Mechanical properties of intact rock and joints

Mechanical properties → elastic properties → engineering design

Mechanical properties → strength → engineering design

rock masses → numerous joints (discontinuities)

rock masses → blocks of intact rock

Deformation of this composite under changing loads is largely determined by:

(1) intact rock elastic moduli and strength

(2) stiffness and strength of joints

high affect on strength
minor influence on elastic moduli

→

Confining pressure, ←
rate of loading,
temperature,
time, and
peculiarities of testing apparatus

Rock includes an enormous variety of materials from:
volcanic glass to reef coral,
fresh granite to welded tuff,
pegmatite to porphyry,
limestone to marble,
shale to slate,
sandstone to quartzite,
peat to coal,
and so on.

genetic or
geological classification systems —seldom relate→ engineering properties

some sedimentary rocks have high strength,
some igneous rocks have low strength

engineering classification systems

Rock Mass Rating (RMR) and Quality (Q) Systems

intact rock properties,
joint properties,
joint spacing,
water is present

The purpose of classification schemes is to assist in determining tunnel support requirements in advance of excavation

American Society for Testing and Materials (ASTM) laboratory tests

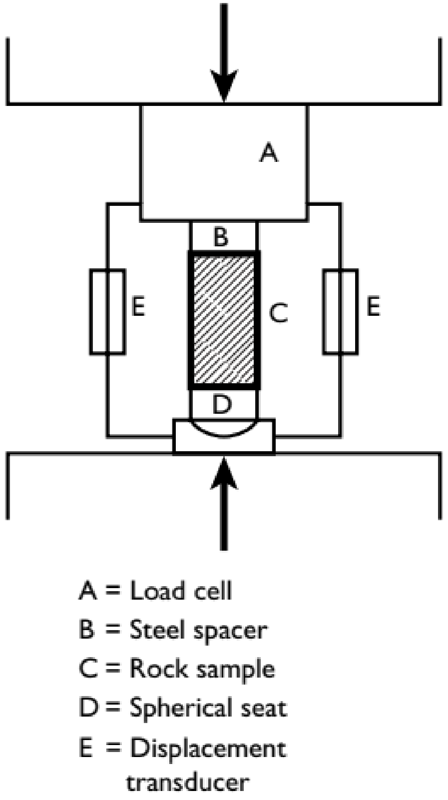
International Society for Rock Mechanics (ISRM) laboratory tests and in-situ

