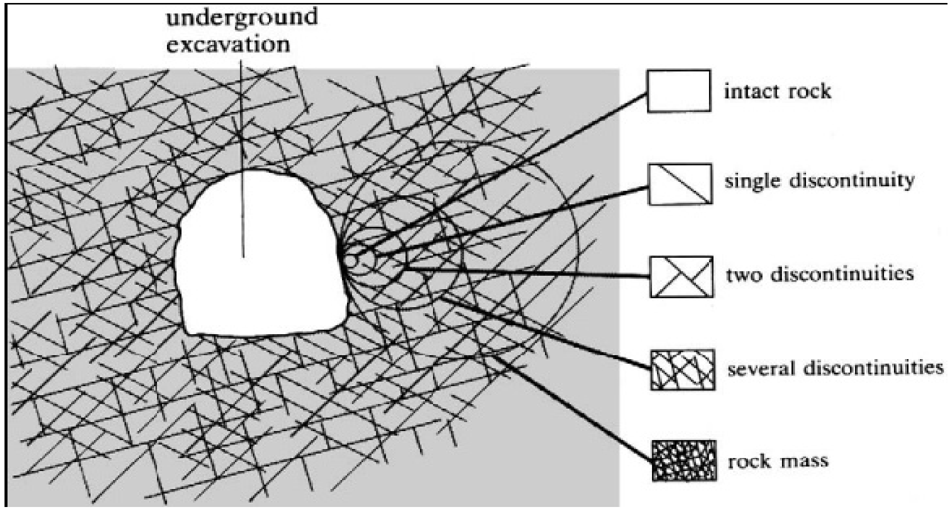
CH4 Rock Strength and Deformability

4.1 Introduction

Intact Rock Materials

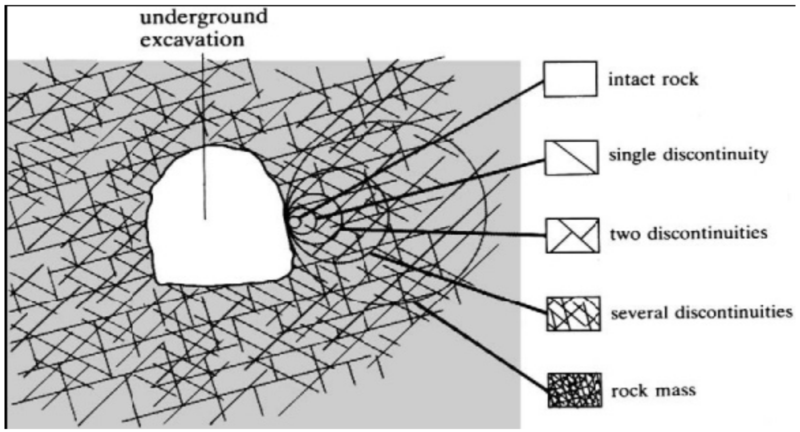
Discontinuities

Rock Masses



Intact rock material that is of concern.

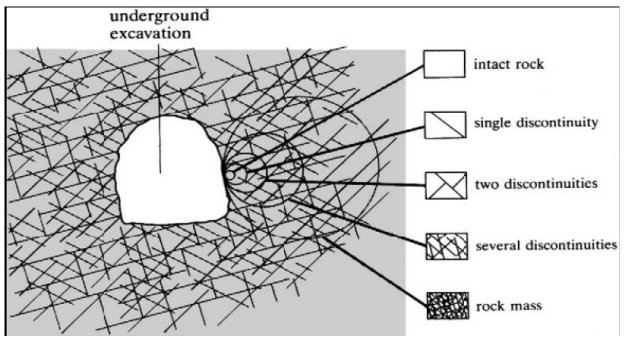
- Excavation of rock by drilling and blasting,
- Stability of excavations in good quality, brittle rock which is subject to rockburst conditions.



CH4 Rock strength and deformability
4.1 Introduction

Single discontinuities, or of a small number of discontinuities, will be of paramount importance.

- Equilibrium of blocks of rock formed by the intersections of three or more discontinuities
- The roof or wall of an excavation, and cases in which slip on a major throughgoing fault must be analysed.

