Use of Fabrics for Improving the Placement of Till on Peat Foundation

C. LUPIEN, G. LEFEBVRE, P. ROSENBERG, J. J. PARE, AND J. G. LAVALLE

Observations made during the construction of test embankments, which were built to investigate the possibility of placing till directly on peat, are reported. The test fills were constructed on two test sites that presented different peat properties. Different uses of fabrics were tested at each each experimental site: as a separation and reinforcement between the muskeg and the fill, as slope protection, and as reinforcement at midthickness of the fill. For comparison, a few test fills were constructed without fabrics. The observations made during construction describe the difficulties encountered in fabric handling and the effect of geotechnical fabrics on the behavior of the fill material and the peat foundation. Of particular interest was the use of geotextile (used as a fill material) as reinforcement at midthickness of the fill to prevent a loss in the bearing capacity of the till. The use of fabrics as reinforcement of the peat foundation proved to be of little significance when the peat offers sufficient strength.

The hydroelectric development of the Nottaway, Broadback, and Rupert (NBR) rivers in the southeast part of the James Bay region in Quebec province, Canada, necessitates the construction of several kilometers of roads across muskeg-covered areas. Canadian expertise with respect to highway embankment construction on peat in northern areas is significant and has been reported by many researchers (1-4). They have shown that the construction problems of an embankment on peat are mainly related to the properties of peat and the construction techniques used.

Fills on peat are normally constructed with free-draining granular material. On the NBR project the scarcity of clean granular borrow material required that silty sand with gravel till be used on long sections of the access roads. Because construction difficulties can be expected with the placement of a silty material in wet conditions, an experimental program was initiated in order to investigate the possibility of placing these tills directly on the muskeg.

Two test sites that presented different peat conditions were retained for the experiments, and four different test fills were constructed at each site. Geotechnical fabrics were incorporated in half of the test fills.

The purpose of this paper is to report the observations made on the various uses of fabrics during construction of the test fills.

CONDITIONS OF TEST SITES

The two test sites, NBR-2 and NBR-3, named after the nearest exploration camps, are located about 238 and 148 km north of the city of Matagami along the James Bay access road (Figure 1). At both sites the muskeg surface inside the perimeter of the test fills is covered with moss, hay, and some conifers less than 2 m high (see Figures 2 and 3). The peat layer is about 2.5 to 3.5 m thick, overlaying a clay deposit with a stiff weathered crust. The water level in the peat was found to vary slightly with the seasons; at the time of construction it was mostly at the peat surface at the NBR-3 site and about 25 cm below the muskeg surface at the NBR-2 site.

The peat is fibrous at both sites. According to the von Post (5) classification system, the NBR-3 peat averages H-4 whereas the NBR-2 peat appears more humified, with an average of H-7. Average water content profiles and the range of variation are shown in Figure 4. The water content at the NBR-2 site increases slightly with depth, and the average value for the whole profile is equal to 1,460 percent. The water content at the NBR-3 site is practically constant with depth, and the average value is 860 percent. Averaged vane profiles shown in Figure 5 also show consistent behaviors for both sites; the average shear strength for NBR-2 is 10 kPa, and for NBR-3 about 20 kPa.

As indicated by these properties, the peat deposits differ significantly at both sites. Compared with the NBR-3 peat, the higher water content and lower strength of the NBR-2 peat reflect a more deformed peat that has a greater potential for failures.

Figure 6 shows the grain-size distribution of the two tills used as fill material at both sites. The percentage passing the 4.75-mm sieve is on the order of 70 percent for the NBR-2 material and 95 percent for the NBR-3 till. The uniformity coefficient is significantly different between the two tills: about 10 at NBR-3 and 40 at NBR-2.

CONSTRUCTION PROGRAM

Four test fills were constructed at each experimental site and different uses of geotextiles were tested. In particular, the geotextiles were used as slope protection membranes (a) to restrain the sloughing of the fill material and (b) for a reinforcement at the top of the peat foundation and in the fill.

