Geological factors and strength of rocks

A common engineering geological feature pertinent to the overwhelming majority of solid rocks is their crystalline structure. Mechanical properties observed on the sample are often significantly different from those observed in situ. Important practical changes in their behaviour during construction occur at the level of heterogeneity which is compatible with the size of an engineering construction.

The principal factors controlling the strength of solid rocks are:

1. mineral composition, structure and texture;
2. bedding, jointing and anisotropy;
3. water content;
4. state of stress in the rock mass.

Strength of rocks

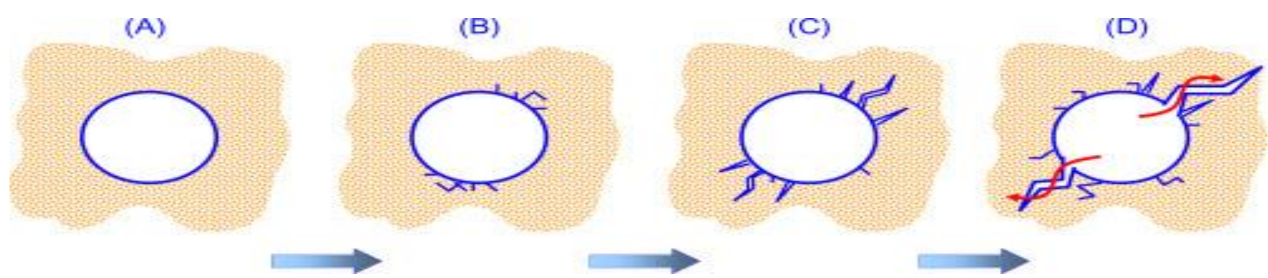
Qualitatively, **strength** can be defined as the resistance to permanent deformation by flow or fracture. In a more precise, quantitative sense, **strength** is the stress level that is required to produce a certain type of permanent deformation, fracture or flow, under well-defined experimental conditions

Rock strength is specified in terms of tensile strength, compressive strength, shear strength, and impact strength. In the context of fracture gradient, only the tensile strength of rock is of importance. The tensile strength of rock is defined as the pulling force, required to rupture a rock sample, divided by the sample's cross-sectional area. The tensile strength of rock is very small and is of the order of 0.1 times the compressive strength. Thus, a rock material is more likely to fail in tension than in compression.

The rock mechanics failure criteria have their limitations and are therefore suitable only for particular applications. In this chapter we use only two of these criteria, used extensively in the oil and gas industry, that is, Von Mises and Mohr–Coulomb failure and expand on the in situ and laboratory testing techniques to measure or estimate their relevant parameters.

During drilling, a leak-off test is performed after each casing is set to examine the strength of the borehole wall below the casing and to ensure that its strength is sufficient to handle the mud weights required for further drilling. Also, during well stimulation, while performing mini-frac or extended leak-off operations, the wellbore is purposely fractured. In conventional leak-off tests, however, the wellbore is usually brought toward the fracturing stage. Either way, the data are collected and tabulated for further fracturing analysis of wellbore. Leak-off tests are the main experimental input to the future analysis of wellbore fracture. It can also be stated that the pore pressure profile and the fracturing profile are the two most important parameters in the wellbore analysis.

