PRE-MINING STATE OF STRESS

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Ref. Book
Rock Mechanics for Underground Mining (3rd Edition)
B.H.G. Brady & E.T. Brown

Chapter-5

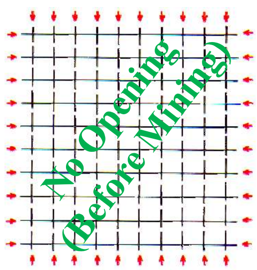
Why study stress?

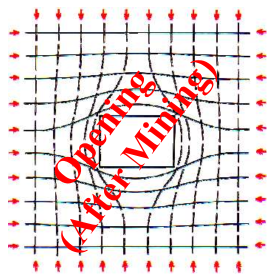
Stress is a concept which is fundamental to rock mechanics principles and applications. There are three basic reasons to understand stress in the context of engineering rock mechanics:

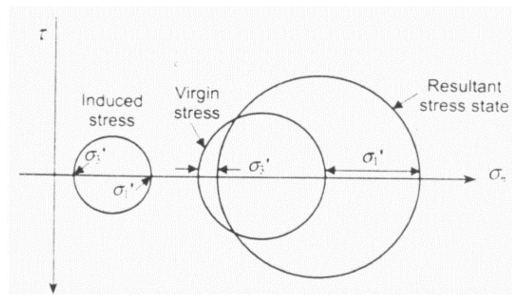
- There is a pre-existing stress state in the ground and we need to understand it, both directly and as the stress state applies to analysis and design.
- During rock excavation, the stress state can change dramatically. This is because rock, which previously contained stresses, has been removed and the loads must be redistributed.
- Stress is not familiar.

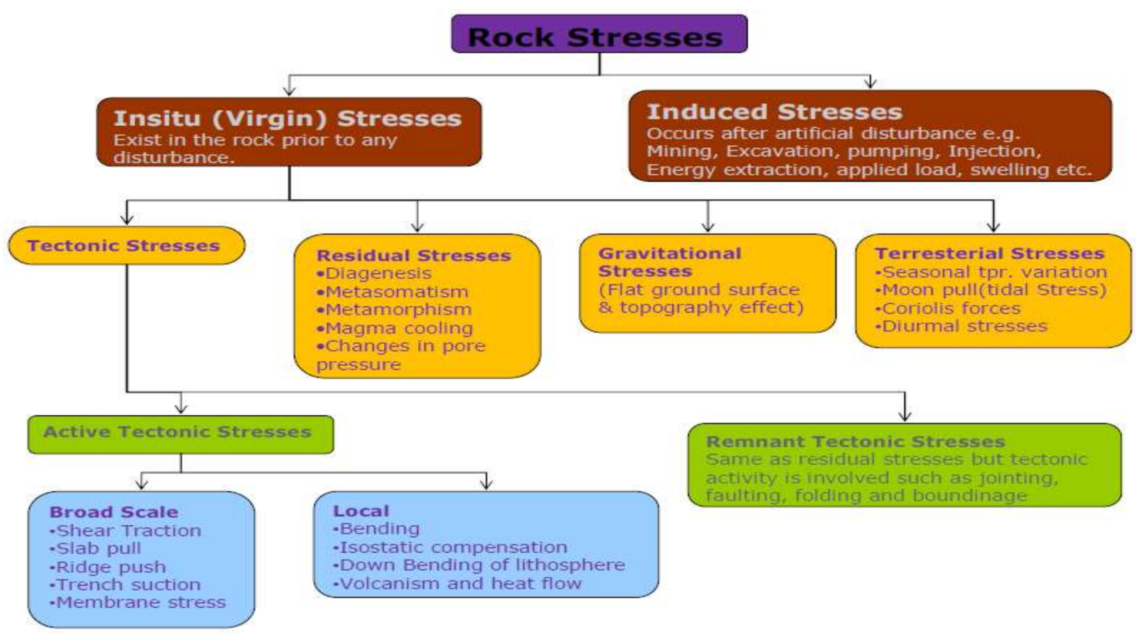
Pre-mining state of stress

An underground rock structure, the rock medium is subject to initial stress prior to excavation. The final, post-excavation state of stress in the structure is the resultant of the initial state of stress and stresses induced by excavation. Since induced stresses are directly related to the initial stresses, it is clear that specification and determination of the pre-mining state of stress is a necessary precursor to any design analysis.