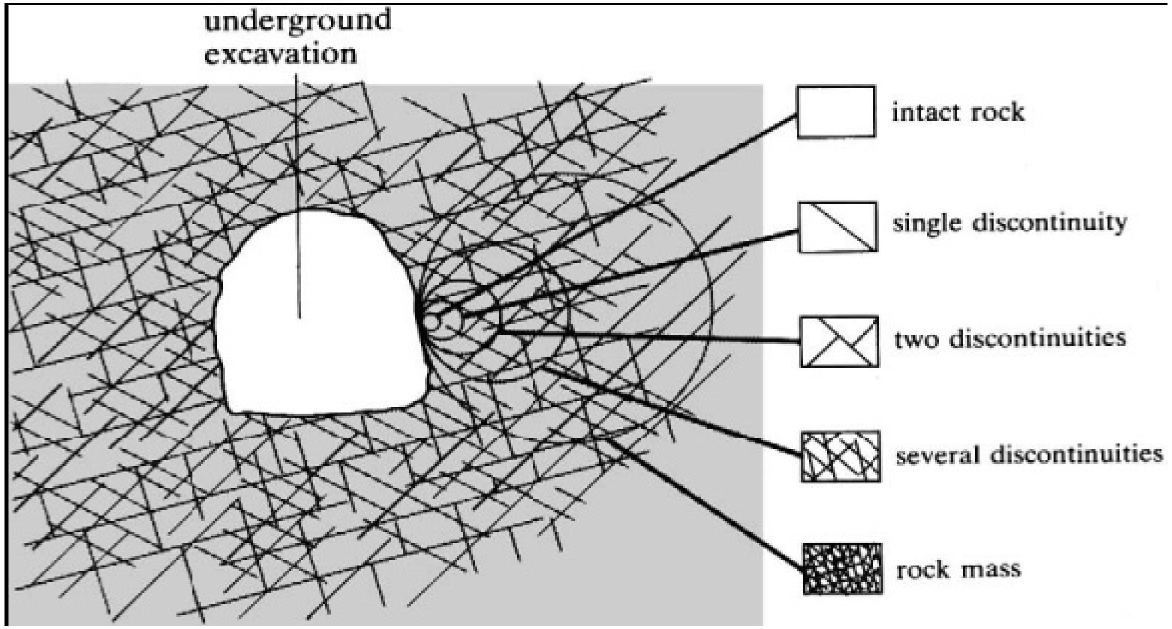


CH4 Rock strength and deformability

4.1 Introduction

Rock Mass (assembly of discrete blocks)

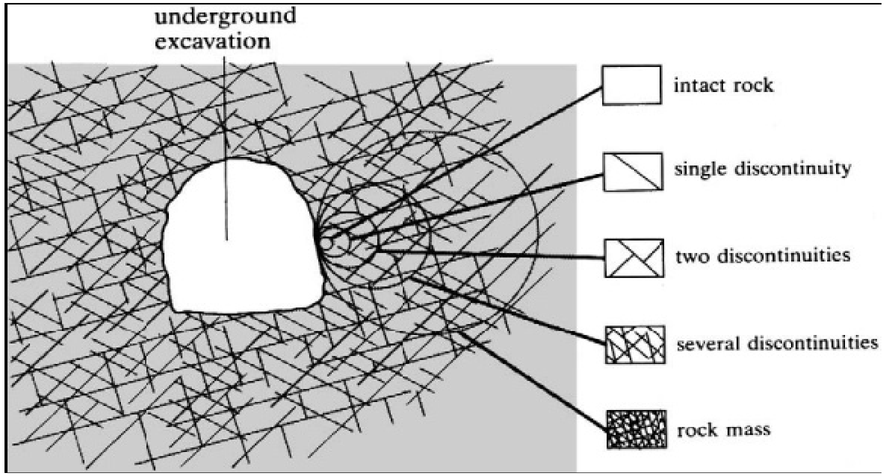
- Global response of a jointed rock mass in which the discontinuity spacing is small on the scale of the problem domain.



CH4 Rock strength and deformability
4.1 Introduction

In which the rock surrounding the excavations is always subject to high compressive stresses, it may be reasonable to treat a jointed rock mass as an equivalent elastic continuum.

Rock material and discontinuity properties may be combined to obtain the elastic properties of the equivalent continuum.



CH4 Rock strength and deformability

4.1 Introduction

The transition from intact rock to a heavily jointed rock mass with increasing sample size.

