# DAM REHABILITATION USING GEOSYNTHETIC CLAY LINERS

Following is a case study of Bentomat CLT used to rehabilitate the upstream face of the Idaho Springs Reservoir dam in Colorado. Bentomat CLT was chosen due to the difficult site conditions and short construction season. Since the installation of Bentomat CLT, seepage has been greatly reduced to acceptable levels.

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# DAM REHABILITATION USING GEOSYNTHETIC CLAY LINERS

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Dams have been constructed throughout history to capture and protect valuable water supplies and to control flooding. Like much of our nation's aging infrastructure, dams need to be inspected regularly and maintained. Seepage must be monitored and controlled when public health is endangered. If repairs become necessary, dam rehabilitation can be both difficult and costly.

For the past twenty years, geosynthetic clay liners (GCLs) have been used as hydraulic barriers to control flooding and protect valuable water resources. A reinforced GCL incorporates a layer of low permeability sodium bentonite clay between two geotextiles. These geotextiles are bonded together through a needle-punching process where fibers are entangled to provide reinforcement. Sodium bentonite was formed by the reaction of volcanic ash and salt water millions of years ago. This natural material absorbs water and provides the liner with its high swelling, self-healing and low permeability properties. For high head conditions, such as a dam, a geomembrane can be laminated to the needlepunched GCL to provide a composite liner.


Figures 1a and 1b. Idaho Springs Reservoir and Dam.

The Idaho Springs Reservoir (Figure 1) is located on the eastern front of the Rocky Mountains, 40 miles west of Denver, Colorado. Its primary function is to provide water supply storage for the City of Idaho Springs, Colorado and the surrounding service areas. Built in the early 1900s, an earthen dam controls flooding and protects camp sites and recreation areas in the valley below. By 2000, the Office of the State Engineer, Dam Safety Branch, had placed restrictions on the reservoir's capacity due to the deteriorated condition of the dam and evidence of significant seepage. Prior to the lining project, five significant seepage locations were observed on the downstream side of the dam. One seep exited onto the berm road at the downstream toe (Figure 2) and there was standing water around an observation well located just downstream of the dam. The reservoir capacity is 270 acre-feet at the crest of the spillway, however, water storage was limited to just 120 acre-feet because of the excessive dam embankment seepage.

Figure 2. Seep at downstream toe of dam prior to rehabilitation

A feasibility study was completed on the dam. The original concept for addressing seepage was to seal all apparent leaks with gunite or concrete, perform hot asphalt injection grouting along the dam face, and to install a free draining rock berm along the toe of the dam. Upon uncovering the dam face, larger than expected voids, piping and organic materials were found. An alternative design needed to be developed in order to more adequately address the existing seepage. The remote location of the dam made hauling clay costly. Also, the short construction season at the high elevation limited options.

The final approved design called for the placement of a Bentomat® CLT geosynthetic clay liner (GCL) along the dam face to the spillway abutment and past the outlet structure. In addition to bentonite clay sandwiched between two geotextiles, Bentomat® CLT has a 20 mil HDPE membrane laminated to the outer surface. This provides a composite hydraulic barrier with a maximum hydraulic conductivity of $5 \times 10^{-10}$ cm/s per ASTM D5887. Direct shear testing was performed between the GCL and the adjacent soils under hydrated conditions per ASTM D5321. The test data indicated a peak friction angle of 45 degrees.

Repairs to the dam's upstream face began in the fall of 2000 and were completed in the summer of 2001. The GCL was delivered by flatbed truck. Rolls were 15-feet wide with a panel length of 150 feet. The self-sealing ability of the bentonite allowed for a 12-inch panel overlap without the need to weld the geomembrane panels. The GCL panels were anchored into a trench at the crest of the dam and unrolled down the dam face with a backhoe and spreader bar assembly (Figure 3).

Originally, the GCL was planned to be keyed into the clay aquitard below the reservoir. However, large boulders were encountered in the subsoil at toe face. Alternatively, the contractor rebuilt the subgrade and the GCL was run out 20-25 ft past the toe along the base of the reservoir. Approximately 100,000 square feet of GCL was used in total. Cover soil was placed over the GCL and the existing rip-rap cover layer which had been removed, was screened and reset at a uniform 3-foot thickness across the dam face.


Figure 3. GCL Installation

Since the lining project, the downstream toe of the dam has remained dry and water in the observation well just downstream of the dam is 6' below the ground (see Figure 4). Seepage has been greatly reduced to acceptable levels.



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Figure 4. Observation well downstream of dam.

**Summary**

In the decades to come, billions of dollars will be necessary to rehabilitate our nation's dams. With limited funding, cost effective and reliable repair solutions will be needed. By providing hydraulic containment, slope stability, and quick installation, GCLs can play a vital role.

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