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

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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.

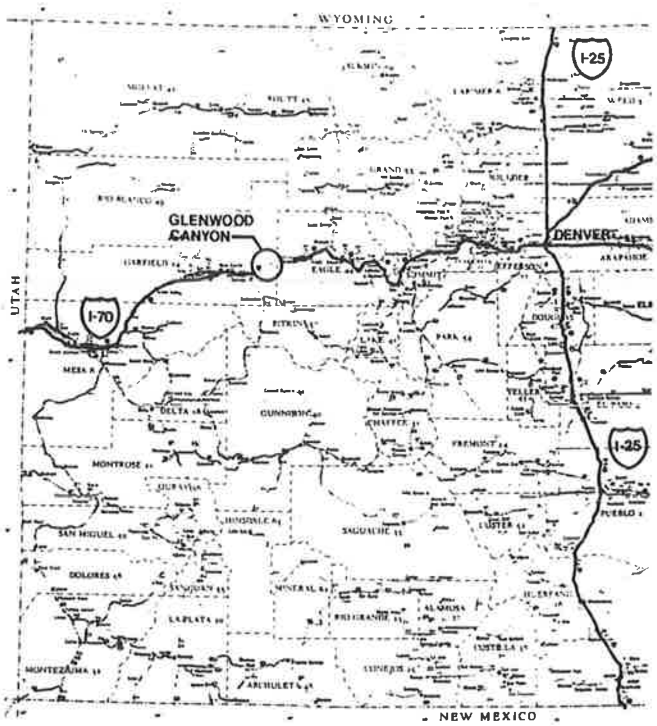
BACKGROUND

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.

Figure 1. Location of Glenwood Canyon.



Problem

The damming of the river was probably the result of a catastrophic event. Based on Carbon-14 dating, lacustrine deposition occurred over an approximate 2,000-year period and ended about 7,000 years ago. This segment of the canyon's history is still a unique and interesting puzzle for project geologists. It has presented unique and difficult problems for foundation designers because it was assumed in the early design phases that bedrock would be found at shallow depths beneath the river and that foundations would not be a problem in the otherwise severely constrained Interstate corridor.

The first project designed for the area where the compressible deposits were found included a rigid, posttensioned cantilever wall with a cantilever pavement section (1). This design was obviously incompatible with the geology. Geologists and engineers could safely predict that significant differential settlements would occur, but predicting the amount of settlement and the time required were beyond the state of the art. Laboratory tests indicated a settlement range of 4 to 40 in., and settlement times of 6 months to 15 years.

Surcharging was not possible due to limited space, and wick drains were deemed prohibitively expensive. Architects and designers finally relented on their insistance for rigid structures and allowed the use of flush-faced flexible walls, but only with the stipulation that the first project be used as a full-scale test to determine the field behavior of the lake deposits.

The only flexible retaining wall system fully approved for use by FHWA on the Colorado Interstate system was the Reinforced Earth Company product. Because extensive requirements for flexible walls in the canyon would be needed, it was decided that other systems should be tested to determine if one or more could be approved for competitive bidding. The I-70-2(90) project was designated experimental to allow testing of these other systems and to monitor behavior of the lake deposits. Four wall types were tested: Wire Wall, Retained Earth, Reinforced Earth, and geotextile walls. The design, construction, and performance of the geotextile wall tests are discussed in this paper.

Objectives of Geotextile Wall Tests

Geotextiles have been model tested as earth-reinforcement systems for a number of years (2,3), and several walls have been successfully constructed (4-6). The walls offer an apparently significant economic advantage over most proprietary systems, yet enough questions remain concerning design parameters and long-term stability to cause reluctance on the part of designers to fully accept this type of system.

None of the full-scale geotextile walls reviewed for this research had shown significant creep, and all have performed satisfactorily, even under loadings imposed by heavy logging trucks. However, none of the full-scale tests was designed to determine limiting bounds for geotextile as an earth-reinforcement system. Many of these walls had high live loadings; therefore, dead loads did not produce low factors of safety, and creep resistance was not tested.

A primary objective of the Glenwood Canyon test was to determine lower stability limits for a geotextile earth-reinforcement system. This was investigated by designing at or near equilibrium safety factors on portions of the walls to test the reliability of current design procedures.

A second objective was to demonstrate that the system could be constructed by a major contractor. Most other walls had been the products of special crews, which caused labor and other costs to be disproportionately high.

A third objective was to demonstrate overall cost-effectiveness of the geotextile reinforcement system when directly compared to other systems. A more reliable cost comparison was possible when several systems on the same project were erected by the same contractor.

A fourth objective was to investigate the tolerance to differential settlement, and a fifth objective was to demonstrate a facing system that could perform for the design life expectancy of a wall system.

A final objective was to demonstrate, by reduced fabric embedment lengths in the lower portion of the wall, the stability of this system in side-hill and other situations, where the minimization of initial excavations could save a significant amount of money.

TEST DESCRIPTION

The geotextile test wall is approximately 15 ft high and 300 ft long. The wall is divided into ten 30-ft segments, with a different fabric or fabric strength combination used to construct segments 1-8. Segments 9 and 10 are identical to 1 and 2, except the lower fabric layers are shortened.

The segments were designed with different factors of safety. Six segments had very low computed safety factors and were expected to creep, possibly to failure.