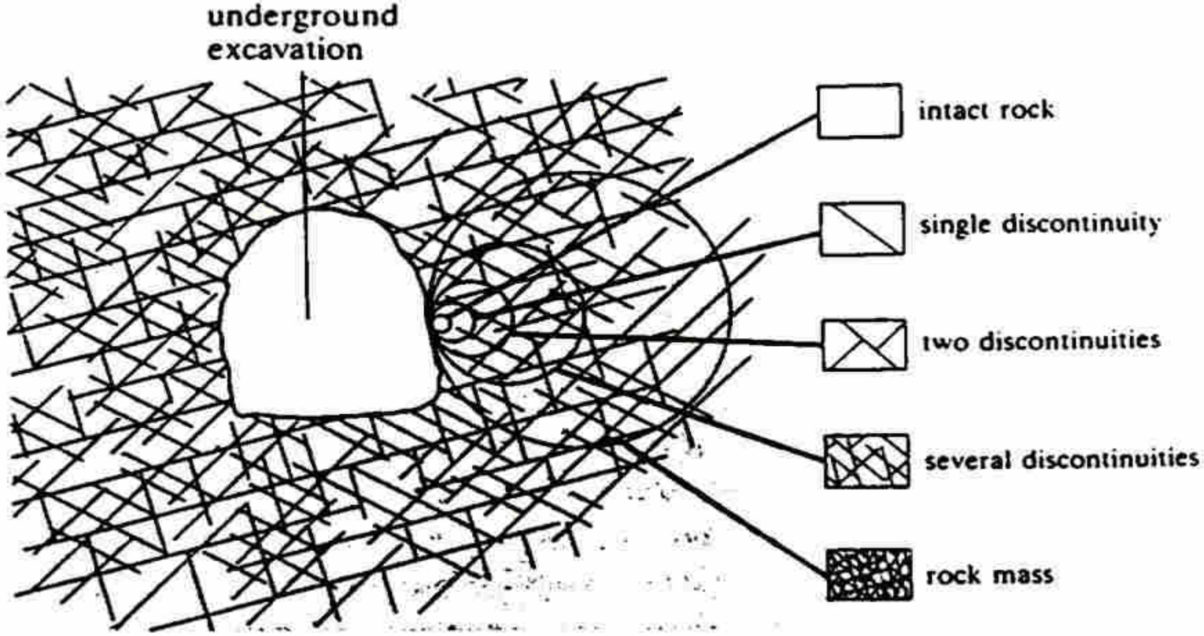
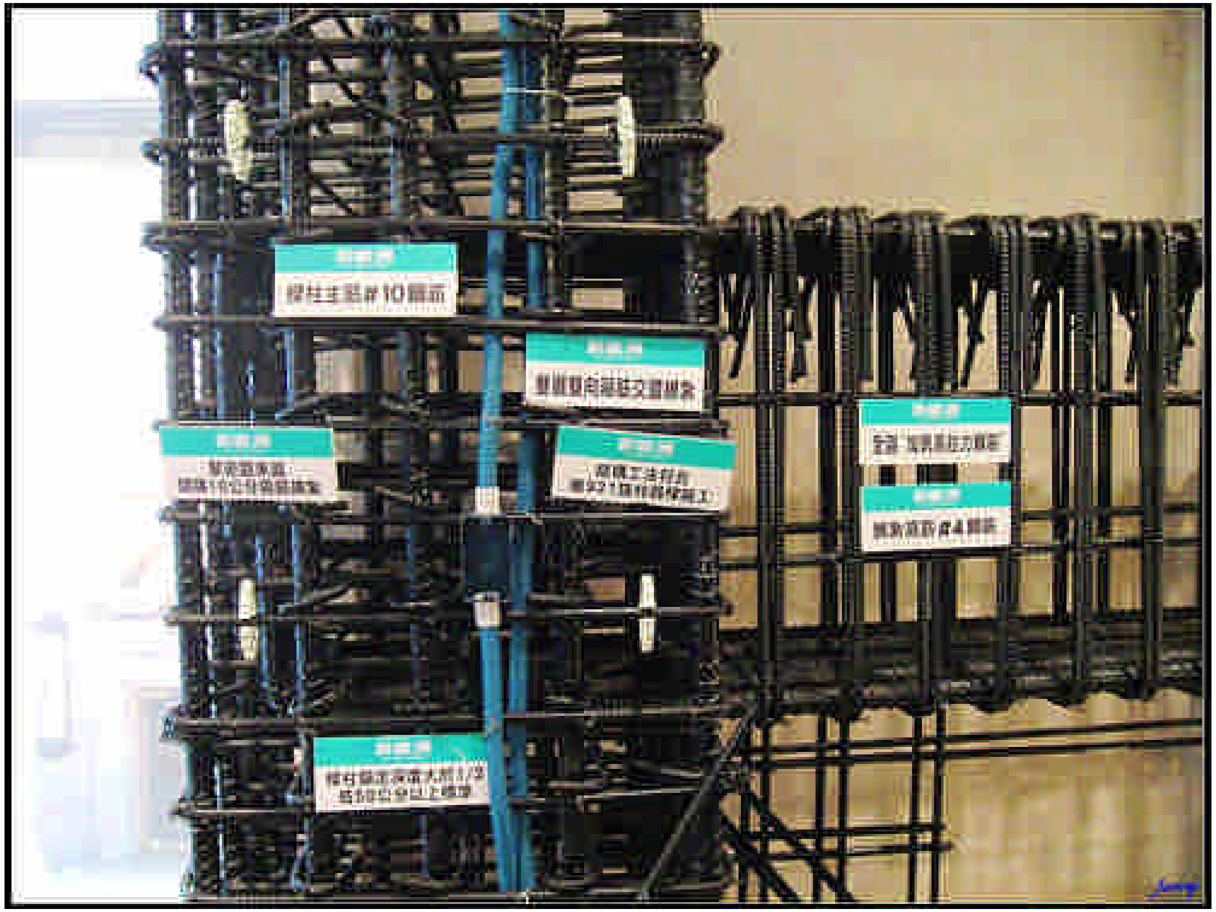


