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Failure of a Small Gravity Dam and the Repair

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SYNOPSIS Late in the summer of 1980, the dam for Snowbird Lake in Forestport, New York, U.S.A., experienced a serious foundation leak made evident by a suddenly erupting geyser near the down-stream toe. Subsequent investigation indicated that a severe piping condition had occurred in the soil foundation. Some degree of erosion had effected the foundation earth for more than half of the dam length. Repairs were performed after dewatering the dam work area. The original dam was retained but provided with a new concrete foundation which included a constructed underdrain. A clay blanket was installed on the dam's upstream side to retard future underdam seepage. An emergency spillway circumventing the dam area was established to protect the dam abutments from being topped should the lake reach flood levels.

INTRODUCTION

The Occurrence

In early September of 1980, the dam creating Snowbird Lake in Forestport, New York, U.S.A., (Figure 1) developed a serious foundation leak made evident by a suddenly erupting geyser near the dam's downstream toe. The owners quickly drained the lake by opening the dam's sluice. Subsequent dewatering of the area in the vicinity of the dam foundation revealed that severe underground erosion and piping had occurred. What apparently was the original path for the piping had become a three-foot (one meter) deep channel beneath the base of the dam. Other soil foundation areas suffered erosion, though of lesser extent. Alltold, some degree of undermining had occurred for more than half the dam length.

Fig. 1. Dam at Snowbird Lake.

Fig. 2. Location Map. Arrow indicates site of Snowbird Lake. Black dots indicate cities of Buffalo, Rochester, Syracuse, Utica, and Albany (West to East).

Location and Function of the Dam

Forestport lies in Central New York State, at the southwest border of the Adirondack Mountains and spacious Adirondack State Park, and approximately 25 miles (40 km) north of the City of Utica, see Figure 2. The location

Fig. 3. Artist's Sketch of Snowbird Lake Dam.

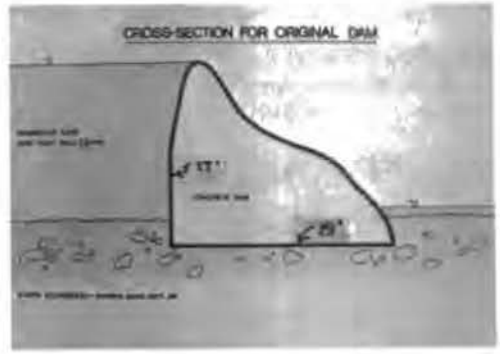

Fig. 4. Diagram of dam cross-section befc repair.

of the present Snowbird Lake dam was also the siting of an earlier cribdam, established for a former lumber and tanning industry to create a waterway for loggers to transport cut trees. A new, larger, concrete gravity structure (Figures 3 and 4) on the order of 65 feet long and 17 feet high, constructed in the period 1967-8, was responsible for creating the present 2½ mile long by 1/2 mile wide (4 km by 1 km) Snowbird Lake. This recreational lake served as the focus for an on-going commercial development of the surrounding 1500 acre, approximately, wooded area (600 hectares), whereby private parcels for residential and campsite use have been offered. The new dam had been in service for approximately 12 years when the foundation failure occurred.

THE INVESTIGATION

Site History

Snowbird Lake Dam exists at a location previously utilized for a timber and boulder cribdam (a factor which events discussed later imply may have been contributory to Snowbird's piping problem). The location represented a natural narrowing in the surface topography along what was then the path of Woodhull Creek. Flow was, generally speaking, east to west. The longitudinal axis for the dams at this location have had a north-south alignment.

An effort by the present owner/developer to locate personnel associated with the 1967-8 construction (the then owners and construction workmen) was generally successful. Interesting history about the dam and construction proceedings unraveled. A local development group organized in the 1960's to improve the lake area and sell surrounding land parcels for campsites undertook the construction of the new dam in 1967. The dam plan was engineer-designed and State-approved (the plans were made available for the 1981 study). The group soon sold to another organization who completed the construction of the dam. The subsequent land-sale activities of this group were limited. The lake and surrounding area passed to the present owner in the late 1970's; this owner was actively engaged in land sales when the underdam seepage problem occurred.

The gathered data indicated the concrete abutments for the cribdam were retained but enlarged as part of the 1967-8 construction. The 1967-8 construction utilized the in-plac glacial till and boulder foundation remainin from the cribdam. Reportedly, unsuccessful attempts had been made to excavate exposed boulder foundation material. A decision followed to build upon the in-place material but to also provide steel dowels anchored in the foundation boulders and extending into th base of the new dam, soto improve the tie between the foundation and dam. The boulder foundation surface was described as being ve rough and uneven. The closely packed assemb of large foundation boulders, as subsequentl observed beneath the dam during the 1981 repair, evoked the possibility that boulders were transported to this location as part of the foundation construction for the cribdam.

Fig. 5. Boring operations to explore fou dation materials. Water in fron of drill rig is lake flow being channelled to the dam sluice.

