# Rock Mechanics Properties

## Young's Modulus:-

Young's modulus also known as the elastic modulus is an important parameter to describe stress and strain relationship. Young's modulus (E), is defined as the ratio of stress to strain, that is:

$$E = \frac{\sigma}{\varepsilon}$$

Where E is young's modulus in GPa, $\sigma$ is stress in N/$m^2$, $\varepsilon$ is strain

Elastic modulus describes the capacity of rock deformation, or the stiffness of a rock. For a high elastic modulus rock, it is less deformable (i.e. stiff). The initial part of the complete stress-strain curve will be steep. For a low elastic modulus (soft) rock, it is more deformable, and the initial part of the complete stress-strain curve will be gentle.

It can be determined in two ways: either by taking the slope of the stress-strain curve at a given point; or by taking the slope of a line connecting two points on this linear portion of the curve (Fig.1). The two slopes are the tangent modulus and the secant modulus. The tangent modulus is conventionally taken as the gradient of the $\sigma - \varepsilon$ curve at a stress level corresponding to 50% of the peak stress; the secant modulus may be determined anywhere over the entire linear portion. Naturally, both of these are approximations to the real behaviour, but are useful and adequate for simple elastic applications.

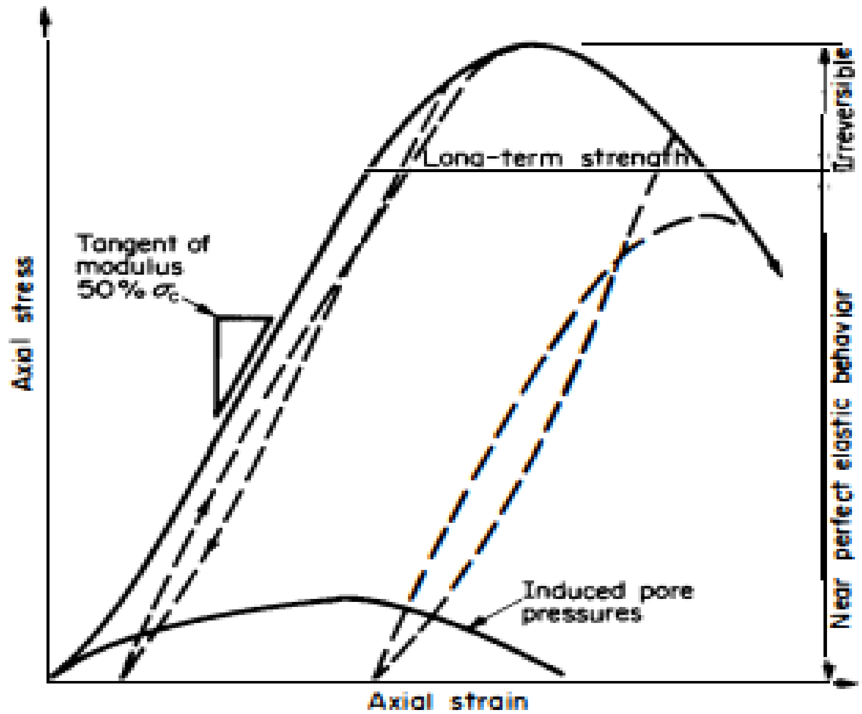


Figure 1. Typical stress-strain curve showing tangent modulus computation.

## Strength:-

Rocks possess strength due to coherence of constituent mineral(s). A mono-minerallic rock with random (isotropic) fabric will show similar strength all around but a polymineralic rock may show variation in

strength from section to section. So is the case with rocks having oriented (anisotropic) fabric. In general rocks are very strong under compressive forces as compared to under shear forces followed by flexural and tensile stresses.

## Compressive Strength:-

Compressive strength is the capacity of a material to withstand axially directed compressive forces. Rocks are seldom naturally loaded in one direction only, and most design procedures require some knowledge of the strength with stress applied in three principal directions. The most usual test for this condition, the triaxial cell system, has two of the principal stresses equal, and so lends itself to a two-dimensional analysis (Harrison and Hudson, 1997). That said, the most common measure of compressive strength is the uniaxial compressive strength or unconfined compressive strength (UCS). Usually compressive strength of rock is defined by the ultimate stress. It is one of the most important mechanical properties of rock material used in design, analysis and modelling.

In its simplest form, the uniaxial compression test is conducted by taking a right cylinder of intact rock, loading it along its axis and recording the displacement produced as the force is increased. In the curve shown in figure (2) as presented by (Harrison and Hudson, 1997), the various aspects of the mechanical behaviour of intact rock tested under these conditions can now be identified.

At the very beginning of loading, the curve has an initial portion which is concave upwards (the opposite of typical soil behaviour) for two reasons: (i) the lack of perfect specimen preparation, (ii) manifested by the ends of the cylinder being non-parallel; and (iii) the closing of microcracks within the intact rock.

After this initial zone, there is a portion of essentially linear behaviour, analogous to the ideal elastic rock. Another important parameter highlighted in Figure (1) is the maximum stress that the specimen can sustain. Under the loading conditions shown in the diagram, the peak stress is the uniaxial compressive strength, $\sigma c$.

