Pre-mining state of stress

5.1 Specification of the pre-mining state of stress

The design of an underground structure in rock differs from other types of structural design in the nature of the loads operating in the system. In conventional surface structures, the geometry of the structure and its operating duty define the loads imposed on the system. For 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.

The method of specifying the in situ state of stress at a point in a rock mass, relative to a set of reference axes, is demonstrated in Figure 5.1. A convenient set of Cartesian global reference axes is established by orienting the x axis towards mine north, y towards mine east, and z vertically downwards. The ambient stress components expressed relative to these axes are denoted $p_{xx}$, $p_{yy}$, $p_{zz}$, $p_{xy}$, $p_{yz}$, $p_{zx}$. Using the methods established in Chapter 2, it is possible to determine, from these components, the magnitudes of the field principal stresses $p_i$ ($i = 1, 2, 3$), and the respective vectors of direction cosines ($\lambda_x$, $\lambda_y$, $\lambda_z$) for the three principal axes. The corresponding direction angles yield a dip angle, $\alpha$, and a bearing, or dip azimuth, $\beta$, for each principal axis. The specification of the pre-mining state of stress is completed by defining the ratio of the principal stresses in the form $p_1 : p_2 : p_3 = 1 : q : r$ where both $q$ and $r$ are less than unity.

The assumption made in this discussion is that it is possible to determine the in situ state of stress in a way which yields representative magnitudes of the components of the field stress tensor throughout a problem domain. The state of stress in the rock mass is inferred to be spatially quite variable, due to the presence of structural features such as faults or local variation in rock material properties. Spatial variation in the field stress tensor may be sometimes observed as an apparent violation of the equation of equilibrium for the global z (vertical) direction. Since the ground surface is always traction-free, simple statics requires that the vertical normal stress component at a
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sub-surface point be given by

\[ p_{zz} = \gamma z \]

where \( \gamma \) is the rock unit weight, and \( z \) is the depth below ground surface.

Failure to satisfy this equilibrium condition (equation 5.1) in any field determination of the pre-mining state of stress may be a valid indication of heterogeneity of the stress field. For example, the vertical normal stress component might be expected to be less than the value calculated from equation 5.1, for observations made in the axial plane of an anticlinal fold.

A common but unjustified assumption in the estimation of the \textit{in situ} state of stress is a condition of uniaxial strain (‘complete lateral restraint’) during development of gravitational loading of a formation by superincumbent rock. For elastic rock mass behaviour, horizontal normal stress components are then given by

\[ p_{xx} = p_{yy} = \left( \frac{\nu}{1 - \nu} \right) p_{zz} \]  

where \( \nu \) is Poisson’s ratio for the rock mass.

If it is also assumed that the shear stress components \( p_{xy}, p_{yz}, p_{zx} \) are zero, the normal stresses defined by equations 5.1 and 5.2 are principal stresses.

Reports and summaries of field observations (Hooker \textit{et al.}, 1972; Brown and Hoek, 1978) indicate that for depths of stress determinations of mining engineering interest, equation 5.2 is rarely satisfied, and the vertical direction is rarely a principal stress direction. These conditions arise from the complex load path and geological history to which an element of rock is typically subjected in reaching its current equilibrium state during and following orebody formation.

5.2 Factors influencing the \textit{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. Stress path in this case is a more complex notion than that involved merely in changes in surface and body forces in a medium. Changes in the state of stress in a rock mass may be related to temperature changes and thermal stress, and chemical and physicochemical processes such as leaching, precipitation and recrystallisation of constituent minerals. Mechanical processes such as fracture generation, slip on fracture surfaces and viscoplastic flow throughout the medium, can be expected to produce both complex and heterogeneous states of stress. Consequently, it is possible to describe, in only semi-quantitative terms, the ways in which the current observed state of a rock mass, or inferred processes in its geologic evolution, may determine the current ambient state of stress in the medium. The following discussion is intended to illustrate the role of common and readily comprehensible factors on pre-mining stresses.

5.2.1 Surface topography

Previous discussion has indicated that, for a flat ground surface, the average vertical stress component should approach the depth stress (i.e. \( p_{zz} = \gamma z \)). For irregular