVE MODELLING:

The resistance of soil to failure (shear strength) is largely derived using the Mohr-Coulomb criterion $\tau = c + \sigma' \tan\phi$. While prevalent, more complex

constitutive models have been developed to describe the nonlinear and stress path dependence behavior.

It has long been the standard formula in engineering design by [14]. In addition, there are various new constitutive models that describe nonlinearity and stress paths [6]; [3]. Meanwhile, critical state theory introduced stress-strain relations beyond simple failure envelopes ([18]; [3]). The finite element approach to these models is described by [25] and Potts and [17].

4.Consolidation and Compressibility

However, Terzaghi's one-dimensional consolidation theory is the main study of time-dependent settlement associated with the expulsion of the excess pore water pressure. To make it possible to describe much richer scenarios of complex loads, he has recently introduced elastic and plastic strain. [21]; [22].

[20] developed graphical methods for time-rate consolidation studies. Recent view of compressibility takes elastic and plastic volumetric strains into account in critical state models [3]

Bearing Capacity of Foundations

Bearing capacity theory is the foundation of a shallow foundation. The conventional solutions are widely used in practice and modification by means of shape, depth and load inclination are included. Terzaghi's bearing capacity equation provided the basis for all shallow foundation equations. Meyerhof [16] and [23] further developed their design to incorporate shape as well as depth and these are detailed in [1] and Das and [5] who also develop various design techniques that allow for such modification in the practical engineering scenario.

Ground Improvement and Reinforcement

When the natural soil can't be used to achieve project requirements, various ground improvement measures like compaction and grouting on a surface are used with deep land mixing and geosynthetic reinforcement to strengthen the strength and stability of soil and it is so the natural soil should need to be improved in order for a mechanical engineering job. [10] established guidelines for mechanical and

chemical stabilization. [9] provides modern techniques of compaction, grouting and deep soil mixing. On reinforcement and separation of slopes, for example, the use of geosynthetics has been shown, [12], which showed the slope is much more stable and bearing workable.

5. Unsaturated Soil Mechanics

In unsaturated soils there is a matric suction and matric suction affects the strength and stiffness greatly. In modern soils we introduce suction as an independent stress variable and make the classical soil mechanics approach more rigorous. However, in unsaturated soils matric suction effects impact the strength and volume change strongly. [7] introduced stress systems which include suction in the condition (subsequent to [8] and [15]). Such frameworks are essential for studying embankments, pavements and expansive soils.

They are from soil dynamics and earthquake engineering

Dynamic loading introduces cyclic stress conditions that may lead to stiffness degradation and liquefaction. Understanding soil behavior under seismic loading is essential in earthquake-prone regions [13]. [19] developed empirical relation between shear modulus and damping and they founded the basis for liquefaction investigation.

Numerical Modeling In Geotechnical Engineering

Using finite element techniques allows simulation of stress strain behavior in complex loading and staged construction [25] and [17] has utilized the technique to integrate richer constitutive models and coupled hydro-mechanical analysis.

6. Conclusions

The concept of soil mechanics is a synthesis of historic theory and technologies. The effective stress principle remains the standard, and the achievements

of modelling, unsaturated soil behaviour, surface structure and computer modelling have widened the horizons of the field in civil engineering theory and practice (e.g.).

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