Figure 4.1 Idealised illustration of the transition from intact rock to a heavily jointed rock mass with increasing sample size (after Hoek and Brown, 1980).

CH4 Rock strength and deformability
4.1 Introduction

Idealized behaviors of

- Linear
- Elastic
- Homogenous
- Isotropic
- Time-independent



CH4 Rock strength and deformability

4.1 Introduction

Characteristics of Rock Materials/Rock masses

Linear vs. Nonlinear

Time-independent vs. Time-dependent

Homogenous vs. Heterogenous

Isotropic vs. Anisotropic

4.2 Concepts and definitions

Yield :A departure from elastic behaviour, i.e. when some of the deformation becomes irrecoverable as at A . The yield stress is the stress at which permanent deformation first appears.

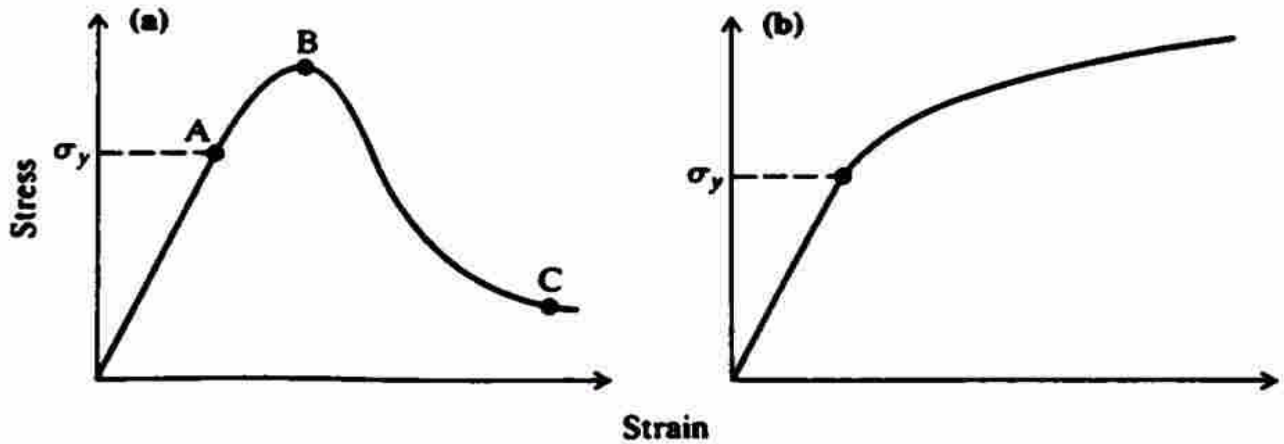


Figure 4.2 (a) Strain-softening; (b) strain-hardening stress–strain curves.

4.2 Concepts and definitions

Strength(or peak strength) :The maximum stress, that the rock can sustain under a given set of conditions, it corresponds to point B .