Geotextiles

Four common, readily available nonwoven geotextiles were selected for the tests. Each fabric was used in two weights. These fabrics represent a range of fabric constructions, polymers, and stress-strain characteristics. None of the geotextiles had particularly high strength or other special character-

Table 1. Test geotextiles.

Trade Name, Manufacturer, and CDOH Code No.	Approximate Weight (oz/yd²)	Filament	Construction
Fibretex, Crown Zellerbach		Continuous, polypropylene	Needle punched
CZ 200	6		
CZ 400	12		
Supac, Phillips Fibers		Staple, polypropylene	Needle punched, heat bonded (one side)
P 4 oz	4		
P 6 oz	6		
Trevira, Hoechst Fibers		Continuous, polyester	Needle punched
H 1115	5		
H 1127	11		
Typar, DuPont		Continuous, polypropylene	Heat bonded
D 3401	4		
D 3601	6		

Table 2. Geotextile strength characteristics.

Geotextile	Ultimate Strength (lb/ft)	Failure Strain (%)	Recommended Working Load	
			No. (lb/ft)	Percent of Ultimate
Fibretex				55
CZ 200	400	140	220	
CZ 400	680	145	375	
Supac				40
P 4 oz	860	65	345	
P 6 oz	1,665	60	670	
Trevira				65
H 1115	455	80	295	
H 1127	1,155	75	750	
Typar				40
D 3401	525	60	210	
D 3601	850	55	340	

istics. The geotextiles tested and some descriptive characteristics are given in Table 1.

The tensile strengths of the geotextiles were determined by a wide-strip tensile test (7). Specimens 8 in. wide and 4 in. long were loaded between grips in simple tension at a constant rate of strain of 10 percent. The specimens were soaked in water before testing. The peak strengths and corresponding elongations as determined by these tests are given in Table 2. Typical load-strain curves are shown in Figure 2.

The recommended working loads in Table 2 are selected to prevent failure by tertiary creep. The various phases of creep are shown in Figure 3. Tertiary creep can be prevented by limiting the applied loads to values less than some critical value, below which tertiary creep will not occur during the design life. Experience and tests indicate that this critical value is controlled, for a given geotextile, by loading and environmental conditions. The recommended values were taken from tests performed at Oregon State University (8).

Backfill Soil

The backfill soil was a free-draining, pit-run, rounded, well-graded, clean sandy gravel. Nearly all particles were less than 6 in. Approximately 50 percent passed the 0.75-in. sieve and approximately 30 percent passed the No. 4 sieve. The backfill soil is shown in Figure 4. Compaction specifications required 95 percent of AASHTO T-180. Conservative values of 35° and 130 lb/ft³ were assumed for the angle of internal friction and unit weight, respectively, for the preliminary design calculations.

Instrumentation

Instrumentation at the site was designed to provide both qualitative and quantitative information on settlement in the vicinity of the wall and to identify specific soil layers or zones of settlement. Information on horizontal deflection in the foundation soils and the vertical deflections of the face of the wall was obtained. Measurements of the deflections of the wall face and the surface above the wall were made to indicate settlement and creep of the fabrics. Movements within the backfill soil mass were also monitored.

These measurements were taken with 5 vertical inclinometer (Sondex) installations spaced evenly in front of the wall 5 ft out from the face; 5 manometers installed evenly along the back edge of the wall; 30 horizontal inclinometer-extensometer casings, with 3/test segment spaced vertically in the center of each segment; direct measurement survey posts at the center of each segment; and several survey points on and in front of the wall for direct measurement of changes in elevation. Many of these installations can be identified in Figure 5.

Test Wall Design

The test wall was designed by assuming the fabric layers had to resist a triangular lateral pressure distribution by friction on the portion of the fabric layer extending beyond the Rankine failure surface. This method was used by Lee and others (9) for Reinforced Earth walls. The method was modified for fabric walls by researchers at Oregon State University (2,10), and it has been used by the U.S. Forest Service (4,5,11) and the New York State Department of Transportation (6) to successfully construct several geotextile walls in the United States.

The geotextile wall section that indicates the fabric layer spacings is shown in Figure 6. The general wall layout is shown in Figure 7, which shows the 10 wall segments and identifies the fabric types in each. This figure also shows the locations of some of the instrumentation installations.

Each test segment is 30 ft long. The fabric layers all extend 12 ft into the fill, except for the lower layers in segments 9 and 10 (Figure 6). All segments incorporate a stronger geotextile (Trevira H 1155) for the lower three layers. Segments 5, 6, and 8 incorporate a lightweight fabric for the upper layers (10-17) and a heavier weight of the same fabric for the lower layers (4-9). All other segments use a one-strength geotextile, except for the cover fabric (layer 18) and the lowest layers (1-3).

To facilitate construction, geotextile layer spacings are the same in all wall segments. Therefore, because the geotextiles have different strength characteristics, the factors of safety are different for different segments. Design relative loads for each wall segment are given in Table 3. The relative load is the computed load expressed as a percentage of the appropriate ultimate load (strength) given in Table 2.

Safety considerations dictated that the wall should not fail rapidly during construction; therefore, some conservatism was retained in the design method. However, the data in Table 3 indicate that many computed loads are well above the recommended values in Table 2, and in two segments the loads approach the ultimate loads. It was expected from this design that the wall would exhibit significant strains in some fabric layers, and deflections of the wall would be evident. In some segments, failure by tertiary creep was considered a real possibility.

