Geotextile-Reinforced Wall: Failure and Remedy

Reinforced walls and embankments are a small, but ever growing application of geosynthetics. Since the first geotextile-reinforced wall was constructed by the U.S. Forest Service in 1974, more than 200 such walls have been constructed using either fabrics or grids. This application is still in its embryonic stage, however, and is very sensitive to failure that may be perceived by civil engineers as condemning such applications.

As more and more successful walls have been constructed, it has become apparent that the design of the system to connect the facing to the geotextile is key to the engineering and economic success of the wall. This article deals with the design, and subsequent redesign, of such a system. Even with the necessary redesign, the wall was completed at substantial savings to the client when compared to conventional methods.

A Typical Application
Beginning as a very typical commercial project in the growing Research Triangle area of Raleigh, N.C., the retaining wall was part of a small commercial shopping center placed in a confined area. To establish a usable building site, up to 16 feet of soil was removed from the northern limits of the site. Buildings were to be placed within 50 feet of the property line and the owner wanted to maintain vehicle access between the property line and the buildings. Such needs are not unusual and create the need for what are typically referred to as "right-of-way" walls.

The 13-foot wall required to stabilize the cut face was allowed only 8 feet of depth. This gives a depth-to-height aspect ratio of approximately 0.6 and approaches the lower limit for these walls. The overall wall dimensions included a maximum wall height of 13 feet, an average wall height of 10 feet, and a wall length of 340 feet.

Initial economic studies were performed on alternative wall types for use in this application. Commercial proprietary soil reinforcement walls using concrete face panels and metal grids or strips were estimated. Unit costs for these walls averaged $20.00 to $30.00 per square foot of wall face. This resulted in an estimated wall cost of $68,000 without backfill and erosion costs. Total construction costs for these systems were estimated to be approximately $90,000.

A conventional reinforced concrete wall was priced using concrete unit costs typical of the local area. This resulted in an estimated cost of a conventional wall less backfilling in excess of $350,000. The geotextile reinforced wall with a timber facing was estimated to cost less than $30,000. This estimate proved true in the subsequent construction. The economic advantage of such a wall obviously cannot be overlooked.

Geotextile Wall Design
Both initial and replacement walls have the same profile: a maximum height of 13 feet, an embedment depth of 8 feet, and several feet of surcharge including landscaping. Soil backfill in both cases consists of quarry crusher fines. These fines contained up to 20 percent rock dust and are commonly wasted by the quarry. The initial geotextile wall took advantage of the tensile strength of the geotextile and used a 24 inch vertical spacing between layers of geotextiles. As will be discussed later, the replace-
ment wall used a 12-inch spacing between layers of geotextiles. Both walls used pressure treated 6-by-6-inch timbers to form the face. Each layer of timbers was attached to the layer immediately below it using #4 rebar rods driven on 30-inch centers.

A simple limit-equilibrium analysis was performed to establish the tensions in the base layer of geotextile, to find the required vertical spacing of reinforcement, and to confirm the external stability of the wall. These calculations are based on earlier methods proposed by Bell but with several simplifying modifications based on discussions at the June 1987 NATO workshop at the Royal Military College of Canada on reinforced earth walls. The simplified internal forces of the walls are shown in Figure 1. The significant variations between this and earlier methods proposed by Bell are the use of an active earth pressure coefficient and a uniform base earth pressure.

Connection of the geotextile to the timber facing proved to be the critical detail in the success of this wall. The connection details for the first wall and the replacement wall are shown on Figures 2 and 3. The impact of these details form an important lesson learned from this work.

Connection Failure

The initial wall was constructed over a six week period with no direct supervision by the designers, S & ME, Inc. The owner used construction labor associated with the commercial project and used the wall as a filler project for these work forces. Upon completion of the basic wall, the landscape contractor placed topsoil on the top of the wall, seeded it, and installed erosion control mats. Nearing completion of this work the failure occurred. One evening, the landscape contractor observed a bulge in the lower third of the wall. At that time all work on the wall stopped and workers were ordered to stay clear of the structure. By the following morning, a section of the timber facing had rotated and fallen from the face of the wall. The geotextile wall now resembled a wrapped-face wall and appeared to be very stable in spite of the facing collapse. While no one had been present during the actual collapse of the facing, evidence indicated that its fall had occurred rapidly. The upper layers of geotextile reinforcement had been pulled out without disturbing the overlying fill.