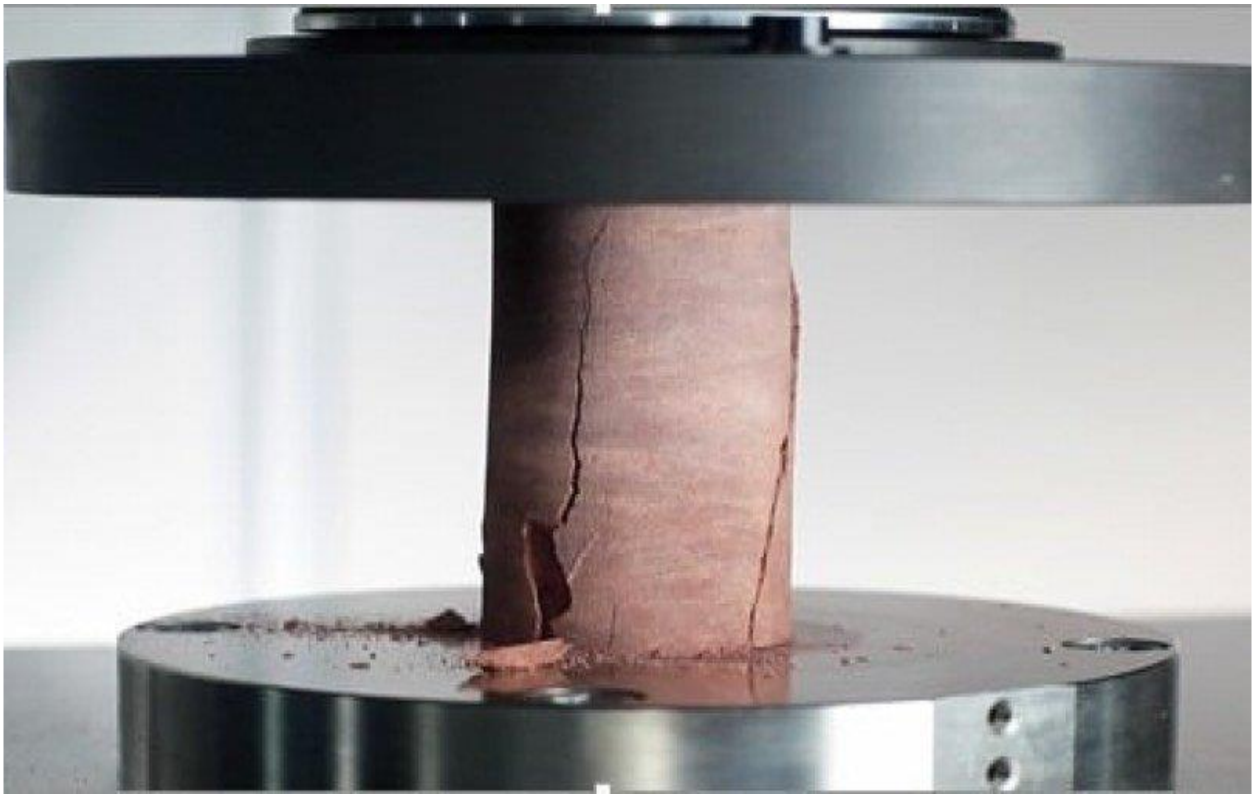
Fracturing of the wellbore is initiated when the rock stress changes from compression to tension. This was discussed in Chapter 9, Rock Strength and Rock Failure, when defining the tensile strength of rock material. By increasing the wellbore pressure, the circumferential (hoop) stress σ_ϑ reduces accordingly as per Eq. (11.31), and eventually falls under the tensile strength of the rock. Therefore, fracturing occurs at high wellbore pressures. A sequential schematic of fracture



As described in chapter: Rock Fracture and Rock Strength, in general conditions, rock is a brittle material. The weakness of brittle materials is that they are easily broken or fractured under tensile loads, particularly compared with compressive ones. In other words, their tensile strengths are often less than their shear strengths and much smaller than their compressive strengths, as shown by Eq. 3.12. Because shear cracks are seldom found in the micro-scale observations during rock tests, as described in chapter: Rock Fracture and Rock Strength

Rock	Tensile Strength (MPa)	Compressive Strength (MPa)
Limestone	18.00 ± 0.62 (20)	41.45 ± 3.52 (4)
Sandstone	19.17 ± 0.21 (23)	77.59 ± 1.59 (5)
Sandstone	23.10 ± 0.48 (19)	80.83 ± 2.21 (10)
Sandstone	24.21 ± 0.83 (8)	90.48 ± 3.86 (4)
Mudstone	35.17 ± 3.17 (4)	50.07 ± 3.79 (4)
Limestone	36.28 ± 1.24 (24)	142.55 ± 6.14 (5)
Limestone	38.76 ± 2.69 (23)	142.97 ± 19.10 (8)
Ironstone	44.28 ± 4.48 (5)	190.69 ± 17.93 (4)
Sandstone	65.66 ± 0.83 (11)	167.66 ± 9.86 (5)

Laboratory tests to determine strength of rocks :



Mechanical properties

Stress and strain

When a stress σ (force per unit area) is applied to a material such as rock, the material experiences a change in dimension, volume, or shape. This change, or deformation, is called strain (ε). Stresses can be axial—*e.g.,* directional tension or simple compression—or shear (tangential), or all-sided (*e.g.,* hydrostatic compression). The terms stress and pressure are sometimes used interchangeably, but often stress refers to directional stress or shear stress and pressure (*P*) refers to hydrostatic compression. For small stresses, the strain is elastic (recoverable when the stress is removed and linearly proportional to the applied stress). For larger stresses and other conditions, the strain can be inelastic, or permanent