Chapter 1
Introduction

1-1. Purpose

The purpose of this manual is to provide information and guidance on the use of roller-compacted concrete (RCC) in dams and other civil works structures. This manual does not cover RCC for pavements. Elements discussed include investigation and selection of materials, mixture proportioning, design and construction considerations, construction equipment and techniques, inspection, and performance. This manual is intended to serve as a companion to Engineer Manual (EM) 1110-2-2000, "Standard Practice for Concrete for Civil Works Structure." The user of this manual should have a copy of EM 1110-2-2000 and the references listed therein.

1-2. Applicability

This manual applies to all USACE Commands having civil works responsibilities.

1-3. References

Required and related references are listed in Appendix A.

1-4. Definition

The American Concrete Institute (ACI) 116R[1] defines RCC as "concrete compacted by roller compaction; concrete that, in its unhardened state, will support a roller while being compacted." Properties of hardened RCC can be similar to those of conventionally placed concrete. However, RCC can also be made with hardened properties that are outside the range of typical properties of conventionally placed concrete. The term "roller compaction" is also defined by ACI as "a process for compacting concrete using a roller, often a vibrating roller." The terms "rollcrete" and "rolled concrete" are no longer to be used.

1-5. Applications

RCC may be considered for application where no-slump concrete can be transported, placed, and compacted using earth and rock-fill construction equipment. Ideal RCC projects will involve large placement areas, little or no reinforcement, and little or no embedded metal work or other discontinuities such as piles. Application of RCC should be considered when it is economically competitive with other construction methods. It may be considered in lieu of gabions or riprap for bank protection, especially in those areas where riprap is scarce. It may be considered for large work pads, aprons, or paved areas, massive open foundations, base slabs, cofferdams, massive backfill, emergency repairs, and overtopping protection for embankment dams. It may be used in lieu of conventionally placed concrete in concrete gravity and arch-gravity dams. RCC may be considered for use in levees where foundations are adequate and may also be used in caps for jetties to reduce the amount of required rock. For many dam projects, the use of RCC may allow a more economical layout of project features such as an over-the-crest spillway as opposed to a side channel spillway for a comparable embankment dam. A comprehensive summary of RCC dams with heights greater than 15 m (50 ft) has been compiled by Dunstan (1997). A wide range of performance objectives is possible with RCC. Structures designed in a manner similar to those utilizing conventional concrete can be constructed using RCC with many of the same characteristics. It is also possible to design structures requiring less demanding performance, consequently making them more economical.

[1] All ACI references are listed with detailed information in Appendix A.

1-6. Objective of RCC Operations

RCC was initially developed to produce a material exhibiting the structural properties of concrete with the placing characteristics of embankment materials. The result was a material that, when properly designed and constructed as a gravity structure, should be more economical than comparable earth-rockfill and conventional concrete structures. To achieve the highest measure of cost effectiveness and a high-quality product similar to that expected of conventional concrete structures, the following RCC design and construction objectives are desired: RCC should be placed as quickly as possible; RCC operations should include as little manpower as possible; RCC design should avoid, as much as possible, multiple RCC mixtures and other construction or forming requirements that tend to interfere with RCC production; and RCC design should minimize complex construction procedures. RCC structures have been designed for a wide range of performance conditions, from low-strength more massive structures to high-strength less massive structures. It is critical that the design of the structure be coordinated with the performance requirements for the RCC material and the specification requirements for construction.