CONSTRUCTION

Construction procedures used on the Glenwood Canyon wall were modeled after Forest Service guidelines (5). The steps required to complete each lift are shown in detail in Figure 4. Different stages of the actual construction are shown in Figure 5. The partly completed wall with the forms set for the next lift (step 1, Figure 4) and the fabric spread (step 2, Figure 4) is shown in Figure 5a. In Figure 5b the backfill for the new layer is being placed. In Figure 5c the backfill is being spread (step 3, Figure 4) and the windrow built (step 4 Figure 4). In Figure 5d the fabric is folded back over the windrow (step 5, Figure 4) and the backfill lift is completed (step 6, Figure 4).

Based on field observations during construction, few modifications for construction of future walls would be made to the general plan used for the test series. It would be prudent to design thin (6- to 9-in.) lifts for the first 2 to 3 ft to allow the field crew to become familiar with the technique. It takes a new crew 3 or 4 lifts to develop their technique so that they can obtain a uniform wall face.

Figure 2. Geotextile load-strain curves.

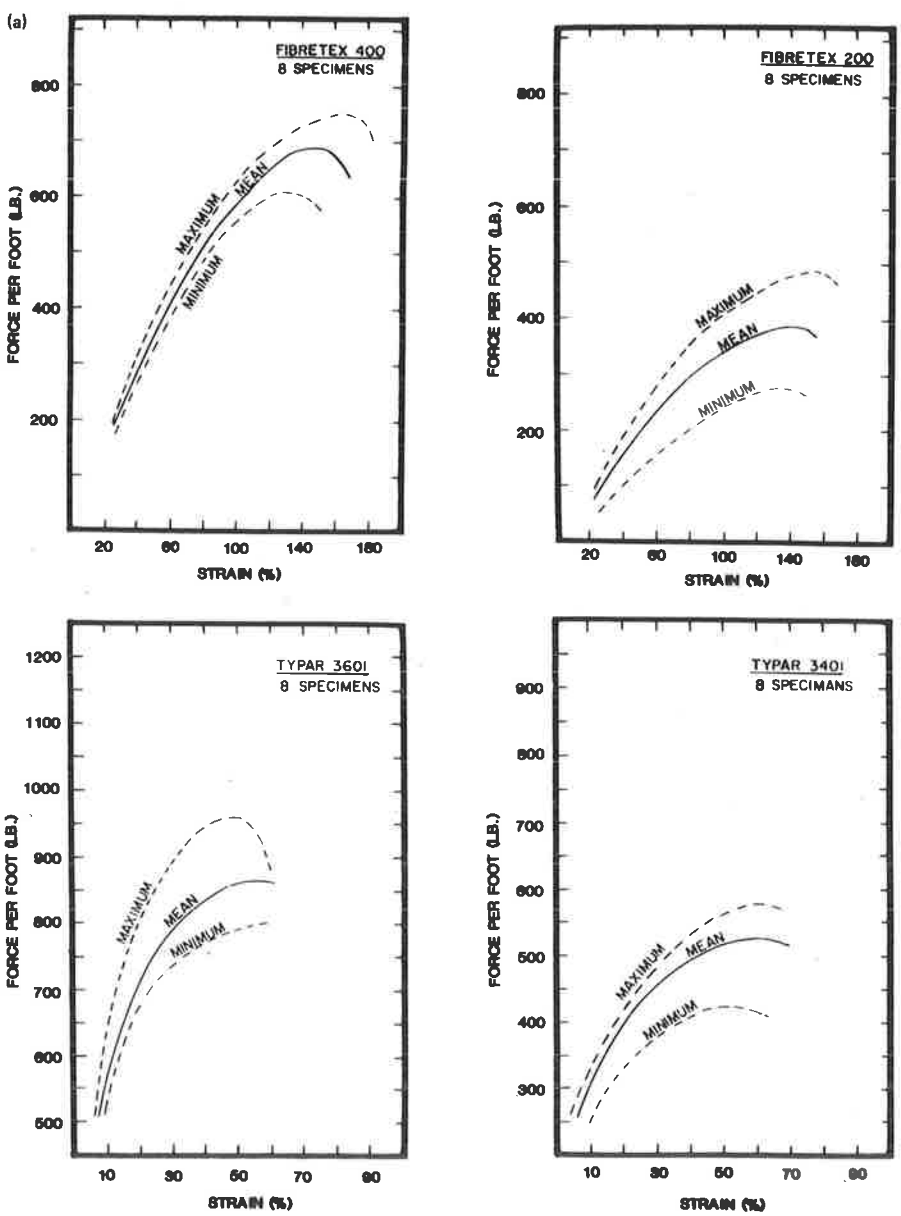


Figure 2. Continued.

