Chapter 6
Miscellaneous Construction Features

6-1. River Diversion

Control of the river during construction is accomplished by the construction of cofferdams and rerouting of the river to permit foundation preparation and construction of the embankment in the dry. In narrow steep valleys, a diversion tunnel is usually constructed in one of the abutments, and the river is diverted through the tunnel by an upstream cofferdam. A downstream cofferdam may also be required to control the tailwater. In wide valleys, after construction of the outlet works and most of the embankment except for a gap at the river, river flow is diverted through the outlet works. To do this, it may be necessary to excavate a diversion channel from the river and to block off the river channel by dumping fill. An earth cofferdam can then be constructed upstream across the gap, tying into embankment sections already constructed, or as the case may be, to an abutment on one side. Following construction of a downstream cofferdam, if needed, the foundation of the closure section of the dam is prepared in the dry and the closure section constructed. Cellular-type cofferdams constructed in connection with lock-and-dam projects are beyond the scope of this manual, and only embankment-type cofferdams are discussed below.

a. Cofferdams. The schedule and method of cofferdam construction and the degree of construction and control required are influenced by the diversion scheme. Sometimes the cofferdams can be built in the dry using normal embankment construction procedures, but in other cases cofferdam construction may involve placement of fill under water. Current Corps of Engineers policy requires that the location, sequence of construction, source of materials, zonation, section geometry, top elevations, construction methods, and time schedule be specified.

(1) River closure. Cofferdam construction for river closure can be accomplished by placing loose material such as earth, sand, gravel rock, or precast concrete elements from one bank to the other. The type of material required depends on the severity of river currents. The closure should be scheduled during low river stages when conditions are favorable for embankment placement and flood possibility is at a minimum. Two methods of placement are generally used. One is the end fill method, as shown in Figure 6-1, where fill is dumped or pushed off the end of the embankment to advance it across the river. The other is the level method, in which the fill is placed across the river at the same height. The first method is simpler, but may require large rock or concrete elements to withstand erosion by high current velocities caused by the channel width reduction. The second method keeps velocities low, since water flows over a long section of the cofferdam crest as it is being built. However, special facilities such as a bridge or trestle, a cableway, or barges may be required over deep water to provide a means of dumping fill into the river. In addition, continuous monitoring of underwater fill elevations is required to detect detrimental erosion. A summary of construction methods and equipment used in cofferdam construction is found in EM 1110-2-1602.

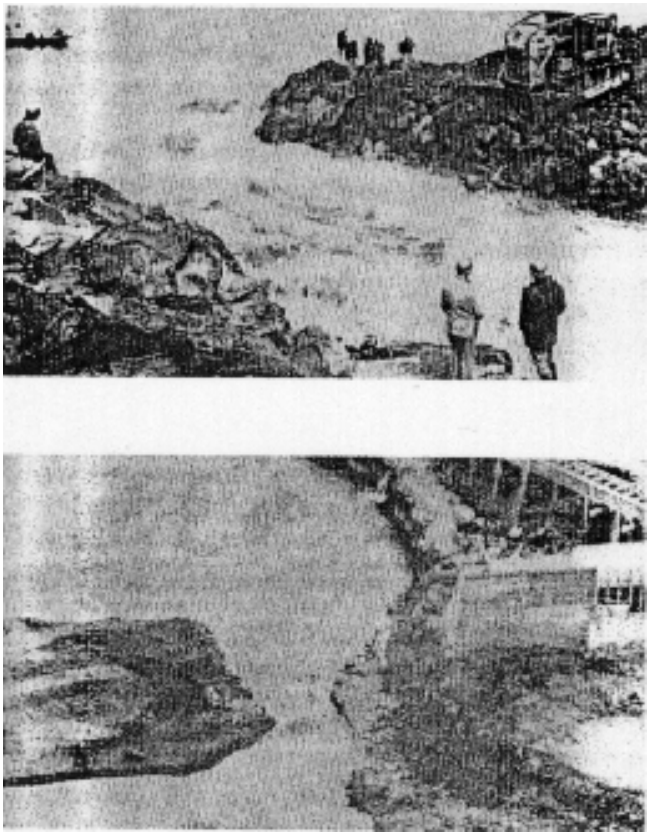

Figure 6-1. Examples of end fill closure method. (a) River closure, cofferdam, Mica Dam, British Columbia; (b) two days before final closure, Dalles Closure Dam, Columbia River

(2) Design and construction requirements.

(a) Normally, cofferdams will be designed by the Government and the contractor may be permitted to recommend changes leading to a superior or more economical and adequate plan (ER 1110-2-8152). Design of a cofferdam by the contractor is allowed only when the construction schedule provides ample review and design time to ensure a competent and safe design or where no major damage or

significant delays would occur from a failure. Compaction procedures as well as other pertinent construction aspects, including construction and surveillance requirements, would be covered in the contract plans and specifications. Inspection and control testing, as outlined in Chapter 5, are required especially for cofferdams which will become part of the dam to ensure compliance with specifications or to determine when specified procedures need to be modified. The safety of cofferdams depends to a large extent on competent construction. Intensive inspection is required to ensure compliance with design requirements and safe construction practices. A contract requirement for quality control by the contractor does not relieve resident inspection forces from performing necessary and adequate inspection and surveillance.

