ROCK STRENGTH AND DEFORMABILITY

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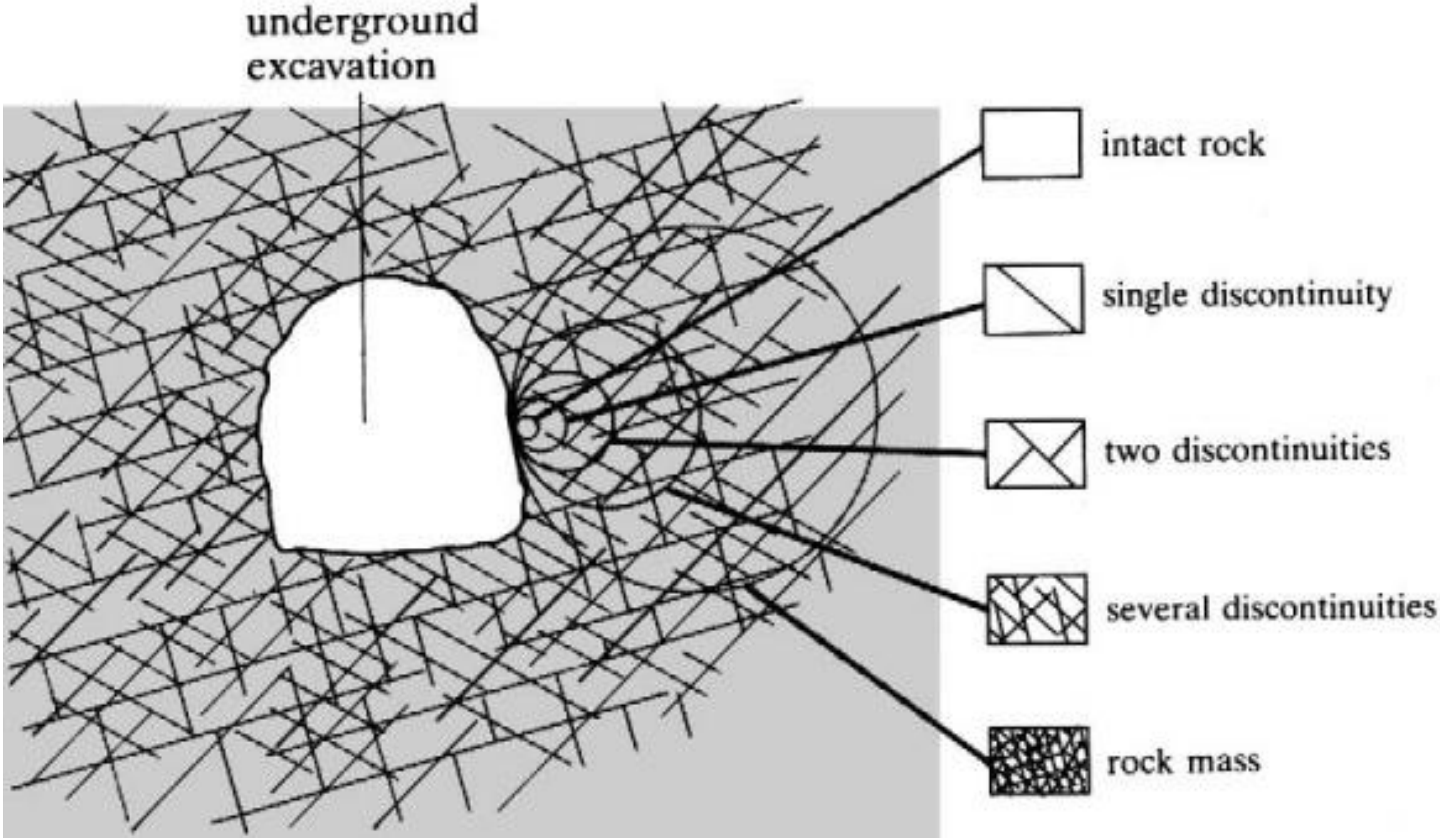
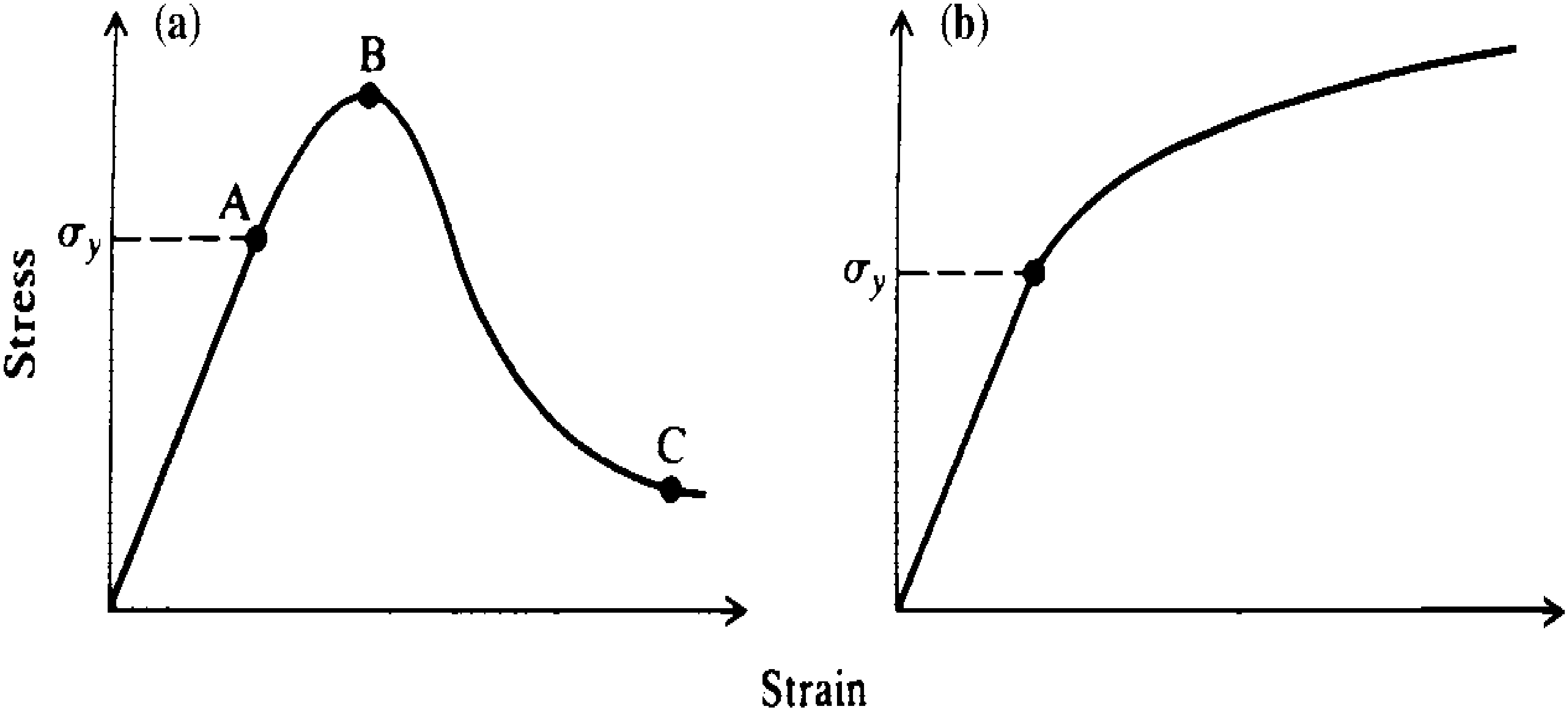
Intact and heavily jointed rock