Geotextiles used for these experiments were those already available in the James Bay area and are identified by their strength and deformation properties (6) in the following table:

Type	Polymer	Fabric Construction	Grab Tensile Strength (N)	Elongation at Breaking Load (%)
A	Polypropylene	Woven	485	16
B	Polyester	Nonwoven	710	35
C	Polypropylene	Woven	800	22

For comparison purposes, some test fills were constructed directly on muskeg without geotextiles or by means of other approaches. The lengths of the test sections varied between 30 and 40 m.

The following is a description of the NBR-3 test fills.

1. Section A (1.5 m thick) was built with a type B geotextile as reinforcement between the muskeg and the fill. A type A geotextile was used on the same test fill to retain the slope material. Both were installed in the longitudinal direction of the test fill. The fabric layout is shown in Figures 7-9.
2. Section B was built directly on the muskeg surface and had a fill thickness of 2 m.
3. Section C was similar to section B but had a fill thickness of 1.5 m.
4. Section D (1.5 m thick) was built directly on the muskeg surface but incorporated a type A geotextile as reinforcement at midheight of the fill (Figure 9). The width of the test fills was about 13 m at the crest.

Figure 1. Location of NBR-2 and NBR-3 test fill sites.

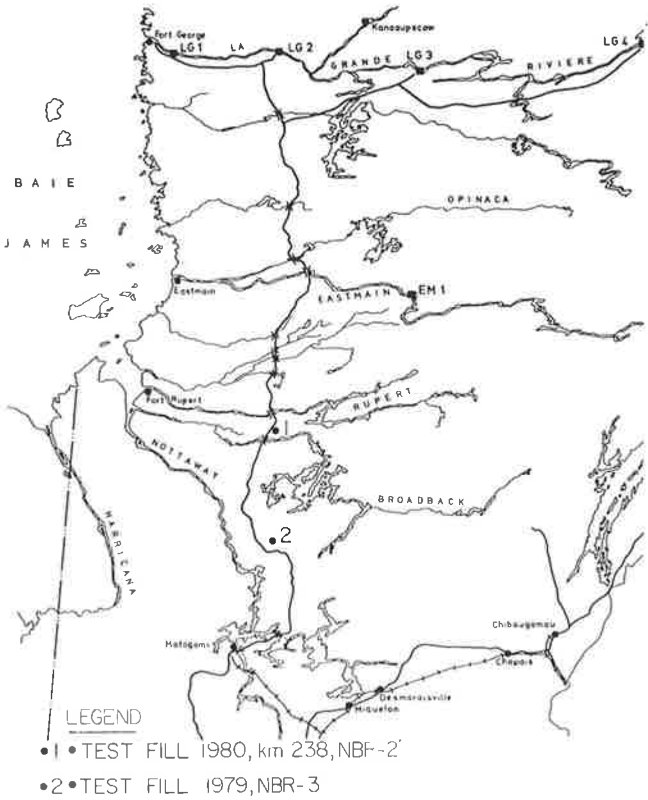
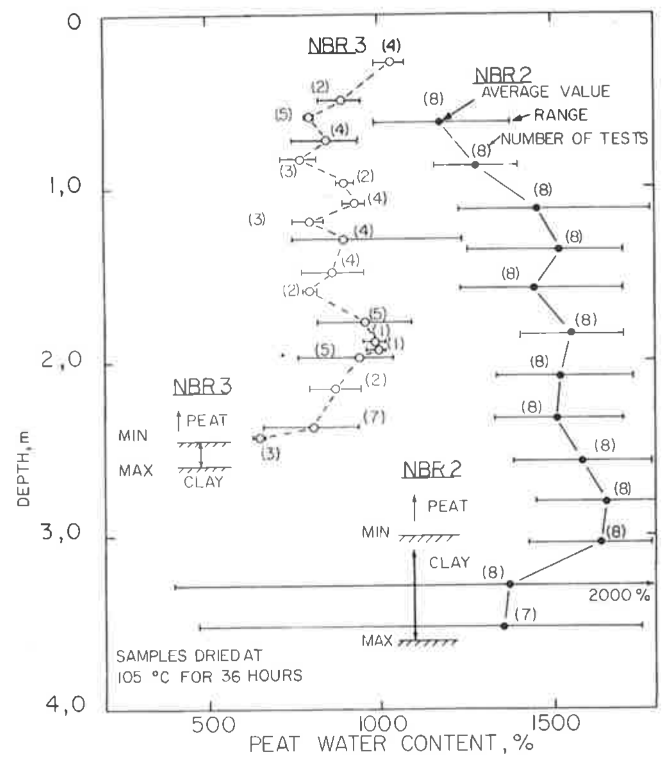


