1 Rock mechanics and mining engineering

1.1 General concepts

The engineering mechanics problem posed in all structural design is the prediction of the performance of the structure under the loads imposed on it during its prescribed functional operation. The subject of engineering rock mechanics, as applied in mining engineering practice, is concerned with the application of the principles of engineering mechanics to the design of the rock structures generated by mining activity. The discipline is closely related to the main streams of classical mechanics and continuum mechanics, but several specific factors identify it as a distinct and coherent field of engineering.

A widely accepted definition of rock mechanics is that first offered by the US National Committee on Rock Mechanics in 1964, and subsequently modified in 1974:

Rock mechanics is the theoretical and applied science of the mechanical behaviour of rock and rock masses; it is that branch of mechanics concerned with the response of rock and rock masses to the force fields of their physical environment.

Clearly, the subject as defined is of fundamental relevance to mining engineering because the act of creating mining excavations changes the force fields of the rock’s physical environment. As will be demonstrated throughout this text, the study of the response of the rock to these changes requires the application of analytical techniques developed specifically for the purpose, and which now form part of the corpus of the subject. Rock mechanics itself forms part of the broader subject of geomechanics which is concerned with the mechanical responses of all geological materials, including soils.

Application of rock mechanics principles in underground mine engineering is based on simple and, perhaps, self-evident premises. First, it is postulated that a rock mass can be ascribed a set of mechanical properties which can be measured in standard tests. Second, it is asserted that the process of underground mining generates a rock structure consisting of voids, support elements and abutments, and that the mechanical performance of the structure is amenable to analysis using the principles of classical mechanics. The third proposition is that the capacity to predict and control the mechanical performance of the host rock mass in which mining proceeds can assure or enhance the economic performance of the mine. This may be expressed in practice by the efficiency of resource recovery, measured in terms of volume extraction ratio, mine productivity or direct economic profitability. These ideas may seem rather elementary. However, even limited application of the concepts of mechanics in mine excavation or mine structural design is a comparatively recent innovation.
It is instructive to consider briefly some of the mechanical processes which occur as rock is excavated during underground mining. Figure 1.1a represents a cross section through a flat-lying, uniform orebody. ABCD and EFGH represent blocks of ore that are to be mined. Prior to mining; the material within the surfaces ABCD and EFGH exerts a set of support forces on the surrounding rock. Excavation of the orebody rock to produce the rock configuration of Figure 1.1b eliminates the support forces; i.e. the process of mining is statically equivalent to introducing a set of forces on the surfaces ABCD and EFGH equal in magnitude but opposite in sense to those acting originally. Under the action of these mining-induced forces, the following mechanical perturbations are imposed in the rock medium. Displacements of the adjacent country rock occur into the mined void. Stresses and displacements are induced in the central pillar and abutments. Total, final stresses in the pillar and abutments are derived from both the induced stresses and the initial state of stress in the rock mass. Finally, the induced surface forces acting through the induced surface displacements result in an increase of strain energy in the rock mass. The strain energy is stored locally, in the zones of increased stress concentration.

The ultimate objective in the design of a mine structure, such as the simple one being considered here, is to control rock displacements into and around mine excavations. Elastic displacements around mine excavations are typically small. Rock displacements of engineering consequence may involve such processes as fracture of intact rock, slip on a geological feature such as a fault, excessive deflections of roof and floor rocks (due, for example, to their detachment from adjacent rock), or unstable failure in the system. The latter process is expressed physically as a sudden release of stored potential energy, and significant change in the equilibrium configuration of the structure. These potential modes of rock response immediately define some of the components of a methodology intended to provide a basis for geomechanically sound excavation design. The methodology includes the following elements. The strength and deformation properties of the orebody and adjacent country rock must be determined in some accurate and reproducible way. The geological structure of the rock mass, i.e. the location, persistence and mechanical properties of all faults and other fractures of geologic