



DR. B.P. VERMA

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PROBLEMS IN SOIL MECHANICS AND FOUNDATION ENGINEERING

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Preface

A number of good books are available on Theoretical Soil Mechanics but the author felt that the students are in need of a book which can help them in solving practical problems in Soil Mechanics. While on one hand students find difficulty in solving the problems, on the other, they do not get a sufficient number of problems for their practice for University Examinations. Keeping this in view, all the solved problems as well as the problems given for practice have been based on the same pattern as set in different University and Competitive Examinations.

This revised edition also contains a new chapter on Machine Foundations and many more Objective Type Questions selected from the examination paper of Civil Services and Engineering Services. Also, solved questions of GATE examinations have been added at the end of the book. Now the book will serve overall purpose of students referring this book for any type of examination.

In the beginning of each chapter, some theoretical background has been given so that students may be able to follow the problems easily ; at the same time, it will help those who want to have a brief idea of the subject. The presentation of this book has been influenced by previous publications by others on the same subject and the author is grateful to the writers and publishers of those works.

The author is indebted to Dr. A.G. Mirajgaokar, Prof. A.V.G. Krishnayya and Dr. B. Sahay for their encouragement and valuable advice

Finally the author thanks his wife Mrs. N. Verma for the encouragement received from her when the book was being prepared.

Suggestions, if any, for the improvement of the book are most welcome and will be gratefully acknowledged.

B.P. VERMA

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1

Properties of Soils

Introduction

In Soil Mechanics we study behaviour of soils under different conditions which are met with in the engineering practice. It consists of the application of the laws of mechanics and hydraulics to engineering problems relating to soils.

The soils unlike steel and concrete do not have unique physical properties. The variables that determine the nature of the soils are so many that each problem under the given conditions requires an independent treatment. But the results obtained by the use of soil mechanics under some simplifying assumptions give an approximation to the actual situation and with the proper allowances for the possible uncertainties the knowledge of Soil Mechanics helps the engineer a great deal in solving any type of problem related to soils.

Soil Mechanics Problems

Problems of soils are mainly classified as :

- (a) Problems of equilibrium or stability.
- (b) Problems of Elastic and Plastic deformations.
- (c) Drainage problems.

For stability it is necessary to know —

- (i) Load imposed on the soil.
- (ii) Magnitude and distribution of stresses induced in the soil by the load.
- (iii) Resistance offered by the soil.
 - (i) Load imposed on the soil depends on the type of structure and the weight of soil.
 - (ii) Taking the soil as an ideal isotropic material, mathematical analysis gives the stresses developed.

Proper allowance is given for the non-homogeneity of soil and other variations.

(iii) Due to the improved methods of soil testing and undisturbed sampling the characteristics of soil and hence the strength offered are known.

(b) *Deformations*. The deformations may be plastic or elastic. Following should be known :

(i) Load imposed.

(ii) Magnitude and distribution of stresses induced.

(iii) Rate, magnitude and differential settlements.

(c) Drainage is involved both in deformation and stability problems.

Significant Properties of Soils

The properties of a soil which are important for a project depend upon the nature of the project. The following properties are important for different types of engineering projects :

(a) *Permeability*. It is a measure of the ability of soil to allow water to pass through its pores. This property is of importance in earth dams and drainage problems.

(b) *Consolidation*. They deal with changes in volume of pores in a soil under load. This property is made use of in computing settlements of structures.

(c) *Shear Strength*. It is a measure of the ability of soil to sustain stresses without failure. This property is of interest in computation of stability of footings under load, stability of fills behind earth retaining structures and stability of earthen embankments.

Other simple physical properties are Atterberg's limits, moisture content, void ratio, relative density, grain size and sensitivity etc.

Weight-Volume Relationship

The soil consists of two parts naming solid and voids. Solid part contains solid particles while voids consist of water or air completely, when it is saturated or dry. When a soil mass is not fully saturated voids consist of both air and water.

Let us take a soil skeleton of volume v and cross-sectional area as unity.

Now total volume of soil consisting of different components is shown in Fig. 1.1.

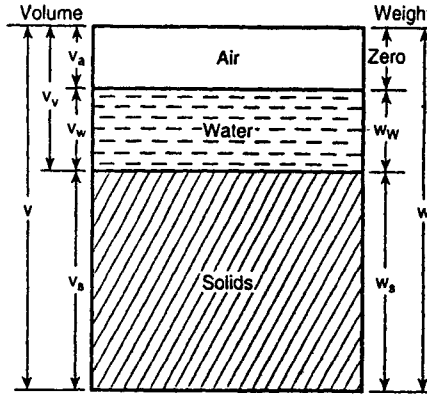


Fig. 1.1

Now v = Total volume of soil mass.
 v_a = Volume of air in the voids.
 v_w = Volume of water in the voids.
 v_s = Volume of solids in the soil mass.

and v_v = Total volume of voids in the soil mass.

$$v = v_a + v_w + v_s$$

and $v_v = v_a + v_w$.