Terminologies and Definitions

- **Fracture** is the formation of planes of separation in the rock material. It involves the breaking of bonds to form new surfaces

- **Strength, or peak strength,** is the maximum stress, usually averaged over a plane, that the rock can sustain under a given set of conditions (point B in the next figure)



Stress-Strain Curves: (a) Strain-softening and (b) Strain-hardening

- The minimum or **residual strength** is reached generally only after considerable post-peak deformation (point C in Figure)
- **Brittle fracture** is the process by which sudden loss of strength occurs across a plane following little or no permanent (plastic) deformation. It is usually associated with strain-softening or strain-weakening behaviour of the specimen as illustrated in Figure (a)
- **Ductile deformation** occurs when the rock can sustain further permanent deformation without losing load-carrying capacity as in Figure (b)
- **Yield** occurs when there is a departure from elastic behaviour, i.e. when some of the deformation becomes irrecoverable as at A in Figure (a)
- **Failure** is often said to occur at the peak strength or be initiated at the peak strength

Uniaxial compression of isotopic rock

- Uniaxial compression of cylindrical specimens - the most widely performed test on rock. It is used to determine the Uniaxial or Unconfined Compressive Strength (UCS), and the elastic constants, Young's modulus, and Poisson's ratio, of the rock material.
- UCS is used for rock mass classification scheme

Standard Test procedure

- International Society for Rock Mechanics Commission on Standardization of Laboratory and Field Tests (ISRM Commission,1979). The essential features of the recommended procedure are:

  (a) 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, approximately 54 mm. The specimen diameter should be at least 10 times the size of the largest grain in the rock.

  (b) 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.