(b)

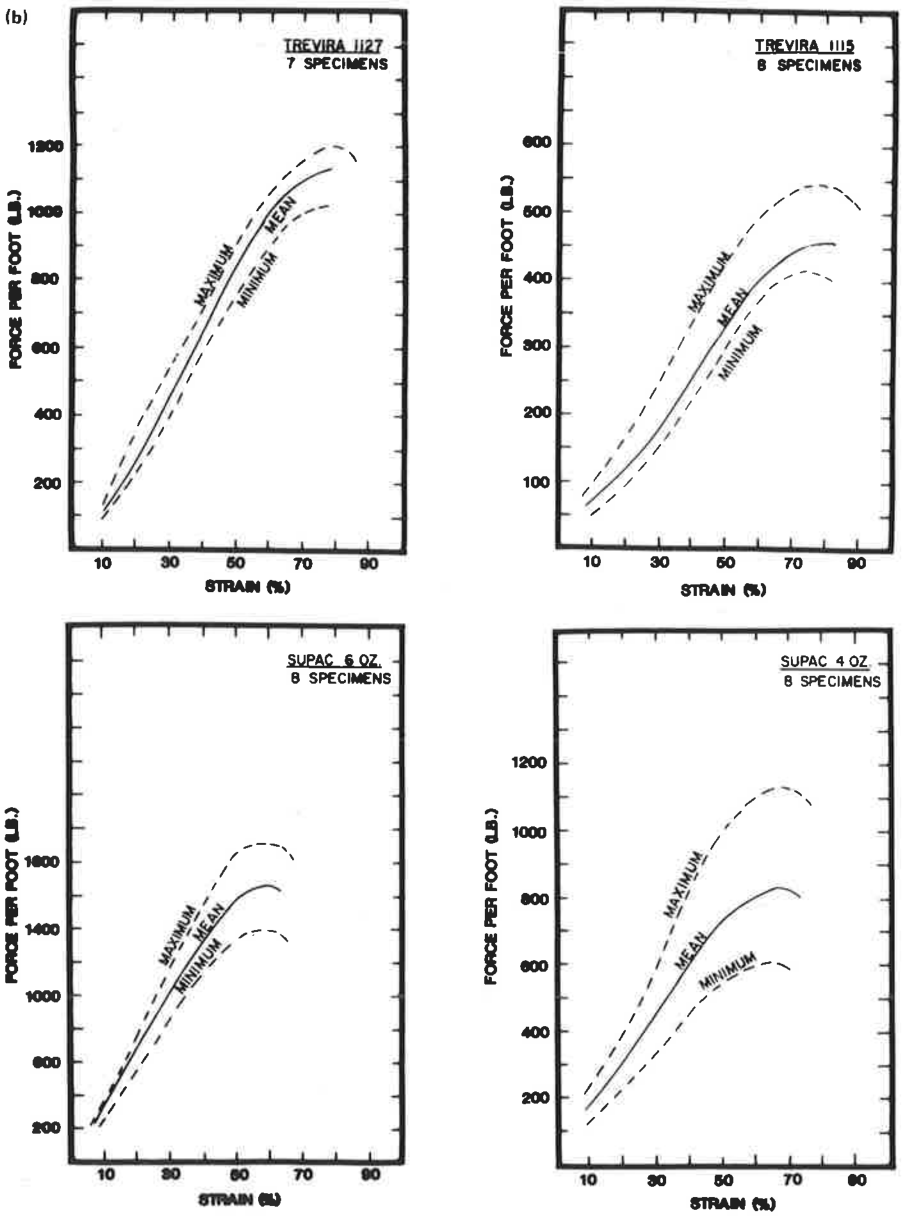
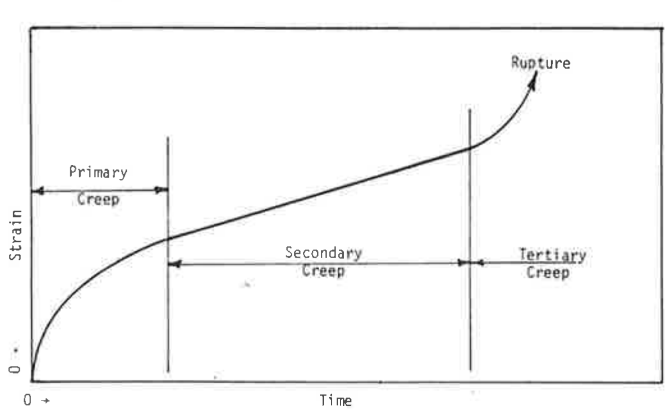


Figure 3. Phases of creep for typical geotextile tested in isolation at constant load and temperature.



The face-forming system used on this project performed satisfactorily. Nevertheless, the experience suggests it is only reasonable for lifts up to about 15 in. Thicker lifts would require a different or modified forming system.

Maintaining design batter, or face slope, requires continual monitoring. The test wall series was planned for a 1-in-10 batter and was constructed with a 1-in-5 batter. This was due to a variety of factors, but the primary one was failure to formally survey each lift.

Many geotextiles must be protected from the sun. Ultraviolet light is the only agent in a typical construction environment that will cause deterioration of either polypropylene or polyester. On this project new lift faces were sprayed within 5 days with a low viscosity water-cement mixture. This fluid penetrated the fabric and set to a brittle

Figure 4. General geotextile wall construction procedure.