Elastic moduli of isotropic media commonly determined in laboratory testing

Young's modulus E

Poisson's ratio ν → statically and dynamically → cylindrical test specimens

Shear modulus G



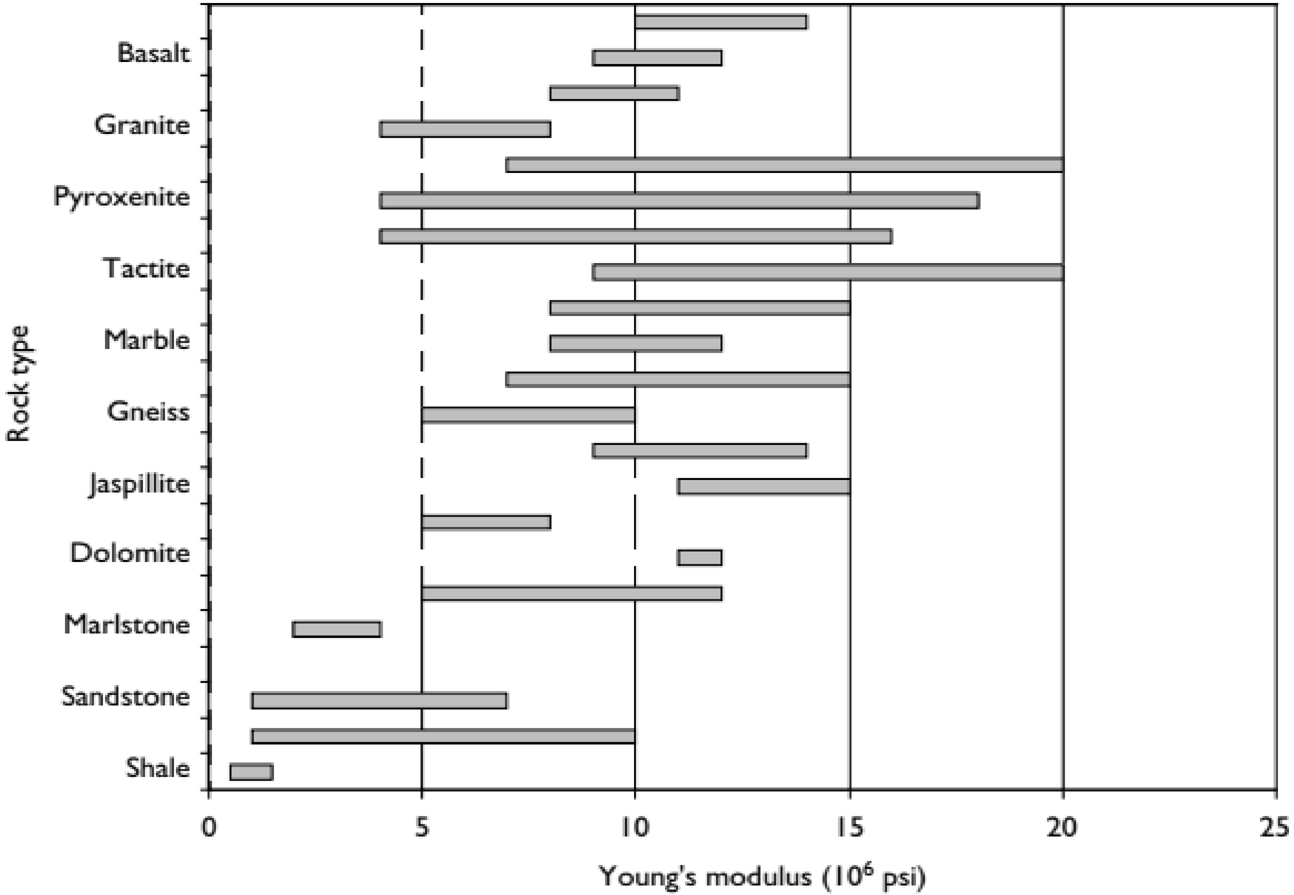
Young's modulus

Cores prepared with smooth ends and with a length-to-diameter ratio (L/D) of two are loaded axially in compression.