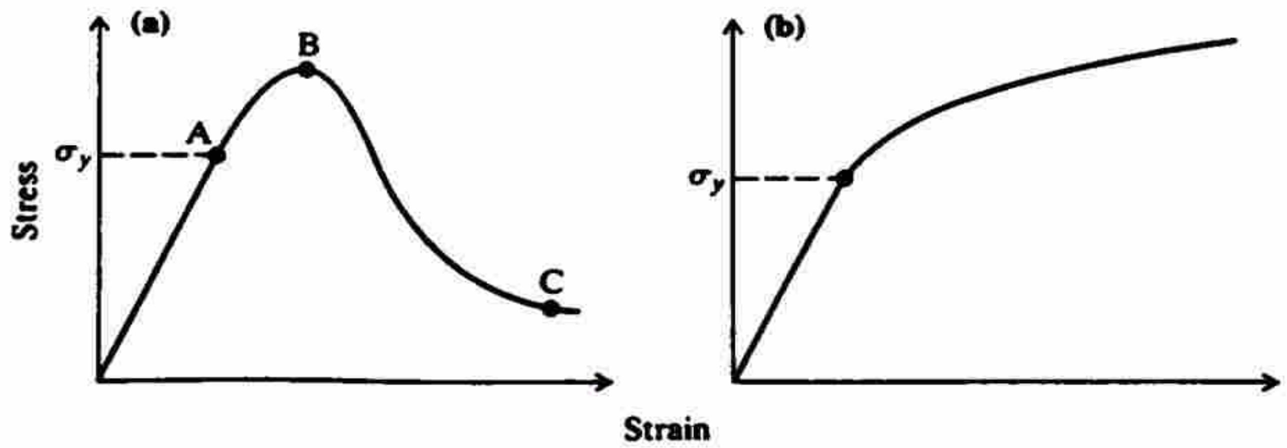


Figure 4.2 (a) Strain-softening; (b) strain-hardening stress–strain curves.

4.2 Concepts and definitions

Residual Strength ：After its peak strength has been exceeded, the specimen may still have some load-carrying capacity or strength. The minimum or residual strength is reached generally only after considerable post-peak deformation (point C).

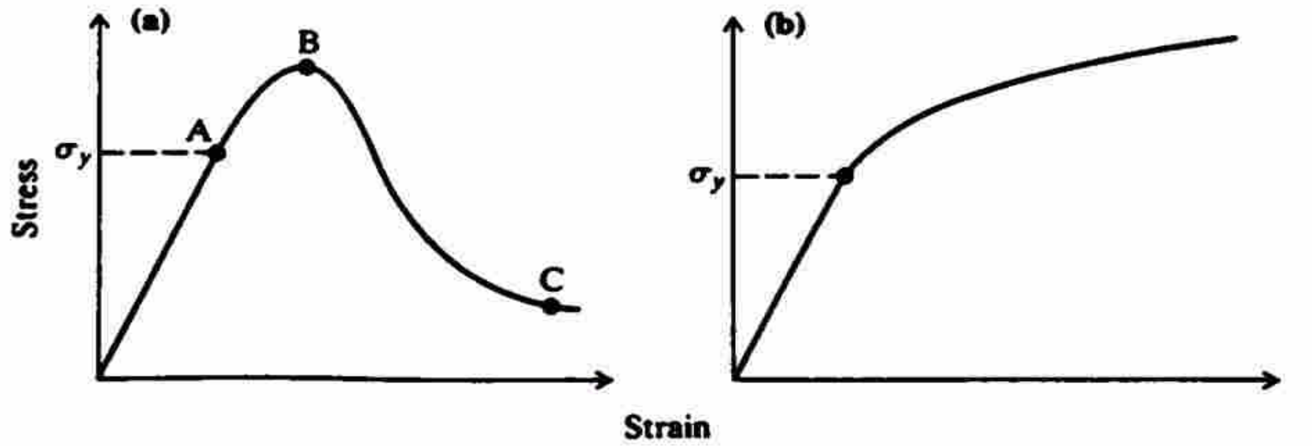


Figure 4.2 (a) Strain-softening; (b) strain-hardening stress–strain curves.

4.2 Concepts and definitions

Fracture(斷裂) The formation of planes of separation in the rock material. It involves the breaking of bonds to form new surfaces.

The onset of fracture is not necessarily synonymous with failure or with the attainment of peak strength.

4.2 Concepts and definitions

Brittle fracture : The process by which sudden loss of strength occurs across a plane following little or no permanent (plastic) deformation. (Figure 4.2a).

Ductile deformation: Material can sustain further permanent deformation without losing load-carrying capacity (Figure 4.2b).