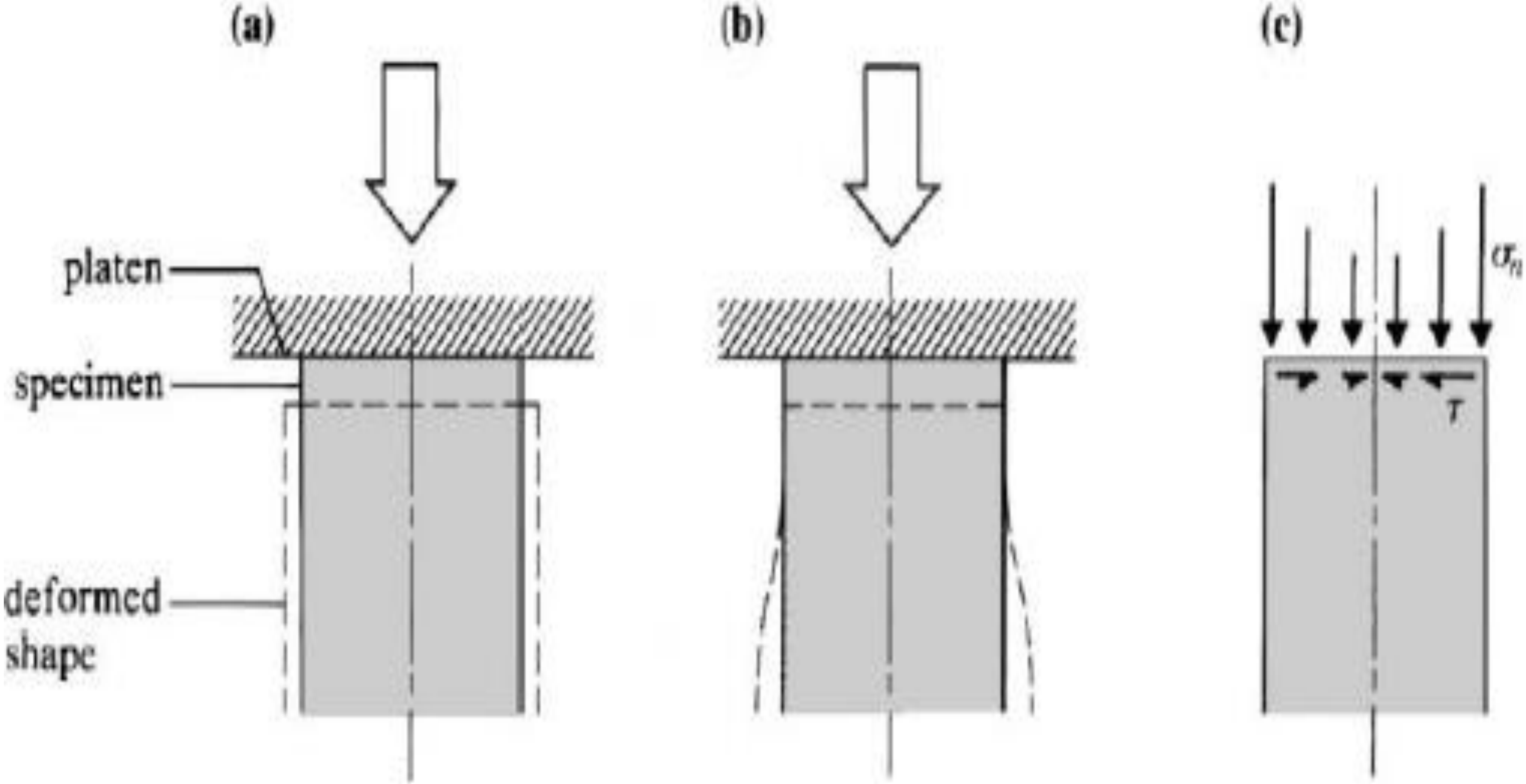
  (c) The use of capping materials or end surface treatments other than machining is not permitted.

  (d) 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.