(b) Slopes of temporary cofferdams depend on the type of material used, degree of compaction, and their height. Cofferdams are often designed on the basis of past experience. If the contractor is permitted to design a cofferdam, it should be required that an analysis of slope stability with plans for construction be furnished. Slopes of cofferdams designed by the Government are specified in the contract drawings.

(c) Seepage under cofferdams and through uncompacted rock-fill cofferdams can be a serious problem unless seepage control provisions such as a cutoff and/or an upstream impervious zone are included. For cofferdams designed by the Government the plans provide necessary measures for controlling underseepage and through-seepage. However, particular attention should be given to any contractor's plans for temporary cofferdams to ensure that adequate seepage control measures are included. It is also important that where thin upstream blankets are placed against rock-fill or coarse gravel, careful attention be given to providing properly graded transitions between the impervious and coarser materials.

(3) Slope protection. Slope protection against wave action is usually not required for cofferdams. However, where a river is restricted to a channel by temporary cofferdams prior to diversion, slope protection against current action may be required. EM 1110-2-1601 should be referred to for guidance on rock weights required to resist various current velocities.

b. Closure sections. After portions of the dam have been constructed with the river confined to a natural or constructed channel, cofferdams are constructed to divert the river through the outlet works so that the closure section can be constructed in the dry. This may cause flooding of upstream borrow areas, in which case alternate borrow areas or stockpiling of borrow materials for the closure section should be considered prior to river diversion.

(1) Foundation preparation and fill compaction. Clearing, stripping, and cleaning of the foundation area in the closure section must be carefully inspected to ensure an adequate foundation. The closure section is generally the highest section of the dam and is constructed to final grade in a much shorter time than the rest of the embankment; consequently, special emphasis on inspection and control testing is justified to ensure that proper materials are placed at the specified water contents and compacted to the desired or specified densities.

(2) Cleaning of adjacent embankment slopes. Riprap placed on the end slopes of completed embankment sections to prevent stream erosion must be removed prior to placing fill for the closure section. In addition, the end slopes must be cut back as necessary to provide unweathered and adequately compacted material adjacent to the closure section fill.

(3) Observations during construction. Because of the rapid construction, the following problems may occur in earth-fill closure sections:

(a) High excess pore water pressures in impervious zones of the embankment and in impervious foundations.

(b) Transverse cracking between the closure section and previously completed embankment sections caused by differential settlement.

(c) Bulging of outer slopes of largely impervious sections from the use of material which is too wet.

The procedures for construction and criteria for compaction stipulated in the plans and specifications for minimizing these problems may include drainage layers in the embankment and at the contact between embankment and foundation (*but never under or through an impervious core*) to help dissipate pore pressures, flattening of slopes, and fill water contents wet of optimum to provide a more plastic fill to minimize cracking. The use of higher fill water contents may, however, accentuate problems of bulging and high pore water pressures. If potential problems are indicated, surface movements data and piezometer readings must be obtained daily and continuous plots maintained so that the development of excessive pore water pressures and/or bulging can be detected early and corrective action taken. Corrective measures taken after consultation with the design office may include slowing down fill placement, removal of

fill, flattening slopes, addition of stability berms, or installation of drains.

6-2. Stage Construction

a. Stage construction refers here to construction of an embankment in stages with substantial intervals of time during which little or no fill is placed. This may be necessitated by environmental conditions which make the construction season very short or because fill placement must be restricted or even stopped to allow excess pore water pressure in the foundation and/or fill to dissipate.

b. Important features of construction control for stage construction include the following:

(1) Review of contractor's plans of operation as required by specifications to establish the adequacy of methods and procedures, and field inspection to ensure that approved time schedules and construction methods and procedures are followed.

(2) Inspection to ensure that the surfaces of completed sections of embankment on which additional fill will not be placed for several months are sealed and/or shaped to drain readily to prevent saturation and adequately protected against erosion.

(3) Inspection to ensure that outside slopes of stage-constructed embankments that will eventually form the final slopes of the dam are within specified tolerances.

(4) Observation and evaluation of piezometer and settlement data for soft foundations and consultation with the design office to determine when fill placement can be safely resumed. The design office has the responsibility to determine when fill placement can be resumed.

(5) Inspection to ensure that protective materials such as riprap, grass sodding, and trash or other debris are removed from previously completed embankment surfaces prior to resuming fill placement.

(6) Inspection of completed embankment surfaces prior to resuming fill placement to determine the need for removal of pervious surfaces materials which have become contaminated with fines or recompaction of surface materials where water content and density are unsatisfactory. Field density and water content tests should be performed to check visual observations.

