

Australian Standard[®]

Methods of testing rocks for engineering purposes

Method 4.3.2: Rock strength tests— Determination of the deformability of rock materials in uniaxial compression—Rock strength less than 50 MPa

1 SCOPE

This Standard sets out the method for determining uniaxial compressive strength, the stress-strain characteristics, Young's modulus and Poisson's ratio of a rock sample in compression in the form of specimens of regular geometry of strength less than 50 MPa. The test is intended for strength classification and characterization of intact rock.

NOTE: Where the measured strength using this method exceeds 50 MPa this method may result in a measured strength that is less than the strength obtained in test method AS 4133.4.3.1.

CAUTION: SOME OF THE TESTS SPECIFIED IN THIS STANDARD INVOLVE THE USE OF PROCESSES THAT COULD LEAD TO A HAZARDOUS SITUATION.

2 REFERENCED DOCUMENTS

The following documents are referenced in this Standard:

AS	
2193	Calibration and classification of force-measuring systems
4133	Methods of testing rocks for engineering purposes

The centre of curvature of the spherical seat surface shall coincide with the centre of the specimen top face.

- (c) A measuring instrument such as vernier or micrometer calipers capable of measuring specimen dimensions to a precision of 0.1 mm.
- (d) Electrical resistance strain gauges, extensometers, optical devices or other suitable measuring devices. Their design shall be such that an average of two circumferential and two axial strain measurements, equally spaced, with the position of the mid point of the gauges or other devices located at the mid-point of the specimen and diametrically opposite each other, can be determined for each increment of load, with a strain sensitivity of not less than 5×10^{-6} .

NOTES:

- 1 Whatever devices are selected, it is recommended that they are checked against the known properties of specimens tested in a manner described in Clause 5. A suitable specimen should consist of a right cylinder of aluminium or steel. Such procedures are essential when using devices other than electrical resistance strain gauges.
- 2 Strain gauges should be bonded to the specimen by a suitable epoxy resin.

Where electrical resistance strain gauges are used, the length of the gauges over which axial strain is determined shall be at least 10 grain diameters in magnitude and the gauges not encroach within $d/2$ of the specimen ends, where d is the diameter of the specimen. Circumferential strain shall be determined over a gauge length of between 5% and 10% of the circumference of the specimen.

NOTE: Electrical resistance strain gauges should only be used for non-friable, coherent rock, which permit an effective bond between the rock surface and the strain gauge. Alternative techniques are generally necessary for rocks that fall outside this category or for rocks whose moisture content precludes the necessary bond between the gauges and the rock surface.

Where dial gauges or LDVTs are used, the dial gauges or LDVTs shall be readable to a minimum of 0.002 mm.

The gauges shall be centrally positioned with a gauge length of not less than d .

4.2 Specimen preparation

The test specimen shall be prepared as follows:

- (a) From a suitable sample prepare a test specimen having the following characteristics:
 - (i) Test specimen shall be a straight circular cylinder having a length to diameter ratio of between 2.5 and 3.0 and a diameter preferably of not less than 45 mm. The diameter of the specimen shall be at least ten times the size of the largest grain in the rock.

NOTE: While a test specimen length to diameter ratio in the range of 2.5 to 3.0 is specified, in accordance with that recommended by ISRM, it is recognized that there is evidence suggesting that a minimum length to diameter ratio of 2.0 may be adequate particularly for rocks with strength less than 25 MPa. Therefore, while a ratio of between 2.5 to 3.0 is preferred, it is possible to extend this range to between 2.0 and 3.0 to allow additional testing where the core lengths are limited. Where the ratio is less than 2.5, it should be noted in the test report.
 - (ii) The ends of the specimen shall be cut parallel to each other to within 1° and at right angles to the sides of the specimen to within 1°.
 - (iii) The ends of the specimen shall be ground flat to 0.1 mm across the face with no surface irregularities. If the ends of the specimen cannot be ground or contain surface irregularities they may be capped using a capping material that has a strength greater than 50 MPa.
 - (iv) The sides of the specimen shall be free of abrupt irregularities and straight over the full length of the specimen.
- (b) Determine the average original diameter of the specimen to at least the nearest 0.1 mm across two diameters at right angles and at the centre and near the top and bottom of the specimen. Calculate the average original diameter (d_o) of the test specimen from the six measurements.
- (c) Measure and record the height of the specimen to 0.1 mm.
- (d) If required, moisture condition the specimen prior to testing.

