10.1 INTRODUCTION

Discontinuities can have an influence on rock mass deformability by a combination of one or more of the following processes:

(i) Displacement of the adjacent blocks can create an air space, or open aperture, that has negligible stiffness compared with the surrounding rock material.

(ii) Shear displacement along a discontinuity with an irregular surface can create a mismatch between the adjacent surfaces. Normal compression across such a discontinuity will lead to local crushing at the contact points and a relatively complex normal force-normal displacement characteristic that depends on such factors as the initial surface geometry, the elastic properties of the rock material and the post-peak characteristics of the rock.

(iii) The rock material adjacent to the discontinuity can weather, can become fractured by shear displacement, or the discontinuity can become filled with imported material, to create a zone that has different mechanical properties from the surrounding rock material.

In most cases the above processes produce a zone of material that is more deformable than the surrounding rock, with an areal extent that reflects the geometry of the original discontinuity and a thickness ranging from a fraction of a millimetre to several metres. In this chapter we are concerned with the influence that such discontinuities can have on the deformability of the rock mass. Rock mass deformability can be a crucial parameter in the design of foundations for large structures such as dams, bridges and high-rise buildings,
and in the design of pressure tunnels. Sections 10.2 to 10.4 present some of the basic principles of rock material deformability, discontinuity stiffness and strain energy. Section 10.5 draws on experimental results and analytical models in a discussion of the factors that influence the normal and shear stiffness of discontinuities. This section is followed by a brief survey of the analytical and numerical methods that have been adopted to predict the influence of discontinuities on rock mass deformability.

10.2 PRINCIPLES OF DEFORMABILITY, STIFFNESS, STRAIN ENERGY AND CONSTITUTIVE RELATIONS FOR A CONTINUUM

The concept of deformability of a continuous material can be understood by considering the uniaxial loading of a cylindrical specimen of length $L$ and diameter $D$ subjected to a uniform uniaxial force $F$, as shown in Figure 10.1a. Changes in $L$ and $D$ relative to their values at zero load are $l$ and $d$, respectively. Taking compressive forces and contractile values of $l$ and $d$ to be positive, we would expect a response such as that shown diagrammatically in Figure 10.1b. If the axial force is kept well within the load capacity band for the specimen, it is reasonable to assume that compressive axial force will produce a gradual reduction in length and an increase in diameter of the specimen, and that a tensile axial force will increase the length and reduce the diameter.

Materials such as unfractured rocks generally exhibit non-linear load-displacement characteristics, particularly at small loads and at loads that exceed about 80% of the load capacity. Characterisation of the deformability properties of materials such as rocks must take account of their non-linear properties by specifying the loads at which properties are measured. The secant force stiffness $K_{sec}$ is defined as follows

$$K_{sec} = \frac{F_{sec}}{l_{sec}}$$  \hspace{1cm} (10.1)

where $l_{sec}$ is the total axial displacement produced by changing the axial force from zero to $F_{sec}$. The tangent force stiffness $K_{tan}$ is defined as

$$K_{tan} = \frac{\Delta F_{tan}}{\Delta l_{tan}}$$  \hspace{1cm} (10.2)

where $\Delta F_{tan}/\Delta l_{tan}$ is the slope of a straight line that is tangential to the axial force-axial displacement curve at some specified axial force $F_{tan}$. Stiffnesses that link lateral displacement to axial force are rarely used.

The conventional method of plotting force-displacement curves, with force on the ordinate axis, carries the implicit understanding that force is the dependent variable, varying according to some function $F = f(l)$ of the