loading and unloading

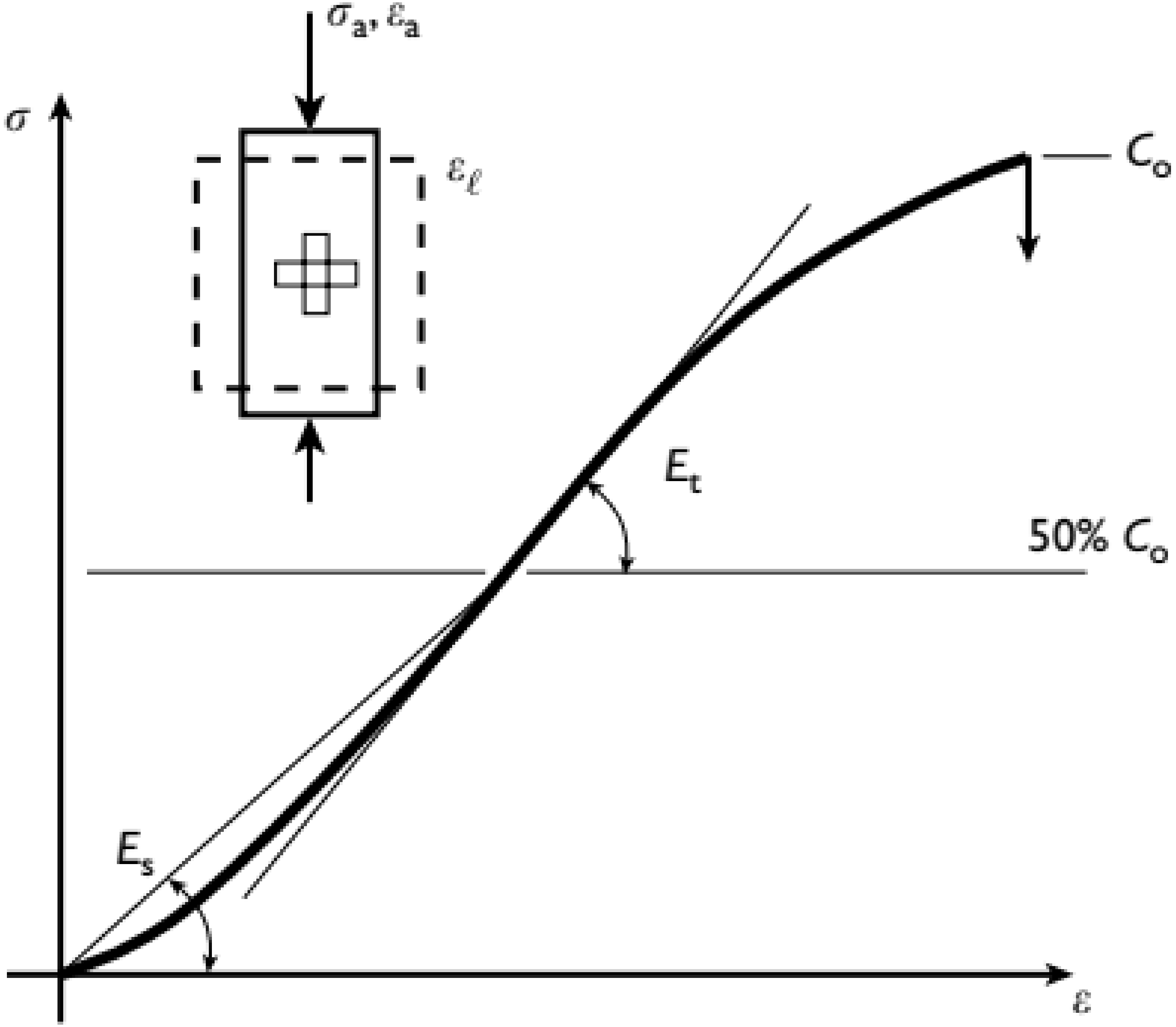
strain gages displacement transducers

Ranges of Young's modulus according to rock type indicates a wide range for a given rock type and no correlation of modulus with rock type.