Proposed by Bielenstein and Barron (1971)

In-situ stress

In-situ stresses are the stresses which developed due to weight of the overlying materials and also due to the confinement and the past stress history at a point below the rock surface of the undisturbed rock mass.

These stresses may vary considerably from one point to other. At some points these are zero whereas at other points they may be very high, even approaching the failure stress.

At a point where in-situ stress is zero, joints are formed in the rocks and it will ease the underground excavations, constructions etc. but if In-situ stress is very high, any small disturbance to the stress field by tunnelling or even excavation may trigger violent release of stored energy in rock and cause failure.

The basic motivations for in situ stress determination are two-fold:

- Engineering analyses require boundary conditions. One of the most important boundary conditions for the analysis of underground excavations is in-situ stress.
- To have a basic knowledge of the stress state (e.g. the direction and magnitude of the major principal stress; the direction in which the rock is most likely to fail; etc.).

Virgin stresses or undisturbed in situ stresses are the natural stresses that exist in the ground prior to any excavation. Their magnitude and orientation are determined by

– the weight of the overlying strata, and

– the geological history of the rock mass

In-situ vertical stress

As a first approximation, the principal in situ stresses can be assumed to act vertically (one component) and horizontally (two components).

For a geologically undisturbed rockmass, gravity provides the vertical component of the rock stresses. In a homogeneous rockmass, when the rock density γ is constant, the vertical stress is the pressure exerted by the mass of column of rock acting over level. The vertical stress component is assumed to increase with depth due to the weight of the overburden.

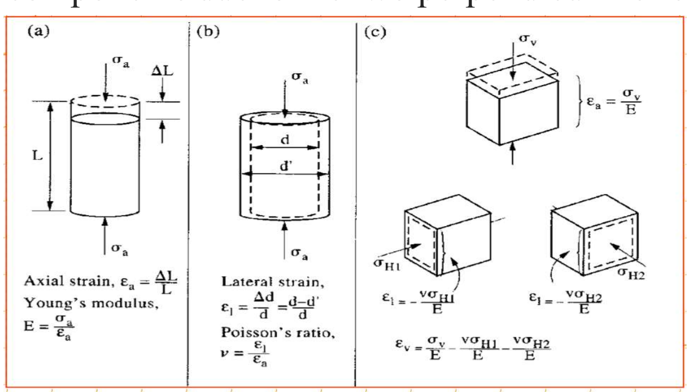
The vertical stress due to the overlying rock is then:

$\boldsymbol{\sigma_z = \gamma h}$ (Where h is depth, and γ is unit weight,.Pascal)

**** As a rule of thumb, taking the average density of rock into account, 40m of overlying rock induces 1 MPa stress.

In-situ horizontal stress

The horizontal stress can be estimated using of elastic theory. If we consider the strain along any axis of a small cube at depth, then the total strain can be found from the strain due to the axial stress, subtracting the strain components due to the two perpendicular stresses.



Hudson & Harrison (1997)

$$\in_v = \frac{\sigma_v}{E} - \frac{\gamma\sigma_{H1}}{E} - \frac{\gamma\sigma_{H2}}{E}$$

$$\in_{H1} = \frac{\sigma_{H1}}{E} - \frac{\gamma\sigma_{H2}}{E} - \frac{\gamma\sigma_v}{E}$$

To provide an initial estimate of the horizontal stress, two assumptions are made-

- the two horizontal stresses are equal;
- there is no horizontal strain, i.e. both ϵ_{H1} and ϵ_{H2} are zero (e.g. because it is restrained by adjacent elements of rock).

Then we can take ϵ_{H1} as zero: $\mathbf{0} = \frac{\sigma_{H1}}{E} - \frac{\gamma\sigma_{H2}}{E} - \frac{\gamma\sigma_v}{E}$

And, because $\sigma_{H1} = \sigma_{H2}$ then $\boldsymbol{\sigma_{H1}} = \frac{\gamma}{1-\gamma}\boldsymbol{\sigma_v}$

Thus the ratio between the horizontal and vertical stress (referred to as K = $\boldsymbol{\sigma_{H1}}/\boldsymbol{\sigma_v}$) is function of the Poisson's ratio: $\frac{\sigma_{H1}}{\sigma_v} = \frac{\gamma}{1-\gamma}$

**** For a typical Poisson's ratio (γ) of 0.25, the resulting K ratio is 0.33. For a theoretical maximum of γ = 0.5, the maximum K ratio predicted is 1.0.