The void ratio 'e' of a soil is defined as the ratio of the total volume of voids to the total volume of solids,

i.e.
$$e = \frac{v_v}{v_s} = \frac{v_a + v_w}{v_s} \quad \dots(1.1)$$

The porosity 'n' of a soil mass is defined as the ratio of the total volume of voids to the total volume of soil mass,

i.e.
$$n = \frac{v_v}{v} = \frac{v_a + v_w}{v_a + v_w + v_s} \quad \dots(1.2)$$

Now
$$n = \frac{e}{1 + e} = \frac{\frac{v_a + v_w}{v_s}}{1 + \frac{v_a + v_w}{v_s}} = \frac{v_a + v_w}{v_a + v_w + v_s} \quad \dots(1.3)$$

and
$$e = \frac{n}{1 - n} = \frac{\frac{v_a + v_w}{v_a + v_w + v_s}}{1 - \frac{v_a + v_w}{v_a + v_w + v_s}} = \frac{v_a + v_w}{v_s} \quad \dots(1.4)$$

The degree of saturation 'S' of a soil mass is defined as the ratio of volume of water to the volume of voids.

$$i.e. \quad S = \frac{v_w}{v_s} = \frac{v_w}{v_a + v_w} \quad \dots(1.5)$$

If the soil is saturated, $v_a = 0$

$$\text{then porosity} \quad n_w = \frac{v_w}{v} \quad \text{and porosity } n = \frac{v_v}{v}$$

$$\text{Then term } \frac{n - n_w}{n} \text{ represents saturation deficit.} \quad \dots(1.6)$$

The water content or moisture content 'm' of a soil mass is defined as the ratio of weight of water to the weight of solids,

$$i.e. \quad m = \frac{w_w}{w_s} \quad \dots(1.7)$$

The unit weight or the bulk unit weight ' γ ' is defined as the weight per unit volume of the soil mass,

$$i.e. \quad \gamma = \frac{w}{v} = \frac{w_s + w_w}{v_s + v_v} = \frac{w_s \left(1 + \frac{w_w}{w_s} \right)}{v_s \left(1 + \frac{v_v}{v_s} \right)} \quad \dots(1.8)$$

Now if G is specific gravity of the solids and γ_w unit weight of water.

$$\therefore \quad \frac{w_s}{v_s} = G\gamma_w \quad \left[\because \frac{w_s}{v_s} = \text{unit wt. of solids} = \gamma_s \right. \\ \left. \text{and } G = \frac{\gamma_s}{\gamma_w}, \therefore \gamma_s = G\gamma_w \right]$$

$$\therefore \quad \frac{w_w}{w_s} = m \quad \text{and} \quad \frac{v_v}{v_s} = e$$

Putting these values in Eq. (1.8)

$$\gamma = G\gamma_w \frac{(1+m)}{(1+e)} \quad \dots(1.9)$$

If the soil mass is dry $w_w = 0$ and $m = 0$

$$\text{Unit dry weight of soil} \quad \gamma_d = \frac{G\gamma_w}{1+e} \quad \dots(1.10)$$

We have

$$e = \frac{v_v}{v_s} = \frac{v_v}{v_s} \times \frac{v_w}{v_w} \\ = \frac{v_v}{v_w} \times \frac{v_w}{v_s} \quad \dots(1.11)$$

Now $\frac{w_w}{v_w} = \gamma_w = \text{unit weight of water}$

$\therefore v_w = \frac{w_w}{\gamma_w}$

Next $\frac{w_s}{v_s} = \gamma_s = \text{unit weight of solid}$

Again $G = \frac{\gamma_s}{\gamma_w} \quad \therefore \gamma_s = G\gamma_w$

and $v_s = \frac{w_s}{G\gamma_w}$

Now putting values of v_w and v_s in Eq. (1.11), we have

$$e = \frac{1}{S} \times \frac{\frac{w_w}{\gamma_w}}{\frac{w_s}{G\gamma_w}} = \frac{1}{S} \times \frac{w_w}{w_s} \cdot G = \frac{Gm}{S} \quad \dots(1.12)$$

For saturated soil $S = 1$

$\therefore e = m \cdot G$

Unit weight of saturated soil ' γ_{sat} '

From Eq. (1.9) $\gamma = \frac{G\gamma_w(1+m)}{1+e}$

$\therefore \gamma_{sat} = \frac{\gamma_w(G+mG)}{1+e} = \frac{\gamma_w(G+e)}{1+e} \quad \dots(1.13)$

Submerged unit weight of soil γ_{sub} is defined as unit weight of saturated soil mass minus unit weight of water.

