CHAPTER - I

INTRODUCTION

1.1.0. GENERAL

The most important single requirement to conduct realistic stability analysis for the structural design in materials is the correct estimation of their constitutive properties. While it has been possible to assume a linear constitutive law such as Hooke's law for engineering materials like steel, it has not been possible to extend the Hooke's law to other engineering materials and most particularly to geologic materials. Nevertheless, as a starting point for structural design in most materials the elastic law is assumed. Rock material is known to exhibit predominantly the brittle fracture characteristics and hence the validity of elastic law such as Hooke's law should be in suspense. Inspite of that, the practice has been to consider the rock material as elastic and isotropic in order to conduct the analysis and design in rock material only from simplistic considerations. From theoretical consideration in case of hard intact rock material as elastic and isotropic bodies it might well appear to produce results probably satisfying certain limited stability aspects.

However, to extend the elastic approach to jointed rocks it will constitute too much deviation from the realistic behaviour. In order to understand the behaviour of jointed rock masses it is necessary to start with the components constituting the system; the intact rock material and the individual discontinuity surfaces.

1.2.0. INTACT ROCKS

Intact rocks refer to the unfractured rocks which occur between structural discontinuities in a typical rock mass. The failure of intact rocks can be identified as brittle implying a sudden reduction in strength without consideration of viscoelastic or time dependent behaviour such as creep when a limiting stress lével is exceeded. The fundamental step to understand the brittle fracture of rocks consisted in adopting the Griffith's postulation. Griffith (1921) postulated that in the brittle materials such as glass,fracture initiated when the tensile strength of the material is exceeded whence stresses are generated at the end of microscopic flaws in the material. In rock, such flaws would be pre existing cracks, grain boundaries or discontinuities. Griffith's theory was originally derived for predominantly tensile stress field. To apply the criterion to rock materials subjected to compressive stress field, it is necessary to modify to include the frictional strength of closed cracks. The original and modified Griffith theories appear to be adequate for the prediction of fracture initiation of rocks but that they failed to describe fracture propagation and failure pattern. However, Griffith theory has proved useful as a mathematical model for studying the effect of cracks on rock. To predict adequately propagation and failure in rock, a number of empirical relationships between principal stresses or between shear and normal stresses at failure have been proposed. It essentially consists of a parabolic Mohr's envelope as predicted by the original Griffith theory in which the effective normal stress acting across a pre existing crack is negative. Because of very quick propagation of fracture initiation under the tensile stress condition, the fracture initiation and failure are practically indistinguishable. When the effective normal stress is positive the envelope to the Mohr circle tends to be curvilinear, but not to the degree predicted by the original Griffith's theory. Under the circumstances the most appropriate approach would be the statistical approach prefered by most engineers. The one which is widely accepted is the empirical equation proposed by Hoek (1983). Recently Parikh and Biyani (1986) modified the Griffith's theory to include the "locked stresses" in the rock from theoretical considerations and verified against experiments under Brazilian test conditions for basalt rock.

1.3.0. JOINTED ROCKS

The behaviour of discontinuities between the intact rocks is a subject of investigation of many research workers since it is not possible to deal on the same theoretical considerations as intact rock materials. The approach of most of the research workers has been the extension of frictional theories between the two bodies, but when discontinuities are non planar filled with gouge material it becomes highly complex involving number of phenomena besides the simple friction between the two bodies. Figure 1.1 illustrates the angular components of shear strength for a non planar joint. In figure 1.1 (a) the joint has idealized, smooth, inclined surfaces. The sliding is just initiated and the resultant force is inclined at an angle of basic friction from a normal to the inclined surfaces. Therefore the tangent of the total friction angle is equal to the ratio of horizontal force to normal force. The real problem, however, involves many different angles deviating from the basic angle of friction as shown in Figure 1.1 (b). Figure 1.1 (c) illustrates hypothetically the statical conditions in a discontinuity, according to which, there are three fundamental components namely basic friction angle, peak dilation angle which is equal to the instantaneous inclina- of the shearing path at peak strength relative to the mean plane and strength component representating the failure of the intact material in the form of asperities. The peak dilation angle has been considered as a very powerful phenomenological parameter of shear strength, since for a given normal stress it represents the minimum energy path between a "sliding up" and "shear through"