Figure 2. NBR-3 test site: surface aspect and instrumentation layout.

Figure 3. NBR-2 test site: surface aspect and instrumentation layout.

Figure 4. Average water content versus depth, NBR-2 and NBR-3 sites.



The test fills at NBR-2 were built to a height of 1 m above the muskeg surface. The final thicknesses varied from 2 to 3 m. The following is a description of the NBR-2 test fills.

1. Section A was built by using a clean granular pad with a thickness just sufficient to support construction equipment. The fill was then completed to final grade with till.
2. Section B was built with a type C geotextile wrapped around the first layer of the fill. In this case the geotextile was installed transversally to the fill by using an overlap of about 1 m between layers. This layout is shown in Figures 9 and 10.
3. Section C was built by using an impervious polyethylene membrane between the till and the muskeg surface.
4. Section D was built by using till directly on the muskeg.

The width of the test sections was 15 m at the beginning of construction, but it was reduced to 10 m due to construction scheduling constraints.

Instrumentation at both sites consisted of open-tube-type piezometers located in the fill and at various depths in the peat foundation, along with settlement plates on the peat surface. Figure 9 summarizes test fill conditions and instrumentation locations.

BEHAVIOR OF TEST FILLS BUILT WITHOUT FABRICS

Fill Material

Fill materials used at both sites have shown different behaviors. Construction difficulties were encountered with the NBR-3 till due to a loss of bearing capacity into the fill. After placement of the fill, the increased pore pressure induced into the peat foundation was transmitted to the fill material.

Figure 5. Average vane profile, NBR-2 and NBR-3 sites.

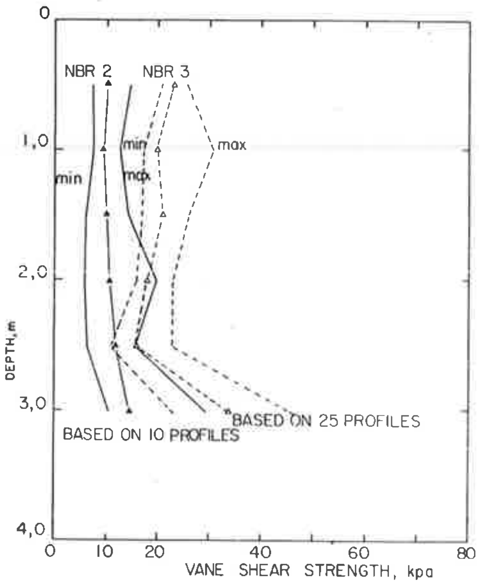


Figure 6. Granulometric ranges of NBR-2 and NBR-3 tills.

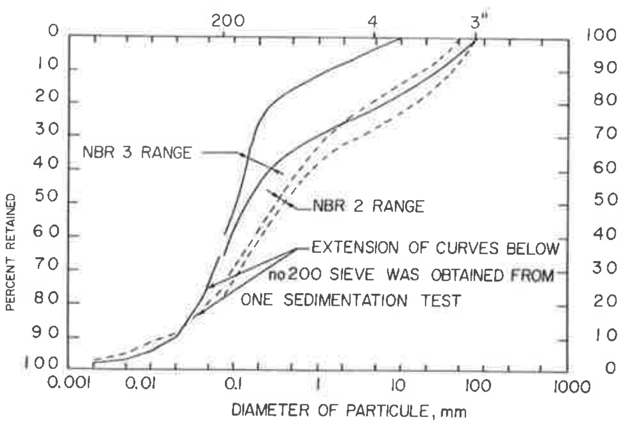


Figure 7. NBR-3 test fill A: type A geotextile as foundation reinforcement and type B geotextile for retaining fill material on slope.