$\therefore \gamma_{sub} = \gamma_{sat} - \gamma_w = \frac{\gamma_w(G+e)}{1+e} - \gamma_w = \frac{\gamma_w G + \gamma_w e - \gamma_w - \gamma_w e}{1+e} = \frac{\gamma_w(G-1)}{(1+e)} \quad \dots(1.14)$

Relation between dry and bulk unit wt.

$$\frac{\gamma}{1+m} = \frac{w_s + w_w}{v} \times \frac{1}{1 + \left(\frac{w_w}{w_s}\right)}$$

$$= \frac{w_s + w_v}{v} \times \frac{w_s}{w_s + w_w} = \frac{w_s}{v} = \gamma_d \quad \dots(1.14 A)$$

$$[\because w_v = w_w]$$

$$\therefore \gamma_d = \frac{\gamma}{1 + m}$$

Limits of Consistency (*Atterberg's Limits*)

Depending upon percentage of water in soil. The soil mass may be in the following state :

- (a) Suspension in liquid.
- (b) Viscous liquid.
- (c) Plastic soil.
- (d) Semi-plastic solid.
- (e) Solid.

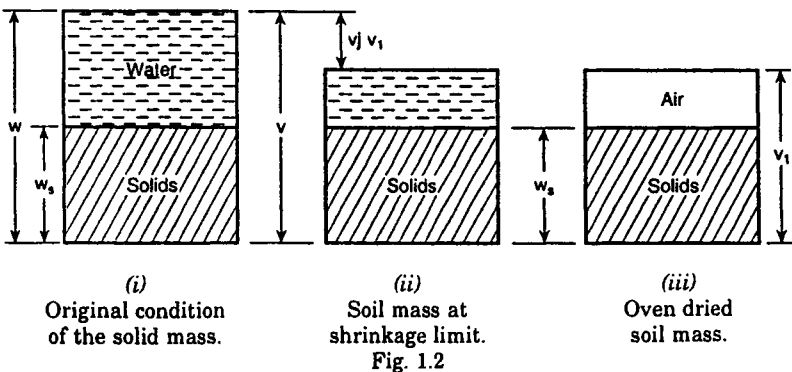
In changes from one stage to another there are important changes in physical properties.

The moisture contents at which the soil passes from one stage to the next are known as *Consistency Limits*.

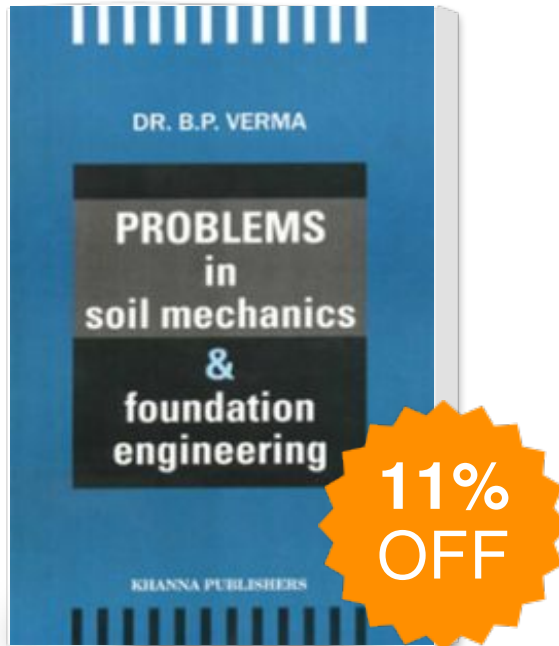
Important Consistency Limits are :

- (i) *Liquid Limit (L.L.)* — the minimum moisture content at which the soil flows under its own weight.
- (ii) *Plastic Limit (P.L.)*—the minimum moisture content at which the soil can be rolled into a thread of 3.1 mm (1/8 in.) in diameter without crumbling.
- (iii) *Shrinkage Limit (S.L.)*—the moisture content after which further loss of moisture does not cause a decrease in the volume of the soil.

A dry sample of soil is mixed thoroughly with water till it becomes plastic. It is moulded into the shape of a prism and weight



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