5 TEST PROCEDURE

The procedure shall be as follows:

- (a) Attach the measuring devices to the specimen.
- (b) Load the specimen continuously and without shock. Apply the load to achieve a displacement rate of no greater than 0.1 mm/min. Plot load and displacement using the continuously recording device until a load deflection curve has been established sufficiently to permit the calculation of the Young's modulus and Poisson's ratio detailed in Clause 6. When performing the test using extensometers where destruction of the measuring devices may occur at specimen failure, the devices may be removed when at least 70% of the estimated strain to failure has been reached. Care should be taken to ensure that the load is maintained such that only minor relaxation of the sample occurs before loading to failure.

NOTES:

- 1 It is desirable that the rate of loading be adjusted to achieve failure of the specimen between 10 and 15 minutes, provided that this rate of loading does not exceed a displacement rate of 0.1 mm/min.
- 2 Where it is required to perform multiple cycles of loading and unloading, a suitable maximum load for the cycle may be taken as half the estimated failure load.

- (c) Continue the test to determine the uniaxial compressive strength of the specimen.

WARNING: MANY ROCKS FAIL IN A VIOLENT MANNER WHEN LOADED TO FAILURE. APPROPRIATE MEASURES SUCH AS A PROTECTIVE SHIELD SHOULD BE USED TO MINIMIZE THE RISK OF INJURY FROM ROCK FRAGMENTS.

- (d) Record the displacement rate applied.
- (e) Record the maximum load on the specimen.
- (f) Record the description of the failure.
NOTE: Appendix B provides guidance on failure descriptions.
- (g) Photograph the specimen before testing and after failure.
- (h) Determine the moisture content of the specimen in accordance with AS 4133.1.1.1.

6 CALCULATIONS

The following calculations shall be carried out at a nominated stress level or a stress level expressed as a percentage of the uniaxial compressive strength of the specimen:

- (a) Axial strain (ϵ_a), recorded directly from strain indicating equipment and then calculated from the following equation:

$$\epsilon_a = \frac{\Delta l}{l_o} \quad \dots 6(1)$$

where

ϵ_a = axial strain

Δl = measured change in axial gauge length (defined to be positive for a decrease in length), in millimetres

l_o = original undeformed axial gauge length, in millimetres

- (b) Diametral strain (ϵ_d), which may be determined either by measuring the change in specimen diameter or by measuring the change in the circumference. Where the changes in diameter are measured, the diametral strain is calculated from the following equation:

$$\epsilon_d = \frac{\Delta d}{d_o} \quad \dots 6(2)$$

where

ϵ_d = diametral strain

Δd = change in diameter (defined to be positive for a decrease in diameter), in millimetres

d_o = original diameter, in millimetres

When the change in circumference of the specimen is measured, the circumference is $C = \pi d$, thus the change in circumference is $\Delta C = \pi \Delta d$.

Consequently, the relationship between the circumferential strain (ε_c) and the diametral strain (ε_d) is given by the following equation:

$$\varepsilon_c = \frac{\Delta C}{C_o} = \frac{\Delta d}{d_o} \quad \dots 6(3)$$

so that $\varepsilon_c = \varepsilon_d$

where

ε_c = circumferential strain

ΔC = change in circumference, in millimetres

Δd = change in diameter, in millimetres

C_o = original circumference, in millimetres

d_o = original diameter, in millimetres

ε_d = diametral strain

- (c) Calculate the uniaxial compressive strength ($qu_{\max.}$) from the following equation:

$$qu_{\max.} = P/A \quad \dots 6(4)$$

where

$qu_{\max.}$ = uniaxial compressive strength, in megapascals

P = applied load at failure, in newtons

A = original cross-sectional area of the specimen calculated using the average original diameter, in square millimetres

Compressive stresses and strains are considered to be positive.