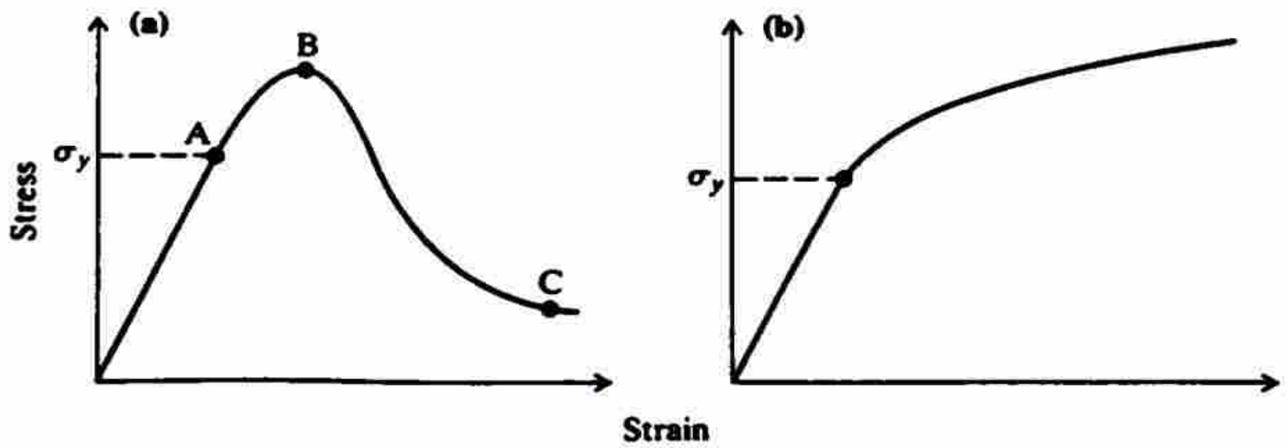


Figure 4.2 (a) Strain-softening; (b) strain-hardening stress–strain curves.

4.2 Concepts and definitions

Failure is often said to occur at the peak strength or be initiated at the peak strength (Jaeger and Cook, 1979).

An alternative Engineering Approach is to say that the rock has failed when it can no longer adequately support the forces applied to it or otherwise fulfil its engineering function.

This may involve considerations of factors other than peak strength. In some cases, excessive deformation may be a more appropriate criterion of 'failure' in this sense.

4.2 Concepts and definitions

Terzaghi's formulation of the law of effective stress, an account of which is given by Skempton (1960), is probably the single most important contribution ever made to the development of geotechnicai engineering.

$$\sigma'_{ij} = \sigma_{ij} - u\delta_{ij} \qquad \textbf{(4.1)}$$

where σ_{ij} :the total stresses, u is the pore pressure, and δ_{ij} the Kronecker delta.

4.2 Concepts and definitions

Experimental evidence and theoretical argument suggest that, over a wide range of material properties and test conditions, the response of rock depends on

$$\sigma'_{ij} = \sigma_{ij} - \alpha u \delta_{ij} \qquad \textbf{(4.2)}$$

where $\alpha \leq 1$,and is a constant for a given case (Paterson, 1978).

4.3 Behaviour of isotropic rock material in uniaxial compression

4.3.1 Influence of rock type and condition

It is used to determine the uniaxial or unconfined compressive strength, σ_c, and the elastic constants, Young's modulus, E, and Poisson's ratio, υ, of the rock material.

For similar mineralogy, σ_c will decrease with increasing porosity, increasing degree of weathering and increasing degree of microfissuring. σ_c may also decrease with increasing water content.

4.3 Behaviour of isotropic rock material in uniaxial compression
4.3.1 Influence of rock type and condition

Thus the uniaxial compressive strength of sandstone will vary with the grain size, the packing density, the nature and extent of cementing between the grains, and the levels of pressure and temperature that the rock has been subjected to throughout its history. However, the geological name of the rock type can give some qualitative indication of its mechanical behaviour.

4.3 Behaviour of isotropic rock material in uniaxial compression

4.3.1 Influence of rock type and condition

For example, a slate can be expected to exhibit cleavage which will produce anisotropic behaviour,

and a quartzite will generally be a strong, brittle rock.

Despite the fact that such features are typical of some rock types, it is dangerous to attempt to assign mechanical properties to rock from a particular location on the basis of its geological description alone. There is no substitute for a well-planned and executed programme of testing.

4.3.2 Standard test procedure and interpretation

Suggested techniques for determining the uniaxial compressive strength and deformability of rock material are given by the International Society for Rock Mechanics Commission on Standardization of Laboratory and Field Tests (ISRM Commission, 1979).