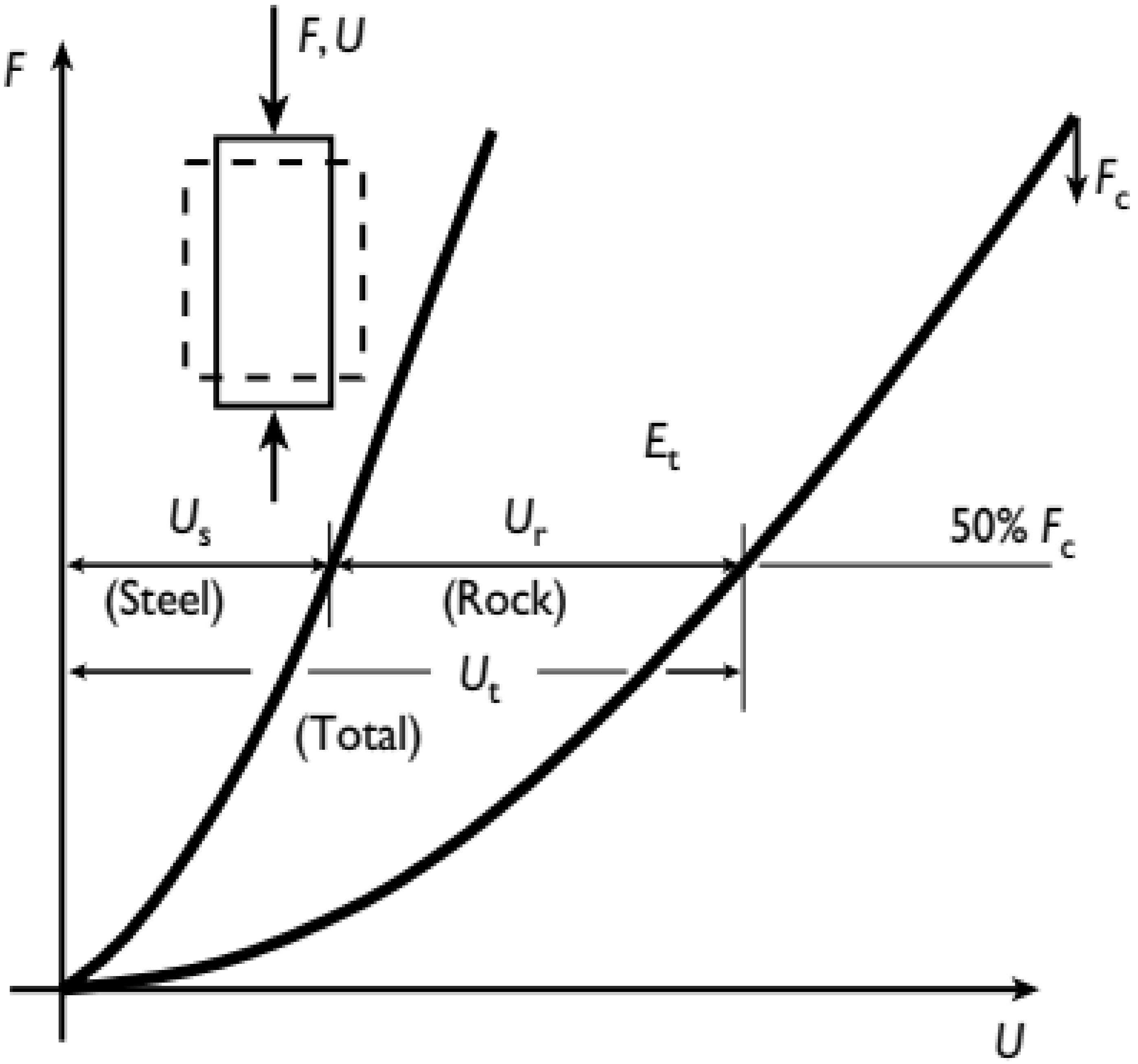
Coal is a rock type that is in a class by itself because of its organic constitution and commercial importance. A wide range for Young's modulus from 1 to over 51 GN/m^2 (0.15 to 7.4 × 106 psi). This large range is caused, in part, by directional dependencies (anisotropy), but mainly by coal rank that ranges from *sub-bituminous* to *anthracite*. A likely range of Young's modulus for most bituminous coal is perhaps 2 to 5 GN/m^2 (0.29 to 0.73 × 106 psi). However, recognition of anisotropy may be important at any particular site.

The theory behind the test for Young's modulus is Hooke's law which in consideration of the uniaxial loading reduces to $\sigma a = E\varepsilon a$ for the axial direction. Thus, a plot of axial stress versus axial strain does indeed allow Young's modulus to be determined by simply measuring the slope of the plot. The plot is usually curved, as shown in Figure 3 where compression is positive. The slope of a tangent to the stress-strain curve defines a *tangent modulus Et*. A line drawn from the origin to a point on the curve defines a *secant modulus Es*. Measurement of the tangent modulus at 50% of the unconfined compressive strength defines Young's modulus for engineering design.



σ_a, ε_a
σ
ε_ℓ
C_o
E_t
50% C_o
E_s
ε

Measurements of axial force and displacement using displacement transducers instead of strain gages allow for a more economical determination of Young's modulus. However, *care* must be taken to account for the displacement of *steel spacers, spherical seats, and other materials in series with the test specimen*. This accounting is easily done graphically, as shown in Figure 4, where a total force-displacement plot and a force-displacement plot *without* the test specimen are presented. The displacement of the test specimen is the difference between the two plots at the considered level of force. According to Hooke's law $\sigma a = F/A = E\varepsilon a = EU/L$ where F, U, A, and L are force, displacement, cross-sectional area of the test specimen, and test specimen length, respectively. Again, data reduction is done at about 50% of the unconfined compressive strength of the material.



F, U
F
F_c
E_t
U_s
U_r
50% F_c
(Steel)
(Rock)
U_t
(Total)
U