- (d) Plot the axial stress against average axial and diametral strains (see Figure 1).

NOTE: Figure 1 illustrates a plot of axial stress versus axial and diametral strains. These curves show typical behaviour of rock materials from zero stress up to ultimate strength (σ_u). The complete curves give the best description of the deformation behaviour of rocks having non-linear stress-strain behaviour at low and high stress levels.

- (e) Calculate the axial Young's modulus (E), defined as the ratio of the axial stress change to axial strain produced by the stress change, using any method employed in accepted engineering practice (see Figure 2).

NOTE: The most common methods used for calculating the Young's modulus are as follows:

- (a) Tangent Young's modulus (E_t) is measured at a stress level which is some fixed percentage of the ultimate strength [see Figure 2(a)].
 - (b) Secant Young's modulus (E_s) as usually measured from zero stress to some fixed percentage of the ultimate strength [see Figure 2(b)], generally 50 percent.
- (f) Calculate Poisson's ratio (ν) from the following equation:

$$\nu = \frac{-\varepsilon_c}{\varepsilon_a} \quad \dots 6(5)$$

Poisson's ratio in this equation has a positive value, since the slope of the diametral curve is negative by the conventions used in this procedure.

NOTE: If electrical resistance strain gauges are used, their transverse sensitivity should be taken into account. The resulting correction for Young's modulus values is small but for Poisson's ratio values it can be significant and leads to the following equation:

$$\nu = \frac{-\varepsilon_c + K\varepsilon_a}{\varepsilon_a - K\varepsilon_c} \quad \dots 6(6)$$

where ε_a and ε_c are the measured axial and circumferential strains respectively per unit compressive stress and K is the transverse sensitivity of the electrical resistance strain gauges.

- (g) Where desired, calculate the volumetric strain (ε_v) from the following equation:

$$\varepsilon_v = \varepsilon_a + 2\varepsilon_d \quad \dots 6(7)$$

where

ε_v = volumetric strain for a given stress level

ε_a = axial strain

ε_d = diametral strain (positive when contracting and negative when expanding)

7 TEST REPORT

The following shall be reported:

- (a) The uniaxial compressive strength, in MPa, expressed to two significant figures.
- (b) Young's modulus, in GPa, expressed to two significant figures.
- (c) Poisson's ratio, expressed to two significant figures.
- (d) Methods of determination of Young's modulus and the axial stress level or levels at which they were determined.
- (e) Graphical presentation of axial and diametral stress–strain curves. See Figure 1.
- (f) Description of failure.
NOTE: Appendix B provides guidance on failure descriptions.
- (g) Photographs of the test specimen before testing and after failure.
- (h) Source and identification (Rock Type) of test specimen.
- (i) Storage history, curing and environment.
- (j) Date of testing.
- (k) Average specimen diameter and height in millimetres to the nearest 0.1 mm and the length to diameter ratio of the test specimen.
- (l) Moisture content of the specimen to the nearest 0.1%.
- (m) Rate of displacement and test duration.
- (n) Any other pertinent observations.
- (o) Reference to this test method, i.e. AS 4133.4.3.2.

