RAS 5791 72-22-ISFSI-Staff Exhibit XX - Rec'd 6/19/02

Template = SECY-028

Soil Mechanics

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Allyn and Bacon, Inc.
Boston

SECY-02

first printing . . . . January, 1966
second printing . . . March, 1967
third printing . . . September, 1967
fourth printing . . . March, 1969

470 Atlantic Avenue, Boston

Library of Congress Catalog Card Number: 65-17868

Printed in the United States of America

CHAPTER 7

Shear Strength

7.1. Failure theories. A theory of failure for a given material is in essence a definition of the conditions that will produce failure in the material. We are accustomed to thinking of failure taking place when a material is subjected to a certain stress usually called strength (i.e., tensile strength). However, other criteria may also be valid as failure theories. For instance, a material may fail after it has been deformed to some specific strain or after it has absorbed a certain amount of energy from the loading process.

Failure can occur in the form of fracture, in which the material disintegrates at a certain stress or strain. An example of this is the stress-strain curve shown in Fig. 12.12. Failure may also take place as yielding or plastic flow. In this case, the strain increases indefinitely at constant stress, as illustrated by the ideal curve in Fig. 5.2(*g*).

In soil mechanics the most successful failure theories to date define failure in terms of stress. In a continuous medium the material is subjected to three principal stresses (see Sec. 5.1); hence, the failure criterion should be expressed as a function of all three principal stresses. It is reasonable to expect that each of the three principal stresses would contribute toward failure (contrast this with the case of simple tension, in which a single tensile strength defines the failure stress).

7.2. Mohr-Coulomb theory of failure. The Mohr-Coulomb failure theory has been found to be very successful in defining failure in soils.

The theory states that failure in a material occurs if the shear stress on any plane equals the shear strength of the material. Furthermore, the shear strength s, along any plane is a function of the normal stress σ on that plane, or

$$s = f(\sigma) \tag{7.1}$$

This function is shown as a curve on the normal vs. shear stress plot [Fig. 7.1(*a*)]. Coulomb (1776) defined the function f as a linear function of the normal stress. Equation (7.1) then becomes

$$s = c + \sigma \tan \phi^{*} \tag{7.2}$$

The Coulomb criterion is shown as a straight line in Fig. 7.1(*b*), with an

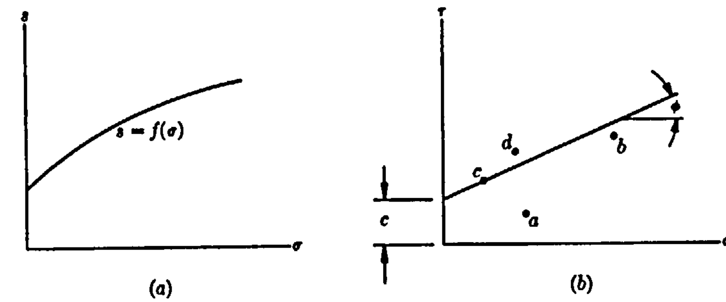

Fig. 7.1. Failure envelopes.

intercept on the τ axis equal to c and a slope equal to $\tan \phi$. The quantities c and ϕ are material properties frequently called *cohesion* and *angle of internal friction*, respectively. The shear strength as defined by Eqs. (7.1) and (7.2) represents the maximum shear stress that may be sustained on any plane in a given material. Any combination of shear and normal stresses that plots as a point below the strength function [points a and b, for instance, in Fig. 7.1(*b*)] represents a safe state of stress, whereas a point on the line [point c, Figure 7.1(*b*)] represents stresses that will result in failure of the material. Stresses that plot above the line [point d, Figure 7.1(*b*)] cannot exist in this material because failure will have taken place before such stresses can be attained. Hence the strength function defines the limiting stress and it is often called the *failure envelope*.

If an element of material is acted on by major and minor principal stresses equal to σ_1 and σ_3 [Fig. 6.2(*b*)], the normal and shear stresses on any plane making an angle θ with the major principal plane are given by equations (6.2). These stresses may also be calculated graphically by means of Mohr's circle of stress. A Mohr's circle with principal stresses σ_1 and σ_3 is

* This failure theory is given detailed treatment because it forms the basis of the analysis of plastic equilibrium (Chapter 8). It is not the only failure theory for soils. Others that are equally valid are presented in Sec. 7.11.