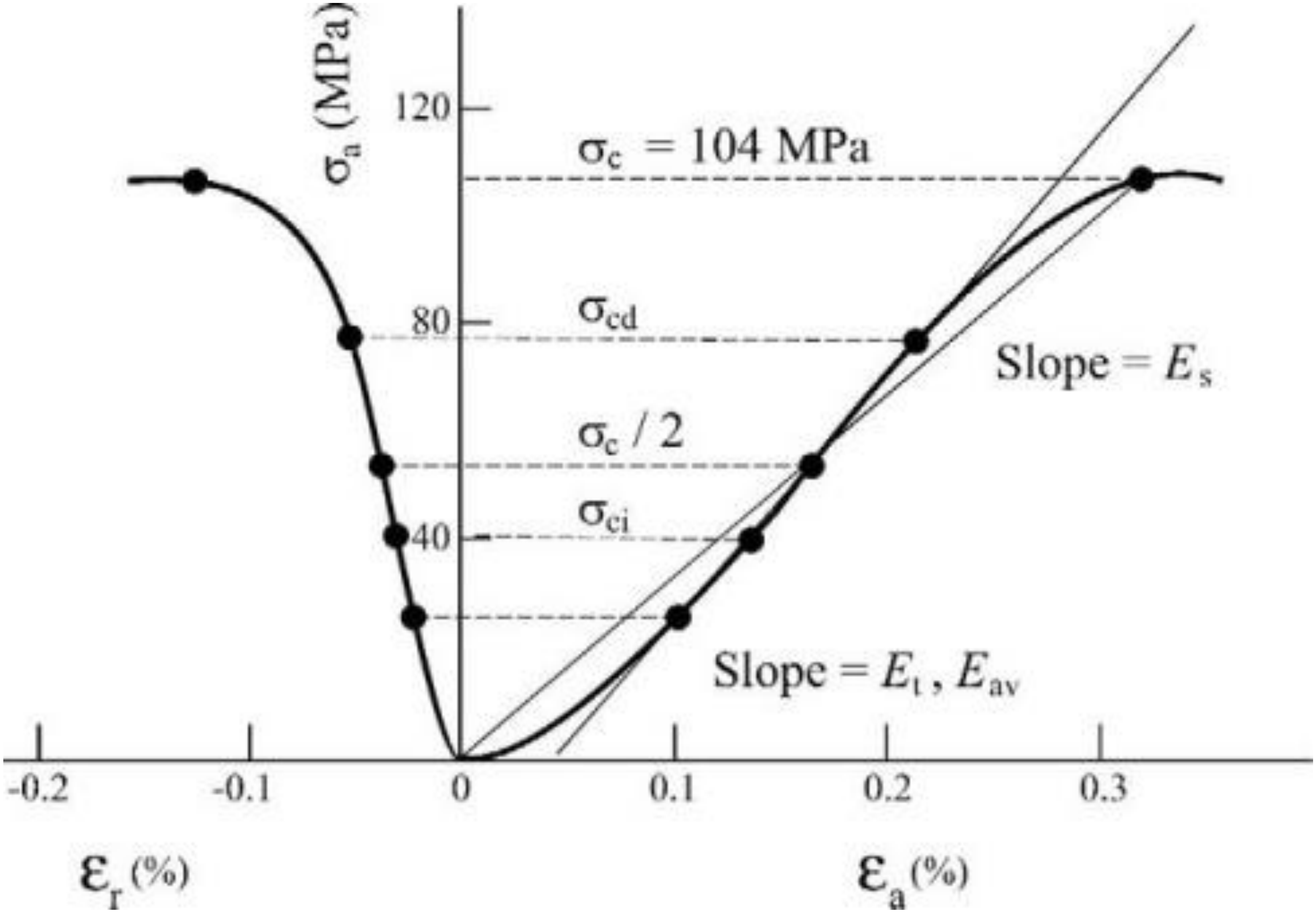
  (e) Load should be applied to the specimen at a constant stress rate of 0.5–1.0 MPa s^{-1}.

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

  (g) There should be at least five replications of each test.


(a)
(b)
(c)
platen
specimen
deformed
shape
σ_n
τ

Sample results of UCS test on rock



(a) **Tangent Young's modulus,** E_t, is the slope of the axial stress–axial strain curve at some fixed percentage, generally 50%, of the peak strength. For the example shown in Figure 4.3, $E_t = 51.0$ GPa.

(b) **Average Young's modulus,** E_{av}, is the average slope of the more-or-less straight line portion of the axial stress–strain curve. For the example shown in Figure 4.3, $E_{av} = 51.0$ GPa.

(c) **Secant Young's modulus,** E_s, is the slope of a straight line joining the origin of the axial stress–strain curve to a point on the curve at some fixed percentage of the peak strength. In Figure 4.3, the secant modulus at peak strength is $E_s = 32.1$ GPa.

Corresponding to any value of Young's modulus, a value of Poisson's ratio may be calculated as

$$\nu = -\frac{(\Delta\sigma_a/\Delta\varepsilon_a)}{(\Delta\sigma_a/\Delta\varepsilon_r)}$$

For the data given in Figure 4.3, the values of ν corresponding to the values of E_t, E_{av}, and E_s calculated above are approximately 0.29, 0.31 and 0.40 respectively.

Because of the axial symmetry of the specimen, the volumetric strain, ε_v, at any stage of the test can be calculated as

$$\varepsilon_v = \varepsilon_a + 2\varepsilon_r$$

For example, at a stress level of $\sigma_a = 80$ MPa in Figure 4.3, $\varepsilon_a = 0.220\%$, $\varepsilon_r = -0.055\%$ and $\varepsilon_v = 0.110\%$.