Factors influencing the in situ state of stress

The ambient state of stress in an element of rock in the ground subsurface is determined by both the current loading conditions in the rock mass, and the stress path defined by its geologic history. The factors on in-situ stresses are:-

- ✓Surface topography
- ✓Erosion and isostasy
- ✓Residual Stress
- ✓Inclusions
- ✓Tectonic stress
- ✓Fracture sets and discontinuities

Methods of in situ stress determination

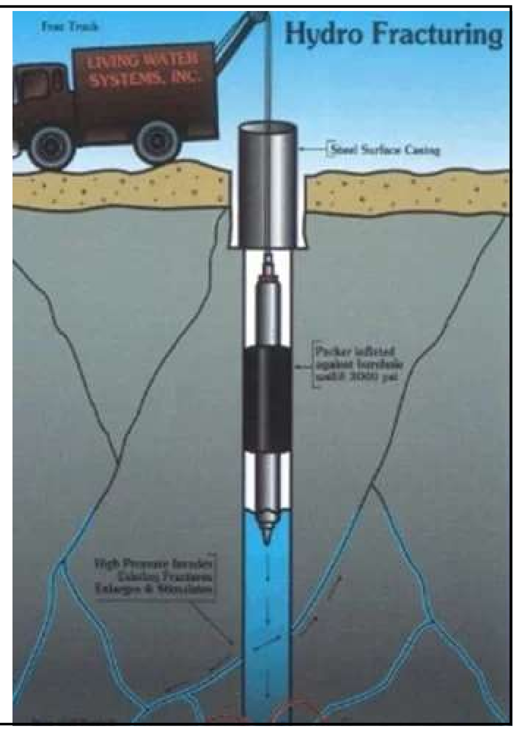
There are three commonly used methods for the determination of in-situ stresses in rocks

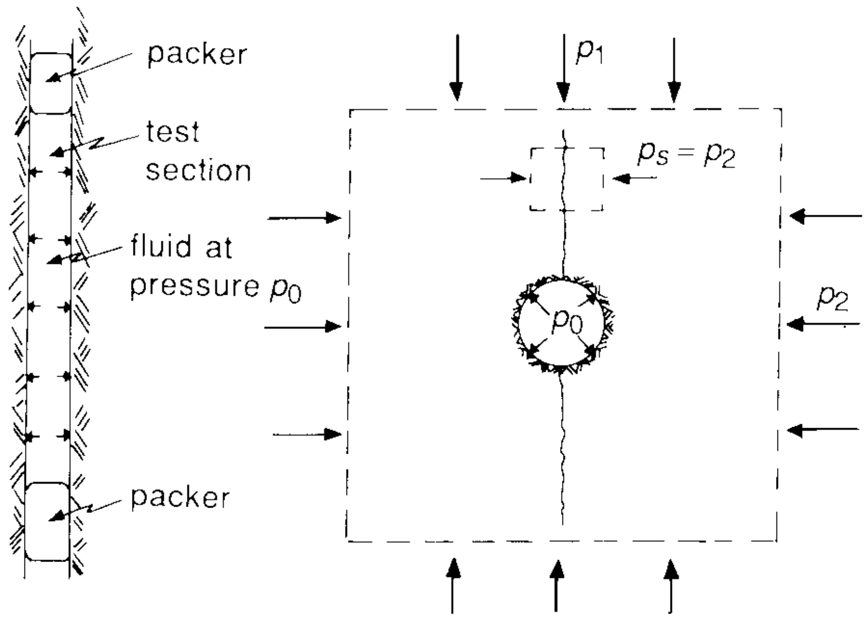
1. Hydraulic fracturing method
2. Flat jack method
3. Over coring method

Compared with overcoring, flatjacks and hydraulic fracturing, some other methods of estimating in situ state of stress are attractive by virtue of the relative ease with which the raw data for the stress determination can be recovered. Of particular interest in this regard are methods based on borehole breakouts, stress history gauging through the Kaiser effect, and differential strain curve analysis or deformation rate analysis.