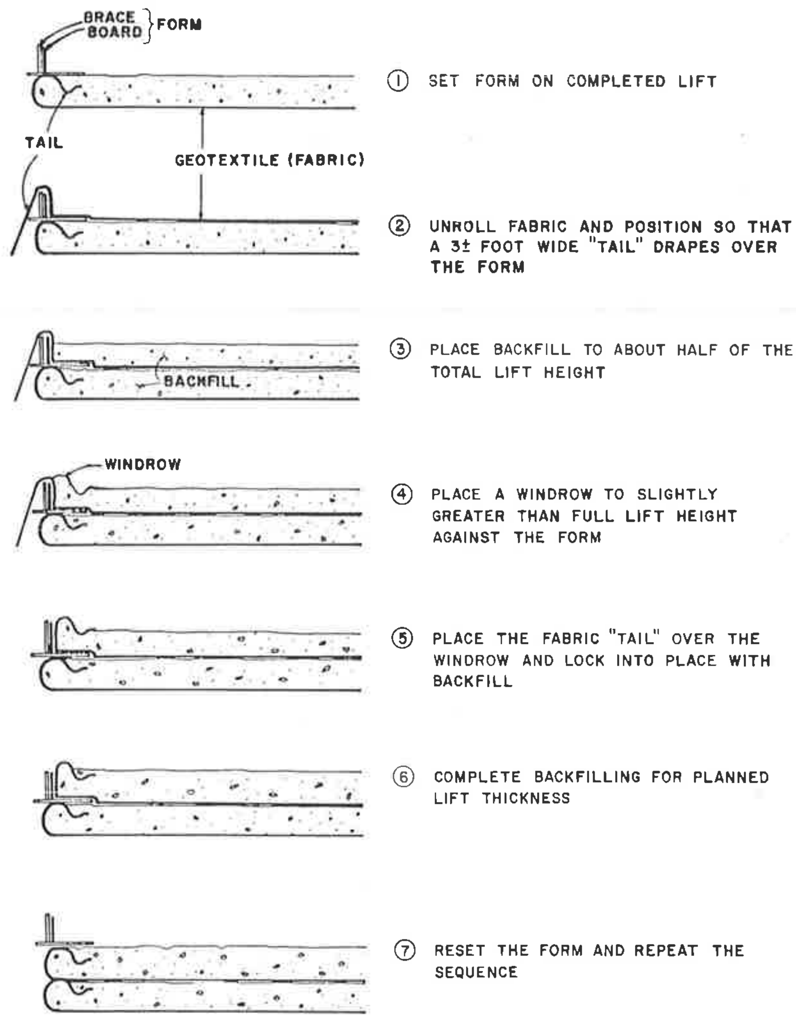


Figure 5. Wall construction.

Figure 6. Geotextile wall section.

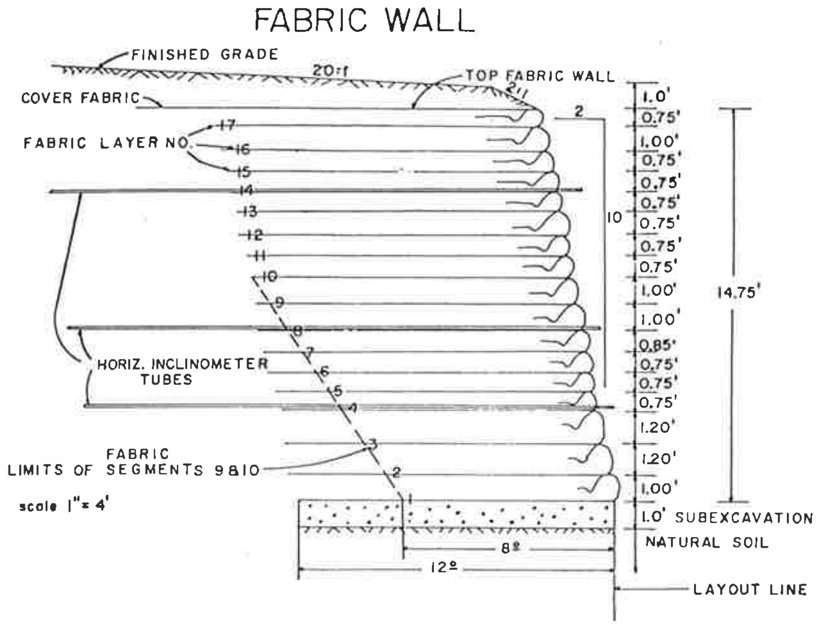


Figure 7. Geotextile wall elevation with test segments and fabric types indicated.

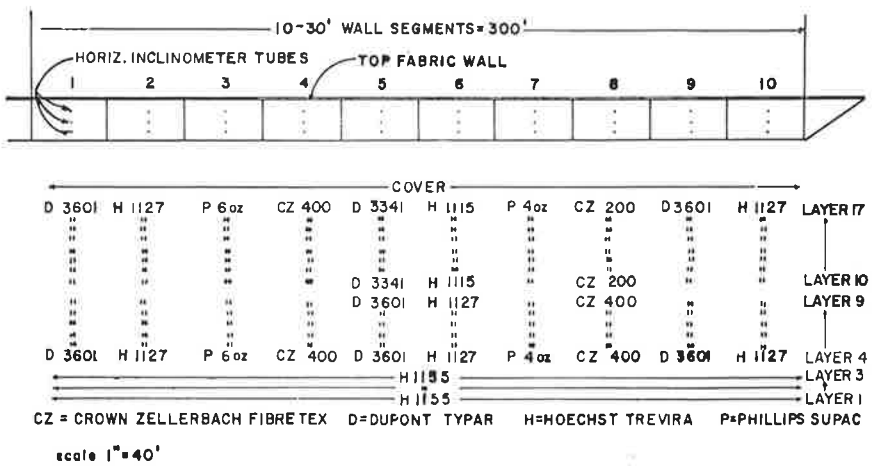


Table 3. Design relative load for test wall segments.