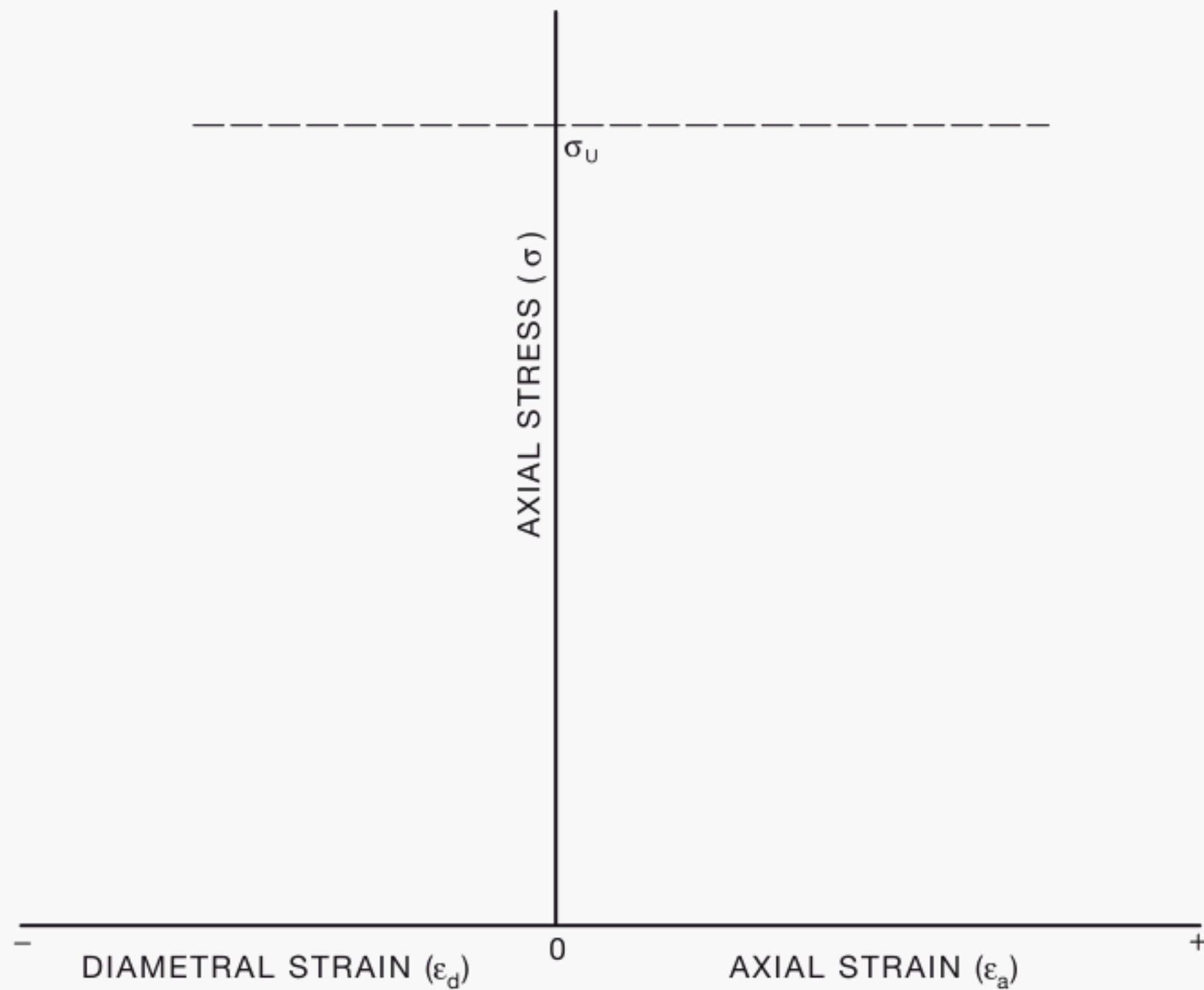


FIGURE 1 FORMAT FOR GRAPHICAL PRESENTATION OF AXIAL AND DIAMETRAL STRESS-STRAIN CURVES

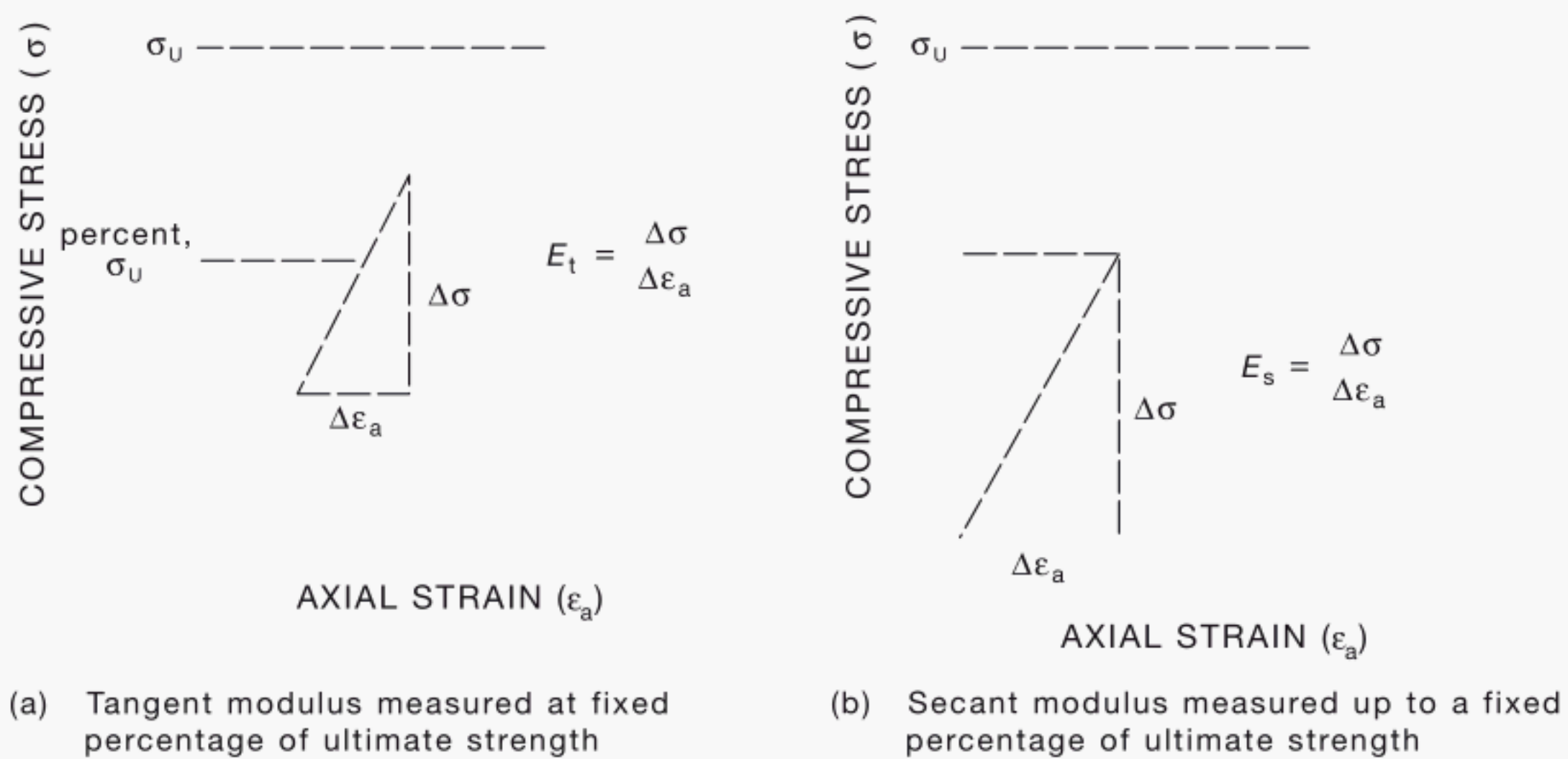


FIGURE 2 METHODS FOR CALCULATING YOUNG'S MODULUS FROM AXIAL STRESS-STRAIN CURVE

APPENDIX A

POTENTIAL INFLUENCES OF MOISTURE CONDITION ON ROCK STRENGTH

(Informative)

The moisture condition of a specimen at the time of testing can have a significant impact upon the deformation and measured strength of the rock. Sound practices generally suggest that laboratory tests should be made upon specimens at a moisture condition representative of the field condition.