Figure 11 shows typical piezometer elevations observed within a few hours after placement of the fill within the test fill A area. The significant piezometer response into the fill is indicative of pore pressure buildup and the saturation of most of the fill. Under such conditions compaction of the fill material is made difficult. The movement of trucks on the fill increases the problem because a pumping action is created, which results in a rise of water toward the fill surface. This phenomenon became so significant at a few locations on the test fills and the access road that a complete loss of bearing capacity occurred and construction equipment could not operate on these zones. The addition of fill material did not improve the behavior of the weakened zones. Geotextile was used to strengthen the fill in these circumstances (see discussion later in this paper).

Sloughing of the slopes with the NBR-3 till was a generalized phenomenon. The slopes were stable immediately after placement of the fill. Then a rise of water level in the slope material was achieved by pore pressure transmission, capillarity, and precipitation. The poorly compacted till near the slopes became unstable under these new water conditions, and sloughing of the slope material occurred. Material losses were important, with resulting slopes varying from 3:1 to 7:1. This phenomenon was especially significant after severe precipitations. Figure 12 shows a typical case.

These stability problems were not observed with the NBR-2 till, even in the case where the fill material was placed on a more compressible peat foundation that had a higher water content. The NBR-2 till behaved more like a clean granular material.

The differences in the behavior of the two tills are mainly explained by the properties of the fill materials. Both tills were nonplastic, but their grain-size distributions were different. The most significant factor is the uniformity coefficient ($C_u = d_{60}/d_{10}$), which was on the order of 10 and 40 for the NBR-3 and NBR-2 tills, respectively.

Figure 8. NBR-3 test fill B: fill material on slope retained by type B geotextile.

Figure 9. NBR-3 and NBR-2 test fill sections.

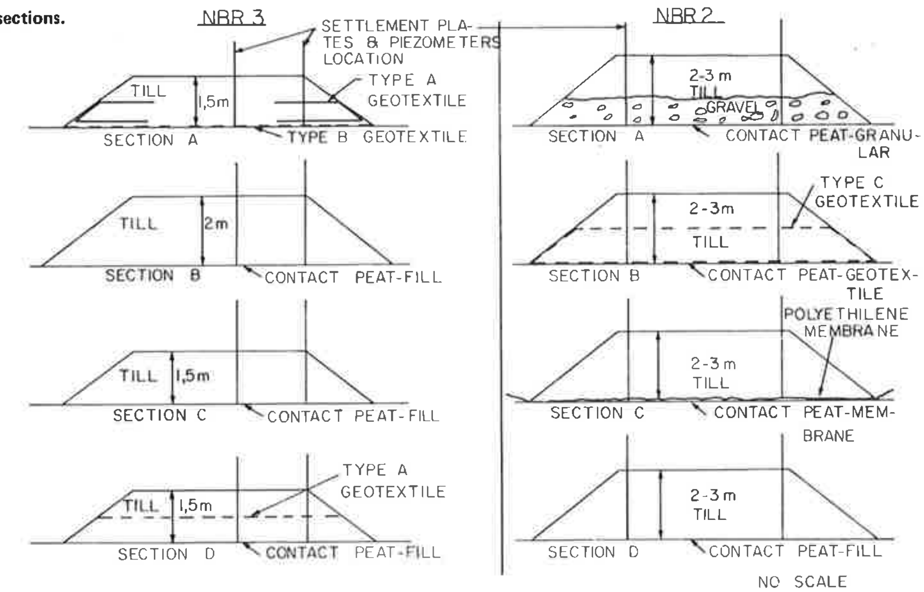


Figure 10. NBR-2, section B: first layer of fill wrapped with type C geotextile.