	Relative Load[a] (%) by Wall Segment									
Layer	1	2	3	4	5	6	7	8	9	10
17	10	7	5	13	16	19	10	21	10	7
16	16	12	8	20	26	30	16	34	16	12
15	17	13	9	21	28	32	17	36	17	13
14	21	15	11	26	34	39	21	44	21	15
13	25	18	12	31	40	46	24	52	25	18
12	28	21	14	35	46	53	28	60	28	21
11	32	23	16	40	52	60	32	68	32	23
10	42	31	21	52	68	78	41	89	42	31
9	54	40	28	68	54	40	53	68	54	40
8	56	41	28	70	56	41	55	70	56	41
7	53	39	27	66	53	39	52	66	53	39
6	53	39	27	67	53	39	53	67	53	39
5	57	42	29	71	57	42	56	71	57	42
4	79	58	40	99	79	58	78	99	79	58

[a]Relative load is the computed fabric load expressed as a percentage of the geotextile ultimate strength.

stiffness. It bonded well and provided excellent protection, even for the smoother fabrics.

Facing

The wall was faced with gunnite. This facing was easily applied by an experienced crew and has withstood differential settlements of about 12 in. over 300 ft in only 3 months with little cracking of the surface. About 65 yd^2 of gunnite were required for the approximately 4,700 ft^2 of wall face.

A number of facades could be adapted for geotextile walls, including logs, treated timber, vertical or horizontal boards, or precast-concrete panels. Any of these systems could be developed cost competitively on a major wall. The wall would be constructed as described previously and the facing attached to the completed wall as a free standing facade tied back to the geotextile wall.

Cost

Costs for the series of geotextile test walls ranged between \$11.00 and \$12.50/ft² of wall face. Variability in the cost figure depended on which items were excluded as special research features and which were included as required for all walls. The cost breakdown in terms of completed square footage of wall face (in 1982 prices) is given in the table below:

Item	Cost ($)
Geotextiles	2.00 to 2.50
Labor	0.50 to 1.00
Equipment	0.50 to 1.00
Backfill (including haul)	5.00
Gunnite	3.00

DISCUSSION OF RESULTS

In general, the construction procedures, costs, and performances of the wall have been satisfactory. Performance to date has been better than expected in that large strains anticipated in some segments of the walls have not occurred. There are several possible reasons for this fact:

1. The instrumentation does not accurately indicate the strains in the geotextiles,
2. The assumed backfill parameters are incorrect,
3. The theory does not accurately model the true mechanisms, and
4. The laboratory geotextile tests used do not adequately indicate the in-soil behavior of the geotextiles.

Table 4. Computed relative loads and recommended allowable geotextile loads.

Wall Segment	Computed Maximum Relative Load (%): Design	As Built: At Rest (Ko)	As Built: Active (Ka)	Allowable Load (%)
1	79	63	39	40
2	58	46	29	65
3	40	32	20	40
4	99	79	49	55
5	79	63	39	40
6	78	63	39	65
7	78	62	39	40
8	99	79	49	55
9	79	63	39	40
10	58	46	29	65

Discussions of each of these reasons follows.

Model tests (2) have indicated that the failure zones in reinforced walls are very narrow. Therefore, the zone of significant strains (initial and creep) in the geotextiles may be narrow. The fabric strains in the test wall may be masked by settlement, at least until strains become large. As of November 1982, the instruments have not indicated fabric strains.

Values of 35° and 130 lb/ft³ were assumed for backfill friction angle (φ) and unit weight (γ), respectively. These values were used to calculate the geotextile relative loads given in Table 3. The maximum design load for each wall segment is tabulated in Table 4. These values reveal that, according to the design assumptions for the critical layers in segments 4 and 8, the factors of safety against an immediate failure were 1.0 (a relative load of 100 equals a factor of safety of 1.0). Other segments had immediate factors of safety of 1.25 or higher. With respect to creep failure (rupture by tertiary creep), all but segments 2, 3, and 10 had factors of safety much less than 1.0. Segment 5, for example, only had a factor of safety of 0.5 (ratio of relative load to allowable load). Obviously, the design calculations were conservative, as failure has not occurred.