4.3.2 Standard test procedure and interpretation

The essential features of the recommended procedure are:

(a) Shape : The test specimens should be right circular cylinders having a height to diameter ratio of 2.5-3.0 and a diameter preferably of not less than NX core size (54mm),. The specimen diameter should be at least 10 times the size of the largest grain in the rock.

(b) Precision of Geometry: The ends of the specimen should be flat to within 0.02 mm and should not depart from perpendicularity to the axis of the specimen by more than 0.001 rad or 0.05 mm in 50 mm.

4.3.2 Standard test procedure and interpretation

(c) End surface treatments: The use of capping materials or end surface treatments other than machining is not permitted.

(d) Storage: Specimens: should be stored, for no longer than 30 days, in such a way as to preserve the natural water content, as far as possible, and tested in that condition.

4.3.2 Standard test procedure and interpretation

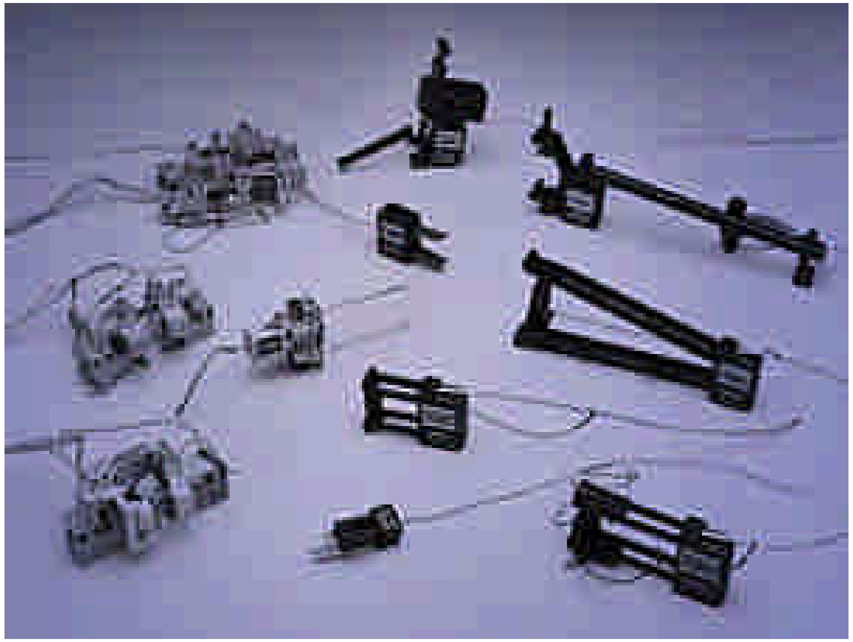
(e) Loading Rate: Load should be applied to the specimen at a constant stress rate of $0.5 - 1.0 MPa\ s^{-1}$

(f) Strain Measurement :Axial load and axial and radial (or circumferential)strains or deformations should be recorded throughout each test.

(g) No. of Test: There should be at least five replications of each test.

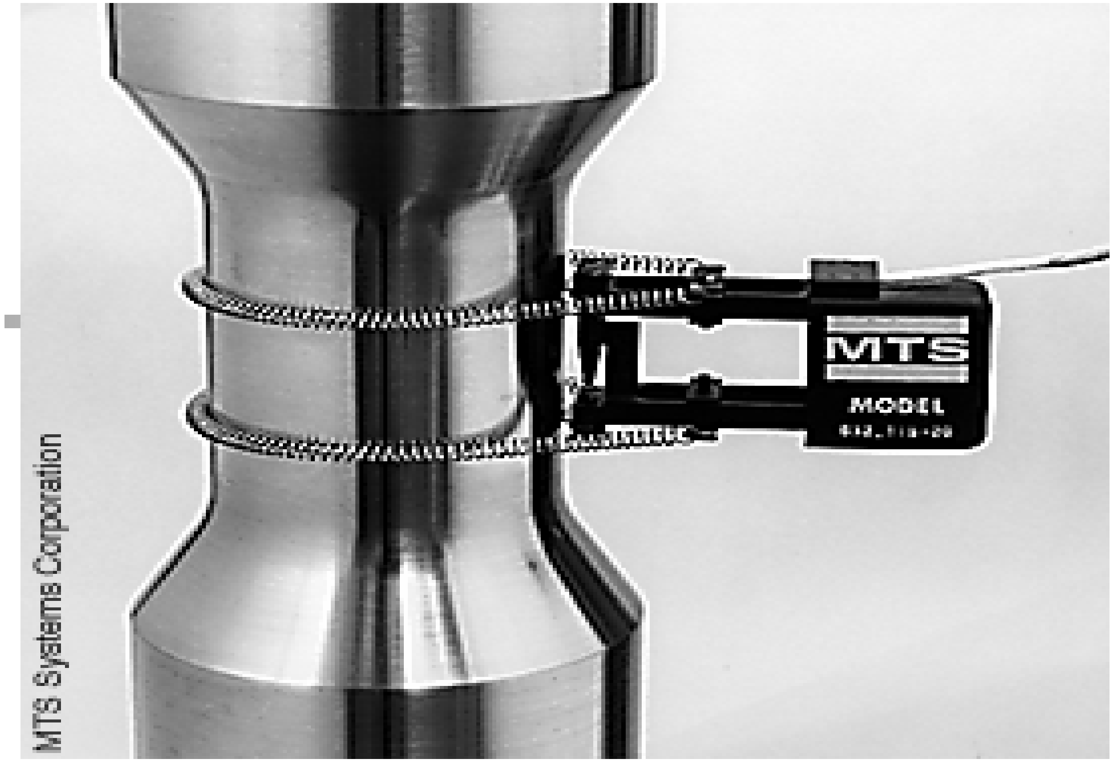
4.3.2 Standard test procedure and interpretation

