CHAPTER 11
SEEPAGE CONTROL IN ROCK FOUNDATIONS AND ABUTMENTS

11-1. General Considerations.

a. The choice of seepage control methods to use in rock foundations and abutments is dependent on a number of factors. Characterization of the foundation or abutment and identification of potential seepage paths is essential. Before any method of seepage control is implemented, the area must be thoroughly explored and tested to assure that the method chosen will apply to the general conditions as well as the conditions locally encountered and will serve the intended purpose. In many cases, a combination of methods can be used to the best advantage for rock foundations or abutments. The use of different control methods becomes particularly important when there is a change in the character of the foundation from one location to another, or a change in seepage characteristics between the foundation and the abutment.

b. Seepage should be cut off or controlled by drainage whenever economically possible. Safety, however, must be the governing factor for selecting a seepage control method. It should be noted that the possibility exists for control measures to cause substantial increases in seepage rather than decreases. Such increases are normally accompanied by reductions in uplift pressures and are therefore desirable if the increased seepage produces no detrimental side effects. In the final choice of a seepage control method, or methods, economic factors must be recognized and evaluated.

11-2. Cutoff Trenches.

a. No cutoff is 100 percent impervious and therefore the reduction in seepage from cutoff trenches is a relative matter. Cutoff trenches are normally employed where the character of the foundation is such that the construction of a satisfactory or effective grout curtain is not practical. Such trenches, when constructed, are normally backfilled with compacted impervious material, bentonite slurry, or neat cement.

b. Construction of trenches in rock foundations and abutments normally involves blasting using the presplit method with primary holes deck-loaded according to actual foundation conditions. After blasting, excavation is normally accomplished with a backhoe. Cutoff of seepage within the foundation is obtained by connecting an impervious portion of the foundation to the impervious portion of the structure by backfilling the trench with an impervious material. In rock foundations, as in earth foundations, the impervious layer of the foundation, in some cases, may be sandwiched between an upper and a lower pervious layer, and a cutoff to such as impervious layer would reduce seepage only through the upper pervious layer. However, where the thicknesses of the impervious and upper pervious are sufficient, the layers may be able to resist the upward seepage pressures existing in the lower pervious layer and thus remain stable. Cutoff of seepage within the abutment is normally obtained by extending the cutoff from above the projected seepage line to an impervious layer within the abutment. The type of backfill material is normally dictated by condition of the foundation or abutment, economics, and degree of cutoff required.

11-3. Abutment Impervious Blankets.

a. Impervious blankets overlying the upstream or riverside face of pervious abutments, or foundations, are effective in reducing the quantity of seepage and to some extent will reduce uplift pressures and gradients downstream. An impervious blanket may be used for earthen or rock abutments; however, a filter material is normally required with rock abutments.

b. The construction of impervious blankets is particularly adaptable to treating exposed pervious areas of abutments which are adjacent to the main structure. In cases where a natural impervious blanket exists on the abutment, ranging in depth from a few feet to many feet, full advantage should be taken of the existing material. Upstream borrow along the abutment should be controlled to prevent excessive excavation of the natural impervious top blanket. Conversely, localized areas which are thin and weak should be reinforced by the addition of additional impervious material.

c. Blankets may sometimes give adequate control of seepage water for low head structures, but for high head structures it is usually necessary to incorporate a downstream drainage system as a part of the overall seepage-control design. The benefits derived from abutment impervious blankets are due to the dissipation of a part of the reservoir head through the blanket. The proportion of head dissipated is dependent upon the thickness, length, and effective permeability of the blanket in relation to the permeability of the adjacent soil, or rock.

11-4. Drainage and Grouting Galleries and Tunnels.

a. Foundation galleries and tunnels in concrete gravity dams provide an exit for foundation drains and convenient facilities for rehabilitation work, or supplemental grouting, if required. The depth of drainage galleries, or exit elevation of the drains, with respect to the tailwater, controls the uplift downstream of the drains or wells. Generally, the lower the elevation of the gallery, the more reduction in head, or uplift, is experienced. If the depth of the drainage gallery is located and the gallery discharges at the elevation of the tailwater, the magnitude of the uplift downstream of the wells is normally very modest. The uplift, however, is controlled by well spacing, well efficiency, and other seepage control measures, such as grout curtains and cutoffs, in addition to the elevation of the drainage gallery and the elevation at which it discharges. In special cases where the drainage gallery is very deep, i.e., below tailwater, it is possible to actually create a negative uplift on the base of a dam. In such cases some of the seepage pumped from the drainage gallery flows through the foundation to the drains from downstream.

b. Grouting curtains are frequently centered along drainage galleries or tunnels. Remedial or supplemental' grouting may be performed from within drainage tunnels. The additional grouting may be performed vertically or in inclined, or sloping, boreholes. Also, should excessive uplift pressures become evident, additional grouting to widen or deepen the curtain may be performed or additional drainage wells may be installed from the gallery to relieve excess pressures.

11-5. Grouting of Foundations and Abutments.

a. The Corps' grouting methods have become less standardized in recent years (Albritton, Jackson, and Banget 1984). Typically, however, a combination of a line of drainage holes and a grout curtain provide an efficient and effective seepage control method. A properly installed grout curtain in the foundation of a structure not only provides a substantial reduction in seepage but also reduces the uplift pressures downstream of the curtain. Conveniently, for the great majority of dam sites, irrespective of type of rock, strike and dip of strata, and faulting conditions, the pervious zone which requires seepage control is relatively shallow and lends itself readily to control by grouting. A comprehensive coverage of drilling methods, as well as grouting methods, is presented in EM 1110-2-3506.

b. Grouting operations in foundations and abutments are not limited to construction of grout curtains. Grouting may be used for foundation repair and filling cavities or voids in limestone or carbonate formations. The requirement for a single- or multiple-line grout curtain is dictated by the condition and integrity of the foundation as determined from preconstruction exploration.

c. Grouting of steep abutment slopes has the potential for causing difficulties and possibly can do more harm than good. Care must be exercised when grouting in abutments to avoid displacements within the rock mass. Even relative low grouting pressures can cause joint opening and decrease the integrity of the abutment.

d. In general the efficiency of a grouting operation for controlling seepage in well graded sediments is proportional to the width of the curtain. In rock foundations and abutments the seepage control accomplished by grouting is not a function of width, however, but is dictated by the effectiveness of sealing seepage paths and open joints identified in the exploration program. The effectiveness of a grouting operation may be evaluated by pre- and post-grouting pressure injection tests for evaluating the water take and the foundation or abutment permeability.

11-6. Surface Treatment of Foundations and Abutments.

a. Surface treatment of foundations and abutments is essential to ensure intimate contact of backfill materials with sound rock. Once a foundation is exposed by excavation, the method of treatment and potential protection against piping of embankment or abutment materials will be dictated by the conditions encountered. All cavities, or caves, should be cleaned and plugged with concrete, both upstream and downstream from the core trench. All openings, fissures, joints, etc., should be cleaned after excavation and treated with dental concrete, where possible. Treatment with dental concrete stops major deterioration of materials that weather rapidly during construction, and helps to prevent lateral piping of the embankment material into the adjacent foundation.

b. If a well-developed, highly solutioned joint system, or similar condition is encountered in the abutment, thick concrete walls may be placed against the abutment. Prior to placement of concrete walls the abutment face must be set back and cleaned, with presplitting being occasionally required.

Concrete walls offer the advantage of either filling or blocking cavities, affording a reasonable condition for treatment by grouting, and provide an abutment "tie-in" for fill placement with ideal conditions for maximum compaction of the adjacent embankment.