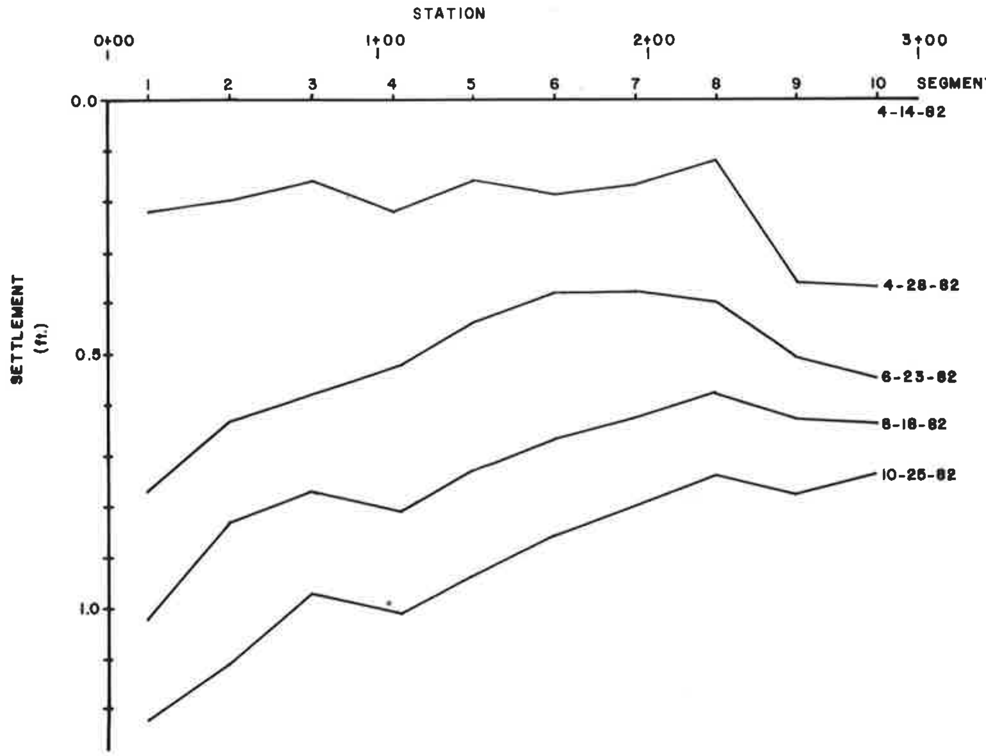
For the as-built sections, φ was about 42° and the average unit weight was about 135 lb/ft³. When these values are used with the other design assumptions, maximum relative loads are as indicated in the third column of Table 4. When these values are considered, the factors of safety against an immediate failure are all greater than 1.0, but factors of safety against creep are still considerably less than 1.0 for 6 of the 10 wall segments. There are apparently more conservative factors than just the assumed backfill parameters.

A major question is the validity of the theory used. The theory does not actually analyze a composite reinforced material. It is actually a pseudo-tie-back analysis. It is known to be conservative (2), but how conservative is not known. The analysis in this design assumed the at-rest earth pressure Ko rather than the active pressure Ka. The at-rest pressure has also been used for similar analyses by other researchers (5,9,10). The use of the at-rest pressure was reasonable when the heavy traffic loads were expected, but they may be excessively conservative for the actual case with dead loads only. The high-elongation geotextiles may encourage the development of the active state. When the maximum goetextile relative loads are further reduced for active lateral earth pressure, the values in the fourth column of Table 4 are obtained. Currently, none of the computed loads exceeds the allowable loads, and creep failures are not indi-

Table 5. Computed average relative loads and recommended allowable loads.

Wall Segment	Computed Avg Relative Load (%): Design: Avg of Layers 5-17	Design: Avg of Layers 4-9	As Built: At Rest (Ko): Avg of Layers 5-17	At Rest (Ko): Avg of Layers 4-9	As Built: Active (Ka): Avg of Layers 5-17	Active (Ka): Avg of Layers 4-9	Allowable Load (%)
1	39	59	31	47	19	29	40
2	29	43	23	34	14	21	65
3	20	30	16	24	10	15	40
4	49	74	39	59	24	37	55
5	47	59	38	47	23	29	40
6	44	43	35	34	22	21	65
7	38	59	30	47	19	29	40
8	60	74	48	59	30	37	55
9	39	59	31	47	19	29	40
10	29	43	23	34	14	21	65

Figure 8. Average total settlement of fabric wall.



cated; however, creep greater than that indicated by field instrumentation would still be expected.

The distribution of the total load among the geotextile layers is another question. The calculations assume the soil stresses increase linearly with depth, and the load on a given fabric layer is equal to the sum of the soil stresses over an area bounded by the mid-distances to the layers above and below it. Field measurements have revealed that the actual loads were more uniform with depth (12,13). Further, for high-elongation geotextiles, such as those used in this study, the more highly stressed fabric layers may yield sufficiently to transfer parts of their loads to adjacent layers. Thus it might be more realistic to average the geotextile layer loads. Averaging assumes no layer can fail unless all layers fail. This assumes that if the load on any layer exceeds the load on adjacent layers, that layer will creep more than adjacent layers, thereby transferring loads to the adjacent layers.

The average geotextile relative loads are given in Table 5. These values do not indicate possible immediate failure; however, for the at-rest case, when the lower portion of the wall is considered, creep failure is still critical for 6 of the 10 segments. Only when the loads for the active pressure case are averaged are the results consistent with field strain measurements on the test wall. At these stress levels, the fabrics would strain approximately 10 percent or less. This is the maximum strain in a layer, not an average. The instrumentation may not detect this magnitude of movement as being due to fabric creep rather than settlement.

These discussions suggest that the theory greatly overestimates stresses in the geotextiles and that past practices have been excessively conservative. Before accepting this conclusion, however, it is necessary to consider the problem of establishing allowable geotextile loads from simple, in-isolation, tensile testing.

It is known that, when confined in a soil, the load, strain, and time relations of geotextiles are changed (14,15). For needle-punched fabrics, these changes are great. The initial strains at relative loads of 20 to 40 percent may be reduced by one-half or more (14). The ultimate strengths, however, are only slightly increased. There is limited evidence that the critical stress needed to initiate tertiary creep failure is not greatly increased (14,16). However, the creep rate at intermediate relative loads is decreased by orders of magnitude. Therefore, the critical loads assumed in this study may be reasonable, but confinement of the geotextiles in the soil may have reduced the initial strain and delayed the development of time-dependent strain. It may be that the higher computed loads, at least as high as the averages, are realistic and that only time is required to develop the expected high strains.