Extensive steel doweling was also provided to tie the new concrete dam to the concrete abutments.

To perform the 1967-8 construction, the lake flow was carried through a diversionary channel excavated south of the dam. An earthen dike/cofferdam was utilized a short distance upstream of the dam site to isolate the work area from the lake flow. Concrete for the base zone of the dam was being mixed onsite, adjacent to the dam. Materials were stockpiled in the work area. A storm occurring when the concrete base was partially completed brought a high volume of water into the lake which then topped the protective cofferdam. Soil from the cofferdam and sand-gravel from the work stockpiles were carried across the unconcreted northerly section of the dam foundation area. Individuals involved with the 1967-8 construction, interviewed as part of the 1981 investigation, indicated that this soil wash was not completely removed from the dam foundation area before concrete placement resumed. Whether related to the flooding occurrence or coincidence, the foundation area covered by the 1967 mishap was the location of the 1980 piping problem.

Subsurface Conditions

Sand, gravel and silt soils, plus numerous boulders, are exposed at the surface of various areas in the general vicinity of the dam. A geologist's report prepared as part of the 1980-81 investigation confirmed that soils in the area of the dam are glacial deposits consisting of assorted boulder, gravel, sand and silt materials. In 1980, soil borings and bored probes (Figure 5) adjacent to the upstream side of the dam encountered similar soil material, in a compact state, to the depths penetrated (on the order of 17 feet, or 5 meters, below the soil surface then existing behind the dam). This depth corresponded to approximately 12 feet or 4 meters below the base of the dam. In the deepest boring, granite rock was cored between a depth of 17½ and 19½ feet, and the drilling then terminated. The granite is representative of the rock underlying the site but could have been boulder material.

Observed Structural Condition of Dam and the Foundation

When the erupting geyser signalled a serious underdam seepage problem, the site owner quickly lowered the lake level by removing stoplogs from the sluice at the southern end of the dam. Attempts to have all subsequent lake inflow guided to the sluice were partially successful. Through the period from Fall 1980 to Spring 1981, a time used to develop concepts for repair and obtain State permits from dam safety and environmental agencies, lake flow passed partially through the open sluice and partially under the dam.

Visual inspection of the concrete dam and the abutments, conducted in Fall 1980 and again in Spring 1981, indicated that no structural damage such as cracking or loss of alignment occurred as a result of the underdam seepage/flow. The dam remained structurally integrated to the abutment walls. The

Fig. 6. Extent of foundation erosion at downstream toe.

Fig. 7. Cavity in foundation earth behind dam, leading to piping channel.

Fig. 8. Piping channel beneath base of dam viewed from downstream toe. Light in lower center area of photo is daylight from upstream side of dam.

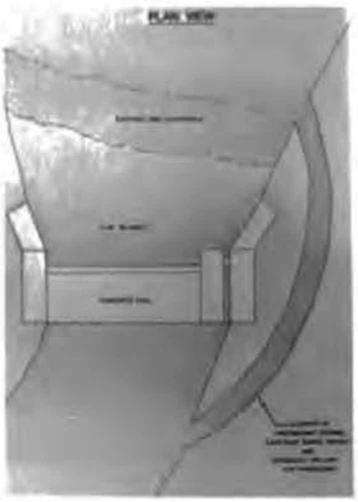

Fig. 9. Plan composite showing relative locations of temporary earthen cofferdam and diversionary channel utilized for the repair operations, and extent of clay blanket finally placed behind dam.

foundation seepage and subsequent underflow had indeed caused loss of earth materials from beneath more than half of the dam length, see Figure 6. Some continuous void spaces extended between the upstream and downstream sides of the dam, Figures 7 and 8. The path for what apparently was the original piping channel was close to three feet (1 meter) in depth. However for the entire zone effected by the seepage and underflow, the base of the dam als remained supported at numerous random location on large boulders embedded into the concrete base as well as the underlying earth. Foundation materials under the abutments and beneath the southerly quarter of the dam's length were noted to be intact and firm/compact, and apparently uneffected by the underdam flow.

THE REPAIR

Design and Construction

Repair and improvement-changes to the dam and surrounding site were undertaken over the summer of 1981. To enable the dam repair to b performed in a dry setting, a diversionary channel circumventing the south abutment was excavated to establish a route for lake inflo to bypass the work area, Figure 9. What were considered as the most feasible plans for repair, as well as the least costly, required that the dam area be temporarily isolated fro the lake. A dry work area would permit bette inspection and evaluation of foundation conditions beneath the dam, and better contro of construction activities.