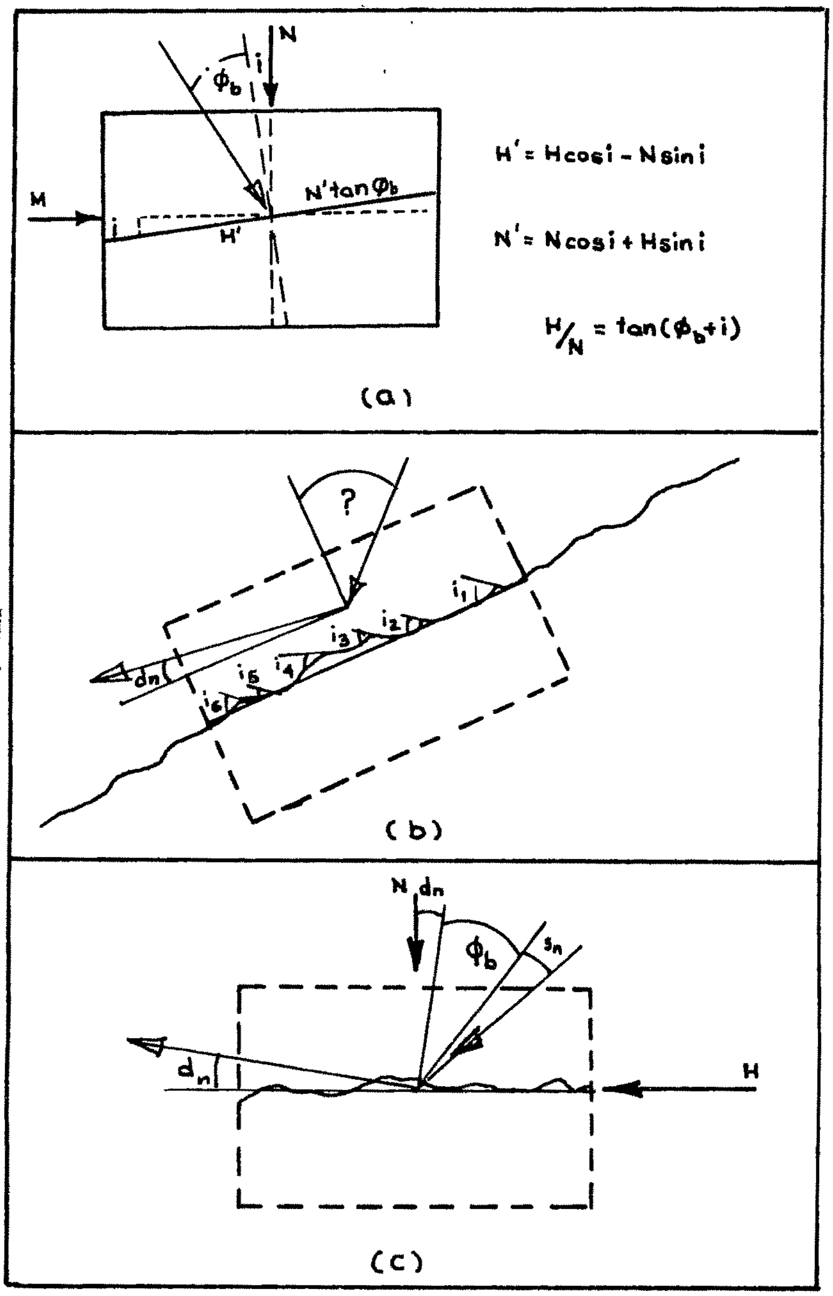

FIG. 1.1 THE ANGULAR COMPONENTS OF SHEAR STRENGTH FOR A NON-PLANAR JOINT.

mode of failure. It is probable that the dilation angle will be at its maximum value just at the instant when peak strength is passed. From the experimental investigations on non planar joints, it has been observed that at low normal stress, a non planar joint continues to dilate with increasing shear displacement but at reduced angle, while at high normal stress a non planar joint might cease to dilate altogether after passing its peak strength. If the normal stress is very high, dilation may not take place at any stage. However, there are not many experimental investigations conducted to clarify in this area of great significance especially for understanding the shearing behaviour of jointed rocks. The work of Barton (1973) provides an important step to go further into the realm of shearing behaviour of jointed rocks.

1.4.0. ANSLYSIS AND DESIGN

The goal behind the various theoretical considerations and experimental investigations is to develop a constitutive relationship for a jointed rock mass amenable to mathematical formulations in order to utilize in a scheme of solution for the analysis and design. The most widely employed solution system is finite element method which needs a stress-strain relationship in an incremental form. A number of joint elements have been developed for engineering applications by finite element method. These elements however, needs to be modified to include the fundamental aspect of dilatancy during shearing particularly when joints are filled with gouge materials of varying material characteristics. The joint element proposed by Heuze and Barbour (1982) is noteworthy.

1.5.0. CONCLUDING REMARKS

In view of the complexities involved in the shearing behaviour of jointed rocks, it is necessary to investigate the behavioural trends of discontinuities under various operating stress fields. The practical situations include both static as well as dynamic stress conditions. In order to undertake such investigations both theoretical and experimental developments are needed since both are complementry to each other.