Figure 12. NBR-3 test site: sloughing of slope material.

Figure 11. NBR-3, test fill A: maximum piezometer readings.

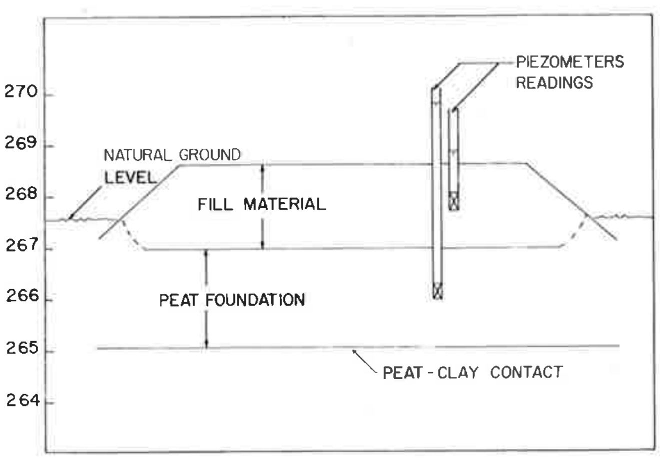


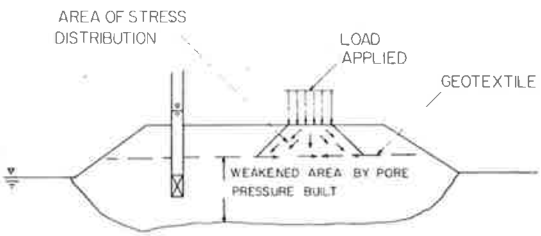
Figure 13. NBR-2, section B: lateral displacement and heave of peat.

Therefore, the difference in behavior of the two tills is the inherent stability of the material itself.

Peat Foundation

Behaviors of the peat foundations were different at both sites. Significant lateral displacement of the peat was observed at the NBR-2 site. The difference in measurements between the settlement plates before and after construction indicated a lateral strain of the peat that varied from 20 to 80 percent. Heave of the peat at the toe and front of the advancing fill (Figure 13) was also observed and was on the

Figure 14. Use of geotextile over a locally weakened fill.



order of 0.7 m. A failure in the peat foundation did occur at section B at this site, which will be discussed later.

No lateral displacement or heave was observed at the NBR-3 site. It is believed that here the compression of the peat primarily was achieved uniaxially.

This difference in foundation behavior is related to the properties of these peats. The NBR-2 peat had lower strength and a higher water content than the NBR-3 peat, which indicates a more deformed and less resistant peat.

BEHAVIOR OF TEST FILLS BUILT WITH FABRICS

Observations made during the construction of the test fills built with fabrics are grouped under the three following subjects: geotextile handling, behavior of the peat foundation, and behavior of the fill material.

Difficulties Encountered in Fabric Handling

Some tree cutting was required at the construction sites before the placement of membranes. The resulting muskeg surface was irregular because of dispersed mounds and some vegetation (Figures 2 and 3). The placement of the geotextile on such a surface was especially difficult under wind conditions, and closely spaced stickers had to be used to secure the geotextile to the peat surface. This operation was conducted before the construction period and required a crew of two to three workers, depending on wind conditions. It is believed that this operation would be more easily accomplished in the case of a flat muskeg surface.

When the geotextile was used as a material-retaining membrane on slopes, placement proved to be especially laborious. It is difficult to have control of the geometry at the foot of the slopes of the fill when a till that contains boulders is used, and the material is placed on an irregular surface. The operation required shoveling to achieve some uniformity of slope geometry, and also to secure the membrane at the surface of the embankment before the placement of the upper layer of the fill.