The moisture condition of the rock specimen should be preserved until the time of testing. However, there may be a requirement by the specifier for the testing of specimens at moisture contents other than that representative in the field.

Studies have shown that the moisture content of the rock, or the saturation state, can have a significant influence on the strength measured in the test. Generally, the strength diminishes when the moisture content increases, with a minimum strength recorded for saturated specimens. Saturation of test specimens prior to testing is sometimes specified in order to measure the lowest strength for a rock.

The moisture content of saturated specimens also reflects voids volume of the specimen, which in turn may provide some indication of the degree of weathering. Therefore, the variation of uniaxial compressive strength (and other properties) with saturated moisture content can be a useful point of comparison.

APPENDIX B

CONCEPT OF FAILURE DESCRIPTIONS

(Informative)

The failures shown in Figure B1 are for use as a guide only and represent the most commonly found. Other modes of failure may occur, particularly in high pressure triaxial tests where brittle-ductile failure may occur, weak sedimentary rocks that may exhibit soil type failure modes, and calcareous rocks that may crush as a result of voids.

Modes (a) and (b) are likely to be valid results typically representative of the uniaxial compressive strength.

Mode (c) may be affected by tensile failure and may not be representative of the true uniaxial compressive strength.

Modes (d) and (e) are likely to be invalid tests with results indicating strength less than the true uniaxial compressive strength.

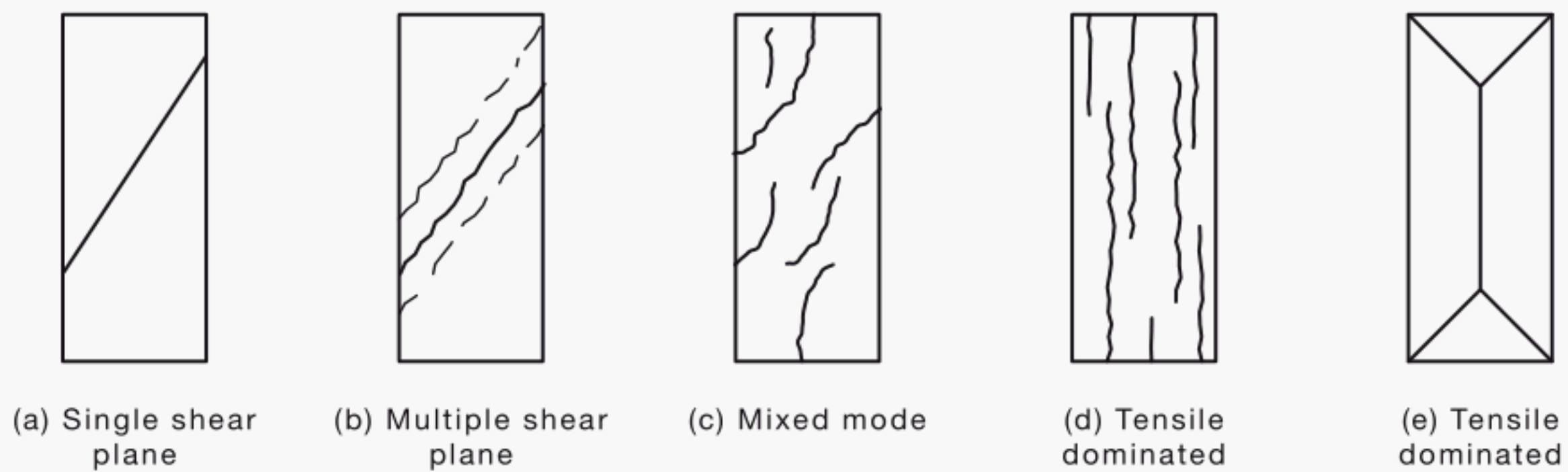


FIGURE B1 ILLUSTRATION OF TYPICAL FAILURES

NOTES

NOTES

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