- Extensometers for General Applications
- Axial Extensometers For Tensile Testing
- High-Temperature Extensometers
- LX Laser Extensometers
- DX2000 High Strain Extensometers
- Extensometers For Other Applications
- Clip-On Displacement Gages
- Knife Edges



4.3.2 Standard test procedure and interpretation

Large Diameter Specimen Attachment Kit As the diameter of a specimen increases, the normal force holding the extensometer in place is reduced. Under such circumstances, this kit provides for a more effective attachment angle, resulting in increased normal force for proper stability. This kit includes two remote spring attachment bracket assemblies that mount on the extensometer arms, and an assortment of 16 tension springs. The large diameter specimen attachment kit expands your range of testing capabilities. Use with models 632.11/12/25 and 634.11/12/25 on specimens larger than 1.25 in. (32 mm) in diameter.



4.3.2 Standard test procedure and interpretation

An example of the results obtained in such a test.

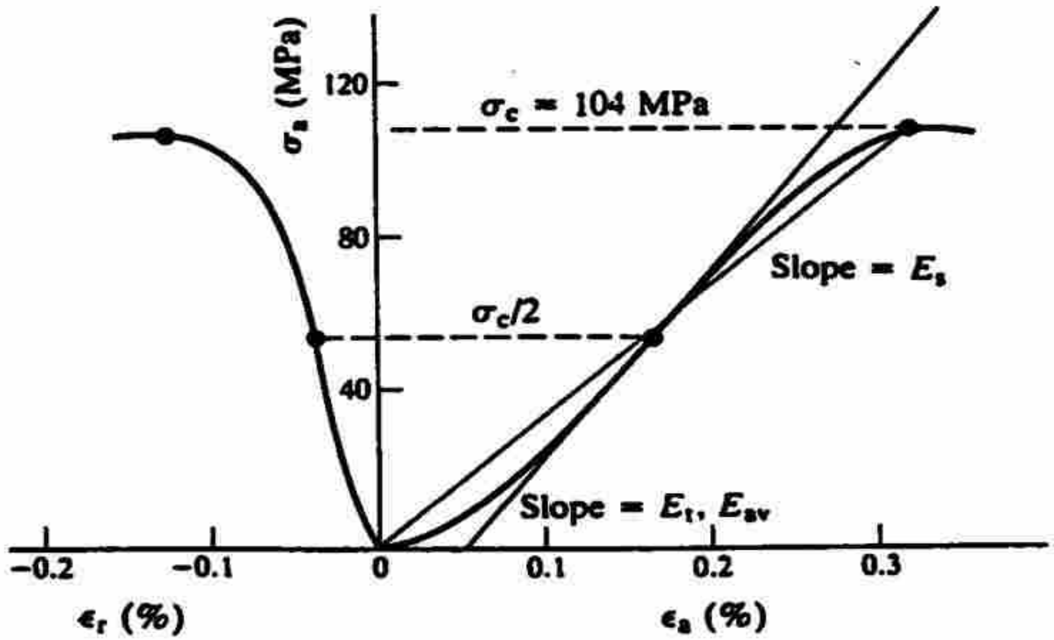


Figure 4.3 Results obtained in a uniaxial compression test on rock.