6-3. Surface Drainage Facilities

Temporary surface drainage facilities are required to keep surface runoff and slope seepage out of excavations, to prevent contamination of filter zones by muddy runoff, to prevent saturation of loose fill before and during compaction, and to prevent ponding of water on compacted fill. Surface drainage is the responsibility of the contractor, as the specifications require certain phases of foundation preparation and embankment construction to be performed in the dry. Past field experience has shown that the provision and maintenance of adequate drainage have frequently been neglected, and more attention needs to be given to them by the inspection force. Grading to direct surface water away from excavations, ditching to intercept water before it reaches an excavation or work area, provision of sumps to collect seepage water, and pumping from the sumps are common means of handling surface drainage. The extent of needed facilities is dependent on the frequency, intensity, and seasonal distribution of precipitation. For permanent drainage facilities for roads and other features, reference should be made to TM 5-820-4.

6-4. Service Bridge Pier Foundations

Piers for service bridges to intake structures are sometimes constructed during early stages of embankment construction. At several dams, lateral deformations of the embankment under the stresses imposed by fill placed after pier construction have caused significant upstream movements of the piers. Therefore, construction of piers should be delayed until the embankment has been carried to near its final height. After construction of the piers, surveys should be made at regular intervals to monitor any movement of the piers no matter what steps are taken to prevent movement.

6-5. Instrumentation

Instrumentation of earth and rock-fill dams includes piezometers, slope indicators, settlement devices, surface movement monuments, internal vertical and horizontal movement indicators, and seismic movement devices (see paragraph 7-3 for required records). Seismic movement devices are described in detail in ER 1110-2-103. Various types of instrumentation devices, procedures for installation, observation and maintenance, frequency of observations, collection, recording, analysis, and reporting of data, and possible causes of malfunctions are discussed in EM 1110-2-1908. The basic description and operating mechanism of instruments generally installed in embankment dams are

given in Appendix E. A comprehensive reference on geotechnical instrumentation for monitoring field performance including calibration, use, installation, and maintenance is given in EM 1110-2-1908.

a. Installation. Installation of instrumentation devices, particularly electronic types, should be supervised, if not actually done, by experienced personnel from within the Corps of Engineers or by firms specializing in instrumentation installation. The Resident Engineer staff must be familiar with the planned locations of all instruments and appurtenant apparatus or structures (such as trenches for piezometer lines and terminal house, etc.) so that necessary arrangements and a schedule for installation can be made with the contractor and/or with the office or firm that will install the devices. Inspectors should inspect settlement gauges furnished and installed by the contractor. Records must be made of exact locations and procedures used for installation and initial observations. Riser pipes, tubes, or leads extending above the embankment surface must be protected from damage by earth mounds, guard posts, or other means. Inspectors should ensure that necessary extensions are added as the fill is constructed to higher elevations. This feature of construction generally occurs at a time when the contractor is anxious to begin or accelerate embankment construction. Therefore, patience, cooperation, and understanding must be exercised by the contractor and the Resident Staff.

b. Observations. Schedules for observations during construction are generally established by the design office. Pore pressure piezometers are observed frequently during construction to provide data for use in slope stability checks and to control, if necessary, the rate of fill construction on soft foundations. Initial observations should be checked to ensure their validity and accuracy, since these readings usually form the basis to which subsequent observations are related. Observations should be plotted immediately after each set of readings is taken and evaluated for reasonableness against the previous set of readings. In this way, it is often possible to detect errors in readings and to obtain check readings before significant changes in field conditions occur. On large projects all records should immediately be processed by computers. This will generally result in the quickest results with a minimum amount of effort. Possible sources of errors other than erroneous readings are discussed in EM 1110-2-1908. ER 1110-2-1925 prescribes the forms for recording instrumentation data and instructions for reporting them.

6-6. Haul Roads, Maintenance Roads, and Public Roads

Haul roads are temporary roads built by the contractor for access to work areas. Maintenance roads (or service roads) are temporary or permanent roads for access by Government forces to facilities requiring maintenance. Public roads include relocated permanent roads and roads for access to public-use facilities at the site.

a. Haul roads. Haul roads, although usually not shown on the plans, should be discussed in the specifications in general terms. The contractor should be required to submit detailed plans for all haul road layouts including grades, widths, locations, and post-construction obliteration and cleanup. Construction control consists generally of seeing that the contractor maintains and operates on the haul roads in accordance with sound safety practices, and enforces adequate traffic control where public-use roads are crossed. Haul roads should not be located near the edge of excavated slopes where the weight of road fill and/or heavy equipment or ponding of water could endanger the stability of slopes. Haul roads up embankment slopes should be scabbed on the outside or final embankment slope and relocated periodically where highly compacted zones could develop in the embankment under the road which could lead to cracking. The contractor should be required to remove haul roads that would endanger slope stability. The practice of placing pervious material across impervious zones to support heavy hauling equipment should be discouraged. If allowed, all pervious material must be carefully removed. Lastly, it is important that environmental considerations be made in connection with haul roads so that no permanent scars in the project aesthetics remain.

b. Maintenance and public roads. Construction control of maintenance or surface roads and public roads is required to ensure compliance with specifications relating to fill, filter, base coarse, and pavement materials; compaction of fills, subgrades, base course, and wearing course; and installation of drainage structures. Field compaction control is similar to that required for earth fill as discussed in Chapter 5.