The repair operation necessitated increasing the dam's resistance to water and other environmental forces which could develop, as well as correcting the condition of underdam flow. Review of the 1967 plans indicated the original dam section had been dimensioned to satisfy design criteria in effect in the

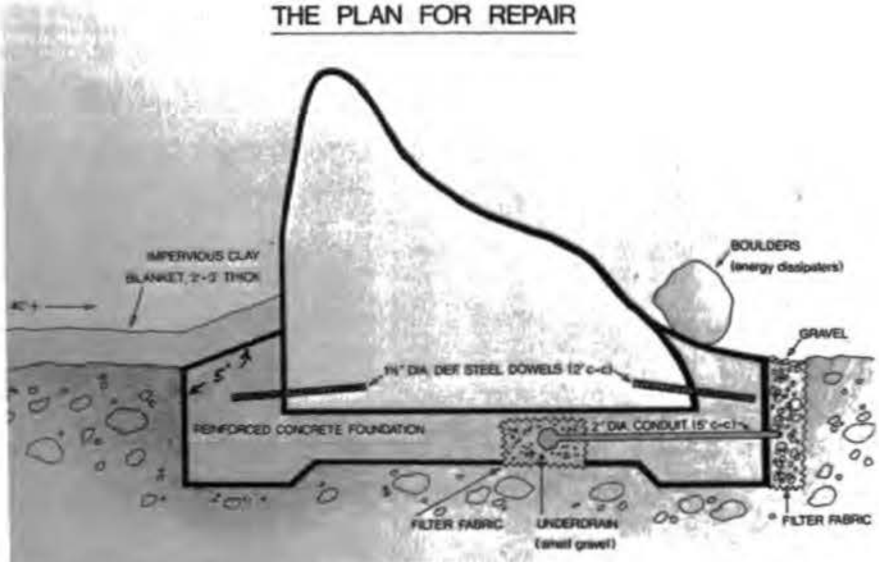

Fig. 10. Diagram showing planned changes to the dam section so to improve stability and retard foundation seepage. Clay blanket actually placed is greater than shown on plan.

mid-1960's. Present criteria in New York State are more stringent, requiring consideration of flood level effects on lateral and uplift water pressures, as well as effect of ice, seismic forces and water waves.

An early plan for utilizing the slurry trench method to construct a deep concrete cutoff wall along the upstream side of the dam (the cutoff wall would also serve as the foundation for a thickness of concrete added against the upstream face of the dam for the purpose of increasing the cross-section), appealing from the design point of view, was abandoned after considering the difficulty and possible problems associated with excavating bouldery foundation earth.

The accomplished plan for repair retained the original dam but involved providing a new reinforced concrete foundation beneath most of the original dam base and having this new foundation extend upstream and downstream in a manner to envelope the lower section of the original dam, see Figure 10. Foundation materials under the southerly section of the dam, observed to be intact and compact, and apparently unaffected by the past underflow, were left in place. Steel dowels embedded into the original upstream and downstream dam face, and projecting into the new foundation, enhanced the integrity between old and new concrete sections. The foundation modification increased the base dimension of the original section by close to 40 percent, and increased the weight/mass of the dam by a similar percentage.

The foundation improvement included an underdrain system to intercept possible future seepage (Figure 10). This underdrain, positioned one-third of the base dimension back from the downstream toe, utilized a permeable geofabric (Mirafi-140) as a wrap to provide separation between the foundation earth and the fine gravel in the underdrain. A series of two-inch plastic conduits, placed at approximately 5-foot centers along the longitudinal axis of the dam and provided with a T-shaped screened end opening within the underdrain, extend to outlet in front of the downstream face as a means for discharging seepage which reaches the underdrain.

The new concrete foundation was constructed by pouring the downstream section first. Gravity effects and vibrators were relied upon to have the concrete flow into the cavity beneath the front section of the original dam. Concrete placement for the upstream section and the cavity beneath the back portion of the dam were subsequently handled in a similar manner.

Means for countering future tendency toward underdam seepage included the placement of a two to 4 feet thick clay blanket behind the upstream side of the dam. An upstream seal was considered as an essential feature of the repair undertaking, and early thoughts for using an impervious liner-fabric were dropped when a source of clay was located on the development property. The clay blanket overlayed the newly constructed upstream foundation projection, and extended approximately 50 feet upstream, as described by Figure 10.

Fig. 11. Dam at Snowbird Lake returned to service.

The diversionary channel for routing lake flow around the dam for the repair period had the intake located a short distance upstream from the work area. Permanent site changes involved with the dam repair included the establishment of an emergency spillway along the location of this subsequently filled-in diversionary channel. The entire length of the dam functions as a spillway, in accord with the design. The emergency spillway, intended to protect the abutments from being topped in periods of high water, will handle flow when levels reach approximately three feet above the dam, but before the elevation for the top of the abutments is reached.

The dam was returned to service, with the lake filled to its original depth, by the end of summer, 1981 (Figure 11).

CONCLUDING REMARKS

The final plan for improvement to the dam site and structure soto correct for underdam seepage and increase stability was developed after evaluating existing conditions, past activities, and needs. Some conditions associated with this dam were considered to be unique but as such made it possible to apply relatively simple design concepts and use relatively simple methods of construction.

ACKNOWLEDGEMENTS

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