Effect of Geotextiles on Behavior of Peat Foundation

The bearing capacity of the peat foundations was different at both sites. This was shown previously by the difference in peat strength, which was 2 times stronger at the NBR-3 site. Observation of the behavior of the test fills built without fabrics confirmed this difference in peat strength between the two sites. The NBR-3 peat, which has an average strength value of 20 kPa, proved to be resistant; therefore the use of fabrics as reinforcement for these test fills was not advantageous. Thus it may be concluded that where the muskeg is not susceptible to bearing failure displacements, fabric is not useful. Experimental studies reported by Vischer (7) indicate the same conclusion.

With respect to the deformed NBR-2 peat, the behavior of the foundation was different, with the lateral displacement varying from 10 to 80 percent, with an average of 45 percent. For the test fill built with a type C geotextile wrapped around the first layer of the fill material, the lateral deformations registered varied between 40 and 65 percent. The fabric used for this test fill had an elongation at breaking load on the order of 20 percent. Even if there was no evidence of fabric rupture, with the comparison between actual and tolerable elongation as established for this product, it is believed that the geotextile at the peat-fill contact surface was brought to failure.

A foundation failure was observed on this test fill. The rupture was evidenced by a crack at the fill surface and a differential settlement of about 15 cm at the crack level. It was possible to reload the affected area and proceed with construction.

Before the construction period it was not expected that the lateral movement of the peat foundation and the resulting elongation of the peat below the fill would be of that magnitude. It is believed that the use of a nonwoven geotextile with an elongation capability of about 100 percent (with the appropriate strength) would have been more appropriate for this deformed peat.

Improvements in Behavior of Fill Material with Use of Fabrics

The use of geotextiles as a slope protection membrane proved to be of interest at the NBR-3 site where sloughing of the slope material was generalized. In test fill A, which was built by using a type A geotextile for slope protection, the loss of material by sloughing was prevented for the protected material. However, the sloughing of the till over this level occurred.

Test fill D at the NBR-3 site, which was built with a geotextile at midthickness of the fill, was easily constructed because the geotextile prevented the occasional losses in bearing capacity of the fill material as in the other test fills. The inherent stability of the fill material at the NBR-2 site was not improved by the use of fabrics because it was unnecessary, as already explained.

As described earlier, construction difficulties were encountered at the NBR-3 site where softening of the fill material had occurred. In these cases, the addition of fill material over the affected area did not improve the situation. The limited areas so affected were repaired by undercutting the till, placing a geotextile, and refilling with till. This method proved to be efficient and improved the performance of the saturated fill. Both geotextiles--type A and B--have been successfully used for this purpose.

The efficiency of the method can be explained either because the saturated fill did not reach sufficient compaction or because the pore pressure buildup into the fill was so significant that the bearing capacity became weak in relation with the loads applied. In such a situation it becomes impossible to achieve compaction of a new layer because the underlying till does not offer a sufficient reaction (see Figure 14). The use of a geotextile allows certain reactions to occur under the compacted layer so that it acts as a reinforcement inside the fill.

CONCLUSIONS

The experimental program reported allowed comparison of the behaviors of test sections built with and without geotextiles. The test fills were built on two different sites and presented different peat conditions in terms of strength and deformation.

The following observations were made during construction:

1. The use of a geotextile as reinforcement of the foundation is not necessary when the peat is not susceptible to bearing failure displacement.
2. The use of fabrics on an irregular and tree-covered muskeg surface presents some handling difficulties.
3. The use of a geotextile for retaining fill material on slopes prevented sloughing of the slopes constructed with a susceptible material, but the handling operation was difficult because of a course till fill.
4. Of particular interest was the use of a geotextile at midthickness of the fill, especially when used locally to make repairs when a loss in the bearing capacity of the fill material occurred.
5. The use of a woven geotextile is normally suggested for foundation reinforcement. However, it was shown that when the foundation material is deformed, a nonwoven geotextile may be more suitable because it allows the foundation to develop more strength.

ACKNOWLEDGMENT

We wish to thank the Société d'énergie de la Baie James for permission to publish this paper.