1-7. Major Advantages

RCC construction techniques have made RCC gravity dams an economically competitive alternative to conventional concrete and embankment dams due to the following factors.

a. Costs. Construction-cost histories of RCC and conventional concrete dams show the unit cost per cubic yard of RCC is considerably less than conventionally placed concrete. Approximate costs of RCC range from 25 to 50 percent less than conventionally placed concrete. The difference in percentage savings usually depends on the cost of aggregate and cementing materials, the complexity of placement, and the total quantities of concrete placed. Savings associated with RCC are primarily due to reduced forming, placement, and compaction costs and reduced construction times. Figure 1-1 shows the relationship of the cost of RCC to the volume of the RCC structure based on RCC projects constructed in the United States.

b. Rapid construction. Rapid construction techniques (compared with those for concrete and embankment dams) and reduced material quantities (compared with those for embankment dams) account for major cost savings in RCC dams. The RCC construction process encourages a near continuous placement of material, making very high production rates possible. These production rates significantly shorten the construction period for a dam. When compared with embankment or conventional concrete dams, construction time for large RCC projects can be reduced by several months to several years. Other benefits from rapid construction include reduced administration costs, earlier project benefits, possible reduction or deletion of diversion facilities, and possible use of dam sites with limited construction seasons. Basically, RCC construction offers economic advantages in all aspects of dam construction that are related to time.

c. Integral spillways and appurtenant structures. As with conventional concrete dams, spillways for RCC dams can be directly incorporated into the structure. A typical layout allows discharging flows over the dam crest and down the downstream face. In contrast, the spillway for an embankment dam is normally constructed in an abutment at one end of the dam or in a nearby natural saddle. An embankment dam with a separate spillway and outlet works is generally more costly than the comparable RCC dam with an integral spillway and outlet works. For projects requiring a multiple-level intake for water quality control or for reservoir sedimentation, the intake structure can be readily anchored to the upstream face of the RCC dam. For an embankment dam, the same type of intake structure would be a freestanding tower in the reservoir or a structure built into or on the reservoir side of the abutment. The cost of an RCC dam intake is considerably lower than the cost of an intake structure for an embankment dam, especially in high seismic areas. The shorter base dimension of an RCC dam, compared with that of an embankment dam, reduces the required size and length of the conduit and penstock for outlet and hydropower works and also reduces foundation preparation costs.

d. Minimized diversion and cofferdam. RCC dams provide cost advantages in river diversion during construction and reduce damages and risks associated with cofferdam overtopping. The diversion conduit for RCC dams will be shorter than for embankment dams. With a shorter construction period, the probability of high water is less, therefore the size of the diversion conduit and cofferdam height can be reduced from that required for both embankment and conventional concrete dams. These structures may need to be designed only for a seasonal peak flow rather than for annual peak flows. With the high erosion resistance of RCC, the potential for a major failure would be minimal, and the resulting damage would be less, even if overtopping of the cofferdam did occur. Significant advantages can be realized using RCC for the construction of cofferdam structures. It offers the benefits of rapid construction, small footprint, and continued operability after overtopping.

