Earth Dam Problems—and the Geological Site Investigation

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Abstract

There are many small man-made lakes in Indiana and a few large reservoirs with dams over 100 feet in height. The major problems encountered in the construction and operation of these structures are seepage around or through their fills, permeability or weakness of foundation bedrock, unsuitable construction materials, instability of natural slopes, subsidence of dam or pool into caverns or mine voids, and tectonic activity. Faulty construction is not within the scope of this paper. To minimize structural inadequacies or failures caused by these problems, the design engineer must be forewarned. An adequate detailed design investigation must be conducted by a capable geologist. The geologist must review all available data relative to the site, study, test and sample the features of the site, submit samples, test data and his interpretations to the soil mechanics laboratory, and present all this information and the laboratory report to the design engineer.

Introduction

Multi-purpose use of stored surface water has increased greatly in recent years. Problems in dam construction, operation and maintenance have kept pace.

In Indiana most dams for water storage have been constructed with earth. The type of earth material is dictated by the type of dam, the site features and the available material.

Problems are encountered during construction and while the reservoir is in operation. The purpose of the geological dam site investigation is to discover the problems so that they may be offset by adequate design.

Simply expressed, a dam must be strong enough to hold back a given volume of water. The permeability and strength of the dam and its abutments are important factors in the successful operation and maintenance of the reservoir.

Pre-design investigations of dam sites vary in intensity. The larger and more elaborate the structure, the more detailed must be the investigation. The compilation and review of data on dam failures or deficiencies has largely determined the steps taken in current dam site investigations.

The causes of inadequacies in all earth fills reported prior to 1952 have been placed in the following order (5):

1)	Overtopping	30%	5)	Slope paving	5%
2)	Seepage	25%	6)	Miscellaneous	7%
3)	Slides	15%	7)	Unknown	5%
4)	Conduit leakage	13%			

Most of the dams referred to in this study are large structures. The writer believes that most of the problems could have been foreseen had an adequate pre-design been employed.

Overtopping usually occurs when the dam has insufficient height or when the outlet structure is inadequate. This design deficiency usually results from inaccurate hydrologic data. In recent years the science of hydrology has become much more reliable and overtopping is no longer a common event.

Based upon the writer's experience and study of recently constructed earth dams in Indiana, the following order for problems encountered is listed as follows:

1) Seepage in overburden or fill
2) Foundation weakness
3) Bedrock incompatibility
4) Miscellaneous.

Seepage occurs through permeable fills, abutments and/or foundations. This leakage results in water loss and, frequently, piping of fine soil materials in fill or adjacent natural ground. Poorly graded (well sorted) sands and gravels are common offenders. Abutment or foundation seepage may occur through layers or lenses of sands and gravels in glacial drift or in alluvial sediments. Fills constructed chiefly with coarse-grained earth materials are subject to seepage. Conditions conducive to either of these possibilities must be recognized in the pre-design investigation. Permeable materials are important components of a good fill, but must be used with silts and clays.

Soft and compressible foundations will consolidate during or after construction. Weak soils located at the base of the dam must be found, sampled and tested. Such weak materials must be either treated or removed. Standard penetration tests, conducted during the site investigation, pin-point weak foundations. Undisturbed samples of the weak material, as indicated by standard penetration tests, are collected and submitted to a soil mechanics laboratory for test data. These data determine the proper solution for the design engineer.

Shale, sandstone and limestone are the bedrock possible to encounter during the construction of dams in Indiana.

Shale is generally impermeable and of adequate strength. Slides and creep occur on hillsides where shale is near the surface. Some shales swell when wet and shrink when dry. Propensity to cause slides or to swell or shrink must be noted in the investigation report.

Sandstone is generally strong and relatively impermeable. Some sandstones are weakly cemented and are therefore permeable, weather rapidly and are often weak. When permeability or strength is in question, adequate testing must be done.

Limestone, when massive and not jointed, provides a good foundation and basin for dams. Cavernous, open and jointed limestone presents problems in maintaining water levels in the reservoir and in making secure the embankment and structural works. When limestone is suspected of being permeable, the bedrock is usually pressure-tested in place. Core samples may be subjected to testing to determine stability.

There are numerous miscellaneous problems that may result in the inadequacy or eventual failure of a reservoir if not discovered in the investigation and allowed for in the design.

Lack of and/or insufficient suitable embankment material may present a serious problem. Sands and gravels, to the exclusion of fine grained soil, or vice versa, are unsatisfactory fill materials.

Haul distance is an important factor in determining the economics of borrow operations. In the construction of the moderate size dams of from 20 to 50 feet of fill height, borrow must be available within 1/4 mile.

Proper placement of fill, proper compaction and satisfactory moisture control are necessary to avoid construction and operation problems (6).

Steep slopes and shallow soils combine to present slope stability problems. During construction, care must be exercised to prevent distrubing slope equilibrium. Unloading the toe of a natural slope may be inviting disaster. Saturation of an otherwise stable slope can also cause a slide. The disaster at the Vaiont reservoir in Italy is an example (3).

Subsurface mining and subsequent subsidence can ruin a dam or its impounded pool. Underground voids resulting from the pumping of oil is believed to be a major contributor to the failure of the Baldwin Hills Reservoir in California (4). Subsidence from coal mining or from oil pumping are not known to have caused damage to dams in Indiana although there is ample reason for concern.

Problems related to tectonic activity have not yet been reported in Indiana. One study of the location of earthquake probabilities indicates that southwestern Indiana is an area of concern (1). There are known and suspected fault areas in the state, many of which appear to be related to the Mt. Carmel fault.

To minimize the hazards related to site problems a pre-design geological investigation of the site is mandatory. This should be planned by and carried out under the direction of a qualified geologist. Minimum requirements for this investigation appear below.

First, all available published or unpublished data relative to the site should be assembled and reviewed. One source of these data is the Indiana Geological Survey.

Second, an adequate subsurface investigation must be carried out in conjunction with a study of all surface features of the site. Field testing, sample collection, and complete and accurate reporting of the site conditions are necessary parts of this requirement (2).

Third, the samples collected must be submitted to a soil mechanics laboratory for testing, analyzing and reporting.

Fourth, the geologists report and the laboratory report must be delivered to and interpreted for the design engineer. An important part of these reports is a recommendation for further study, if necessary.

Fifth, the geologist should make periodic visits to the site after construction has begun to compare conditions actually encountered with those anticipated as a result of the pre-design investigation.

It is my opinion that a well-conceived and an economical site investigation will uncover virtually all adverse site conditions likely to result in dam inadequacies and possible failures.

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