REFERENCES

1. K.O. Anderson and R.A. Hempstock. Relating the Engineering Properties of Muskeg to Some Problems of Fill Construction. Proc., 5th Muskeg Research Conference, National Research Council of Canada, Tech. Memorandum 61, 1959, pp. 16-25.
2. C.O. Brawner and G. Tessier. Road and Railway Construction. In Muskeg Engineering Handbook (I.C. McFarlane, ed.), Univ. of Toronto Press, Toronto, Ontario, Canada, 1969, pp. 150-208.
3. G.P. Raymond. Construction Method and Stability of Embankments on Muskeg. Canadian Geotechnical Journal, Vol. 6, 1969, p. 81.
4. P.A. Brochu and J.J. Paré. Construction de routes sur tourbières dans la province de Québec. Proc., 9th Muskeg Research Conference, National Research Council of Canada, Tech. Memorandum 81, 1963, pp. 74-108.
5. L. von Post. Sveriges Geologiska Undersøknings torvimentering och nogra av dess hittils vunna resultat (SGU Peat Inventory and Some Preliminary Results). Svenska Masskulturiøreningens Tedsherift, Jønkøping, Sweden, Vol. 36, 1922, pp. 1-27.
6. Engineering Geotextiles. Engineering Materials Office, Ministry of Transportation and Communications, Downsview, Ontario, Canada, Rept. EM-45, 1981, 47 pp.
7. W. Vischer. Use of Synthetic Fabrics on Muskeg Subgrade in Road Construction. Forest Service, U.S. Department of Agriculture, Nov. 1975.

Publication of this paper sponsored by Task Force on Engineering Fabrics.

Geotextile Earth-Reinforced Retaining Wall Tests: Glenwood Canyon, Colorado

J. R. BELL, R. K. BARRETT, AND A. C. RUCKMAN

The Colorado Division of Highways elected to use flexible reinforced-soil retaining structures to meet architectural and environmental constraints in the design of I-70 at sites underlain by compressible soils in Glenwood Canyon. Four wall systems were constructed: Reinforced Earth, Retained Earth, Wire Wall, and geotextile reinforced walls. The geotextile reinforced-soil retaining wall tests are described, and design, construction, and instrumentation details are provided. The test wall is 300 ft long and approximately 15 ft high. The wall incorporates four nonwoven geotextiles (each in two weights) in 10 test segments. Instrumentation is provided to monitor settlements and surface and internal deformation of the reinforced soil. The test wall has a gunnite facing. The wall was designed by conventional methods; however, some segments were assigned lower-than-usual factors of safety to provide a more critical test. Since construction, the wall has settled from 6 to more than 18 in. due to foundation consolidation. Test wall performance, however, has been satisfactory, and none of the segments has exhibited distress. Wall design and performance relative to laboratory geotextile strength and creep test results are analyzed, and it is concluded that safe, economical geotextile walls can be designed by existing methods if certain factors, as discussed in the paper, are appropriately considered. Recommendations are also made. It is concluded that construction methods are appropriate for contractor-constructed projects. Cost data are also presented.

The Colorado Division of Highways (CDOH) designed and constructed a geotextile earth-reinforced retaining wall in conjunction with project I-70-2(90) in Glenwood Canyon, Colorado. This was one of four experimental flexible walls constructed on this project. The other wall systems were all proprietary and included Wire Wall, Retained Earth, and Reinforced Earth. Construction was completed during spring 1982.

BACKGROUND

Site Description

Glenwood Canyon is a narrow, steep-walled chasm cut by the Colorado River through resistant limestone, quartzite, and granite. The deep slash through the bedrock was formed by a gradual regional uplift, which caused the Colorado River to accelerate downcutting with limited lateral cutting. The 12-mile-long canyon is located about 150 miles west of Denver in west-central Colorado, as shown in Figure 1.

Geologic investigations indicate that bedrock lies up to 150 ft below the river, and that thick lake deposits, which consist of highly compressible silts and clays, are present through the eastern half of the canyon. The lake deposits indicate that, at one time, a temporary dam was formed at some point in the canyon.