An investigation of the failed wall quickly pointed out the reasons for the detachment of the facing. During construction, the lower timber for attachment of the facing to the geotextile had not been used and no compaction had been performed on the backfill. This resulted in significant voids in the backfill at the face of the wall and led to a "bullying" of each lift as the height of the wall increased. Thus each layer of geotextile reinforcement began to assume the rounded face associated with typical wrapped face construction. This rounding of the face of each lift pulled the lone anchorage timber from the facing in each lift within the lower half of the wall. The landscaping work apparently applied sufficient force at the top of the wall to force this unstable situation to failure.

Revised Wall Design

While the geotextile portion of the initial wall remained stable, there proved to be no effective way of reattaching the timber facing to this structure. A decision was made to entirely rebuild the wall including the fabric inclusions and backfilling. The redesigned wall focused on the stability of the timber facing and not on the minimization of
geotextile. The vertical spacing of the geotextile was reduced to 12 inches. This was not done to reduce the tension in this reinforcement, but to ensure that each row of timbers in the facing was attached directly to a layer of fabric. It is important to note that the geotextile costs in such projects are a small percentage of the total material costs, typically less than 10 percent. The facing, on the other hand, represented nearly a third of the material costs. Thus the reduction of the vertical spacing of the geotextile had a negligible impact on the overall project cost.

In addition to reducing the geotextile spacing, the attachment of the geotextile to the timber facing was redesigned in the replacement wall. The revised connection detail, shown in Figure 3, does not place the batten strip anchoring nails securing the fabric in tension, but uses the more reliable shear strength of such connectors. Laboratory tests confirmed that this connection detail was stronger than the geotextile itself.

Replacement Wall

S & ME, Inc. supervised the reconstruction of the wall using a general contractor to provide the labor force. The construction was built in nine days including time required to salvage the used timbers from the previous wall. The contractor estimated that without the salvage effort and using all new timbers that the construction would have taken five days. This is approximately 600 square feet of wall per day. The first row of timbers was slightly embedded and placed behind an existing curving of the adjacent parking lot. For the first eight feet of wall height, fill was placed behind the wall using a small "bobcat" loader that operated from the front of the wall face. A larger backhoe was used to place the fill once the wall height exceeded eight feet.

Batten strips for the fabric-timber connection were ripped from sheets of

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pressure treated plywood. The small facing strip used to conceal the fabric was also ripped from this same plywood. Placement of the fabric and nailing of the batten strips required approximately 45 minutes for the 340-foot length of the wall. After attachment of the batten strip and geotextile for each layer, the next two layers of timber were placed before the fill was placed on the fabric. In this manner the timber facing acted as the framework for the backfill. No noticeable outward movement of the wall occurred during placement of the backfill. Each 12-inch lift of backfill was compacted using a small powered vibratory roller compactor operated to within one foot of the wall’s face. Significant compaction of the quarry fines was observed, approximately 70 to 80 percent relative density.

The completed wall stands 13 feet at its highest point. The wall was constructed for slightly less than $30,000 or approximately $9.00 per square foot of face. This included $10,000 for the treated timber facing, $2,200 for the geotextile, $400 for the batten strips and $1,400 for nails and rebar pins. The cost breakdown clearly shows the fallacy in sophisticated design methods that attempt to minimize the amount of geotextile used in a wall. These efforts are better spent in exploring alternate facing materials.

Summary
Geotextile-reinforced earth walls offer a significant cost savings over competitive wall systems. The contractor used in the construction of this wall has not gone to using fabric-reinforced walls exclusively. These walls are normally less than 10 feet in height.

The contractor is using the same connection detail, vertical reinforcement spacing, and general geotextile embedment depth. His crews now construct these ‘landscape’ walls without engineering if the height is less than 10 feet. Quite simply he feels that there is no more economical wall available and his clients are pleased with the natural appearance of the wall.

Design procedures for fabric reinforced earth walls including typical connection details have been prepared by S & ME, Inc. for Amoco Fabrics and Fibers Co., and are now available through its distributors. For landscape and commercial walls less than 20 feet in height, the designer-contractor can provide their clients significant cost savings. The keys to success, however, are simple details such as the attachment of the geotextile to the facing and proper compaction of the backfill.

References

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