Hydraulic fracturing method

In this method, water pressure is used to create a crack in bore hole. Water is pumped into a section of the bore hole isolated between two packers. As the water pressure is increased, initial compressive stress in rocks starts reducing and it becomes tensile at some stage. When the tensile stress & tensile strength of rock are equal a crack is formed in the bore hole wall. By continuing pumping, the hole extends further and eventually the pressure down the hole falls to a steady value, shut-in pressure. This method is used to determine in-situ stresses in rock only when the point is at considerable depth below the surface.



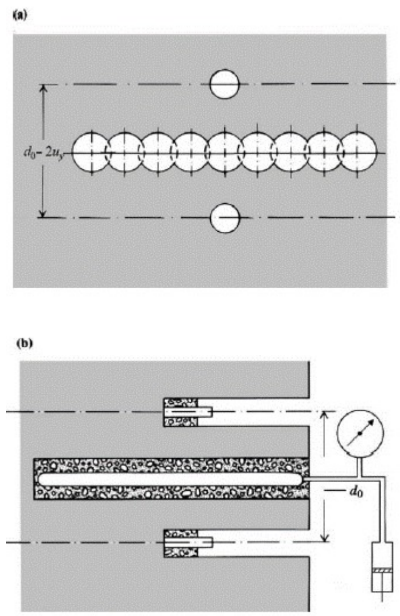


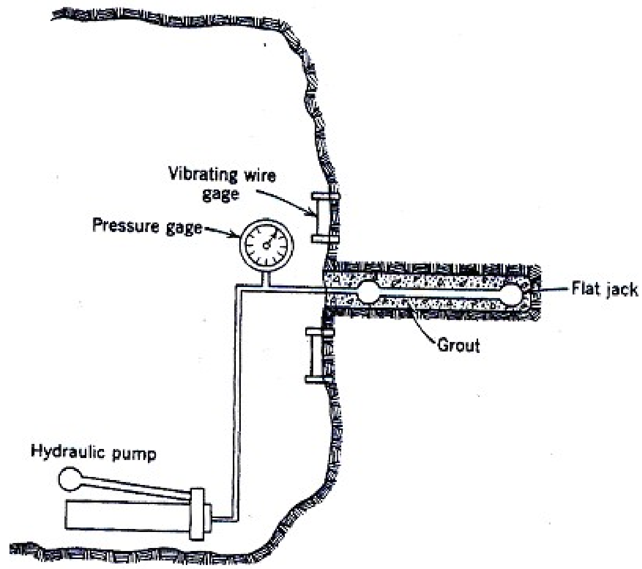
Flat Jack method

In flat jack method, a flat jack is inserted in the rock slot which was formed by cutting the rock with cutting tool. When the cutting is done deformation takes place surrounding the slot. Here, Insitu stress is related to the pressure needed to balance this deformation.

Firstly mark the location of slot and one or more measuring points are installed such that the location of the slot is midway between them. The spacing (d) of the measuring points is kept equal to the gauge length of extensometer.(which is generally 6 inches). Then slot is to be cut deeply, as a result of this cutting, the pins installed at measuring points move towards each other and spacing reduces between them due to initial compression of rock. Now place the flat jack and cemented it. The pressure in jack is gradually increased.

When the pins are returned to initial spacing, then we can say that pressure in jack is equal to the Insitu stresses. This method is used only when there is an access to a rock face.



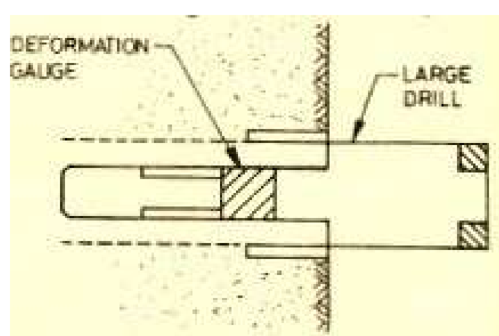


Over coring method

In this method, a small diameter bore hole is drilled into the rock and deformation gauge is inserted into it which measures the change in diameter.

Now, drill the large diameter bore hole concentrically over the small bore hole. Thus a thick cylindrical rock is formed, which is detached from the rock mass and is free of stress.

If the rock was under initial compression, there would be enlargement of diameter, which is measured with the help of deformation gauge. From this deformation values we can calculate the Insitu stresses in rocks.



This method can be used only to measure the Insitu stresses at some distance (up to 5m) away from the rock face.