9 Excavation design in jointed rock

9.1 Design factors

A jointed rock mass presents a more complex design problem than considered previously. The complexity arises from either the number (greater than two) of joint sets which define the degree of discontinuity of the medium, or the presence of a discrete structural feature transgressing such a simply jointed system as a cross-jointed, stratified mass. The problem which arises in these types of media is the generation of distinct rock blocks, of various geometric configurations defined by the natural fracture surfaces and the excavation surface, as illustrated in Figure 9.1. Since the blocks exist in the immediate periphery of an excavation whose surface has been subject to the removal of support forces by the mining operation, the possibility arises of collapse of the block assembly in the prevailing gravitational and local stress fields.

The issues to consider in the design of an opening in a jointed medium are a natural extension of those proposed for the structurally simpler media considered previously. That is, it is necessary initially to determine the likelihood of induced fracture in the rock mass, in the total stress field after mining. For continuous features, such as faults or bedding planes which persist over dimensions exceeding those of the excavation, it is necessary to examine the possibility and consequences of slip under excessive shear stress. Also, since joints have effectively zero tensile strength, a jointed rock mass is unequivocally a no-tension medium. Any part of a jointed medium which is notionally subject to tensile stress will, in fact, de-stress. The process of de-stressing a discontinuum implies loss of control, and possibly local collapse of the medium. Stable, continuous behaviour
of a jointed or granular medium exploits frictional resistance to shear stress, and this resistance is mobilised by compressive normal stress. Thus generation and maintenance of a state of mechanically sustainable compressive stress in the excavation peripheral rock is a basic principle of design in this type of medium.

In addition to considering the quasi-continuous behaviour of a jointed medium in compression, it is also necessary to take account of its explicitly discontinuous properties. Since the rock mass prior to mining consists of an assembly of topographically matched blocks delineated by the joint surfaces, it is necessary to predict the behaviour of the individual blocks when an adjacent surface is developed. For blocks defined in the crown and side walls of an excavation, the requirement is to examine the potential for displacement of each block under the influence of the surface tractions arising from the local stress field, the fissure water pressure and the gravitational load.

9.2 Identification of potential failure modes

The initial phase of the design of an opening in jointed rock follows the methodology defined in Figure 7.1, for design in a continuous medium. This procedure seeks to limit or control the consequences of induced fracture in the rock mass. In the case of jointed rock masses, overall rock mass strength criteria of the type discussed in section 4.8 should be used. Examples of such applications are given by Hoek and Brown (1980). Subsequent analyses to assess effects such as slip and separation on major planes of weakness also employ the general principles established in Chapter 7. In low-stress settings, of course, the strength of the rock mass may obviate any need for the detailed stress analysis proposed in the general design strategy.

In dealing with the specific problems posed by discontinuities in the rock mass, there are two basic analytical requirements. The first is to identify the modes of potential collapse in the block assemblage. The second is to determine the state of equilibrium of the rock blocks and prisms which are involved in the identified collapse modes.

Potential collapse modes are defined by detailed examination of the configuration of blocks identified from the known geometric properties of the discontinuities in the side walls and crown of the excavation. The simplest procedure is to present the known structural data on a stereonet, and to infer the shapes of the blocks generated by the discontinuities and a particular surface of the excavation. By comparing the orientations of the various lines of intersection of the planes which define a block geometry with the inferred direction of the resultant force on the block, kinematically possible directions of displacement of the block can be established. In carrying out this geometric analysis, particular attention must be paid to the crown of the opening, since an obvious mode of collapse is simple detachment of rock prisms in this zone, under gravity load. However, subtle and consequential modes of collapse can also arise in the side walls of an excavation. The intention here is to indicate how unfavourable block geometry and kinematically feasible displacement paths can be recognised, using a stereographic presentation of the appropriate geometric data representing an excavation surface and the structural features.