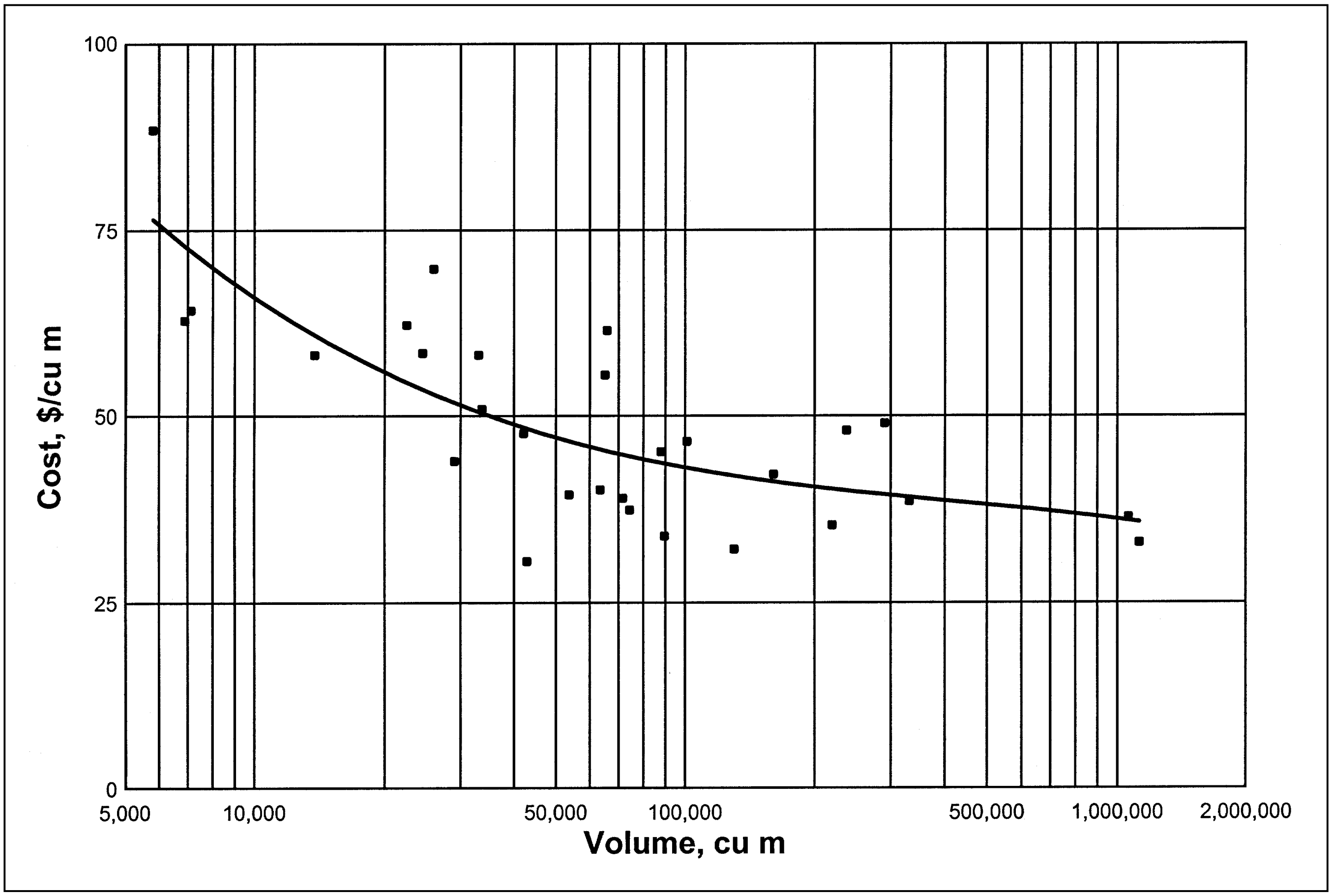

Figure 1-1. RCC costs (1998 price level)

e. Other advantages. When compared with embankment dams, the smaller volume of RCC gravity dams makes the construction material source less of a driving factor in site selection. Furthermore, the borrow source will be considerably smaller and may be more environmentally acceptable. The RCC gravity dam is also inherently more resistant to internal erosion and overtopping.

1-8. Engineering Responsibilities and Requirements

The duties and responsibilities identified in EM 1110-2-2000 apply to RCC structures. During the feasibility stage it may be advantageous to perform a preliminary thermal study to establish gross performance of the structure. Guidance is provided in ETL 1110-2-542, "Thermal Studies of Mass Concrete Structures," for performing these preliminary thermal studies. Later, during the preconstruction engineering and design phase, a more detailed thermal study may be performed to better identify crack control features of the structure. The design team for an RCC project may include many disciplines. As with other mass concrete structures, it is critical that a geologist, engineering geologist, or geotechnical engineer evaluates the foundation conditions, a hydraulic engineer evaluates the spillway and outlet structures, a structural engineer designs the structure, and a materials engineer designs the RCC mixture and coordinates the requisite construction requirements. Coordination by the design team of design requirements, materials requirements, and construction requirements is critical to achieve a cost-effective design.