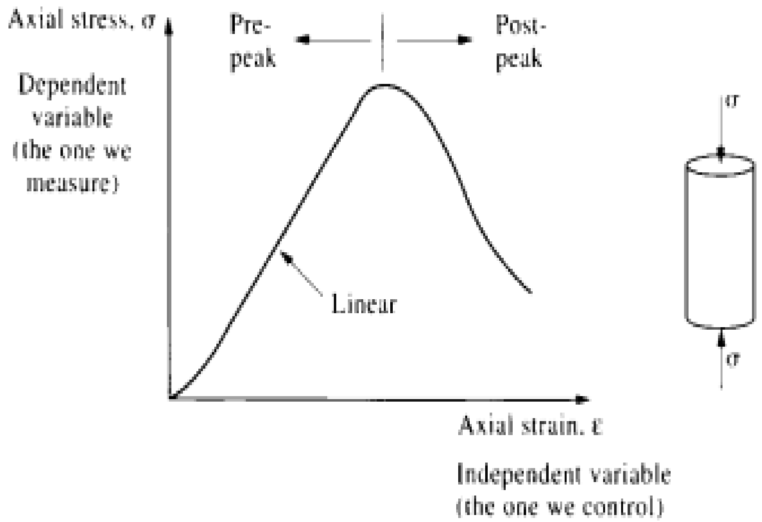


**Figure 1. The complete stress –strain curve (Harrison and Hudson, 1997)**

The specimen diameter in a UCS test is usually 1 in, but 2 in, 3/4 or 1/2 in sizes can also be used provided that the smallest dimension of the specimen is at least 10 times the maximum grain size. The length of the specimen, *l*, should be twice the diameter, d, but other lengths down to a 1: 1 ratio of *l*/d can be used, according to (Ulusay and Hudson. 2007).

For a specimen of diameter d and peak load P, the compressive strength is given as:

$$C_{\circ} = \frac{P}{A}$$

Where $C_0$ is the compressive strength in MPa, P in $Nm^{-2}$ and A in $cm^2$.

The ISRM suggested method (Ulusay and Hudson, 2007) specifies the test conditions much more closely, in that the diameter of the specimen should be not less than NX core 54 mm and the diameter(d), as the specimen specified as between d and d + 2 mm, with a thickness at least d/3 or 15 mm. The use of capping materials or end surface treatment other than machining to within 0.02 mm flatness is not permitted. Figure 2. illustrates the significant features, with the use of only one spherical seat being allowed (Hudson, 1995).

ISRM guidelines (Ulusay and Huudson, 2007) recommend that specimen ends be prepared to the following tolerances: ends perpendicular to the specimen axis within 0.001 rad; and ends flat to 0.02 mm.

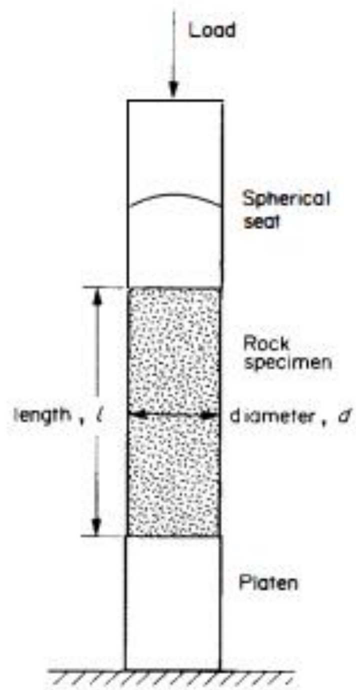


**Figure 2. ISRM uniaxial compressive test (Hudson, 1995)**

According to the ASTM D4543 (2008a) and ISRM suggested methods (Ulusay and Hudson, 2007), the lengths and diameter of the specimens are determined using an electronic caliper. The length is determined to the nearest 0.01 mm by taking an average of two lengths measured perpendicular to each other from the center of the end faces. The diameter is determined to the nearest 0.01 mm by taking the average of two diameters measured perpendicular to one another close to the top, middle, and bottom of the specimen.

To standardise the test length to diameter ratio of cylindrical sample is reduced to 1:1**,** by a formula:

$qu = \sigma c\ (ob) / 0.778 + 0.222\ (D/L)$

Where, **qu** is compressive strength, **σc** is observed compressive strength, D and L is diameter and length of the sample.

The UCS can be related to physical properties porosity and dry density. The rocks with dry density in between 2.5 to 2.9 t/m3 and porosity 1 to 3% may have UCS in the range of 150 to 250 MPa while rocks with dry density in between 1.5 to 2.5 t/m3 and porosity 5 to 15% may have UCS in the range of 50 to 150 MPa. Igneous rocks with very small sized minerals are stronger than their coarse counterparts. Non foliated metamorphic rocks will have higher compressive strength as compared to foliated ones. Geologically older sedimentary rocks due to high indurations and cementation will be stronger than the young sedimentary rocks provided that they are not weathered.