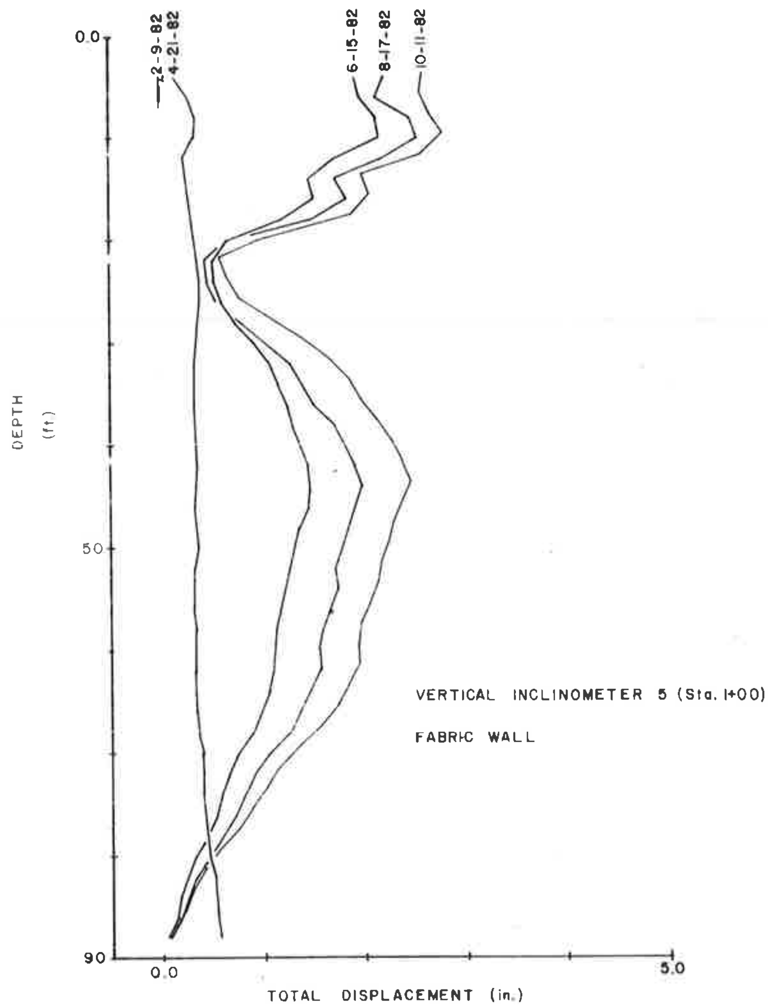
Optical survey measurements for the first 6 months indicate that a relatively large amount of consolidation has taken place in the soils beneath the wall. This settlement has not produced significant cracking in the shotcrete facing to date. The representative settlement data are shown in Figure 8 and the attendant horizontal deflections are shown in Figure 9. All wall instrumentation monitoring will be continued to observe future trends.

Wall segments 5 and 6 have been surcharge loaded. This may help clarify the situation; however, there is a need for full-scale, instrumented walls designed to fail. Only by going all the way to failure with different types of geotextiles for different loadings will it be possible to verify or modify design methods and select appropriate safety factors.

The surcharge load was added too recently to provide data for this paper. These results will be analyzed in a future report.

The use of stronger fabrics will allow building walls with fewer, thicker lifts. This appears to

Figure 9. Horizontal deflections of fabric wall.



offer an economic benefit because of reduced labor. However, experience in these tests suggests that the forming method used is not generally practical for lifts greater than about 15 in. Thicker lifts will require a different method. A more sophisticated method will probably not be economical except on very large jobs. The use of strong geotextiles, therefore, may not offer significant savings except in special cases or for high walls where they would be used in the lower layers.

Some fabrics are stronger in the machine direction than in the cross-machine direction. However, to use this extra strength it is necessary to cut the fabric roll into many short sections and sew them together before installation. This is probably not cost effective. It is probably best to use the cross-machine strength in design. This must be considered when sampling and testing geotextiles.

Although geotextile costs are not to be ignored, the cost data for this wall indicate that geotextile costs are a small percentage of total wall costs. If excavation is required, this percentage cost becomes even smaller. Therefore, the use of conservative allowable loads and other conservative design assumptions does not unduly increase costs.

CONCLUSIONS

The results of this study suggest the following conclusions.

1. Geotextile reinforced walls are economical and practical.
2. Construction procedures are practical for large contractor-constructed projects.
3. Suitable simple, economical, durable facings can be adapted for this system.
4. The mechanisms of geotextile reinforced soil are not well defined. Further, the stress, strain, and creep behaviors of geotextiles embedded in soils are not fully understood, and the ability to evaluate geotextiles and rationally select allowable loads is limited.
5. Designs based on the Rankine model that use at-rest earth pressures as previously published will give economical, safe, practical designs for the following conditions: cohesionless backfill; maximum allowable relative loads, as specified in this paper to limit creep; when allowable loads are applied to the average loads computed, as indicated in this paper for high-elongation geotextiles; and a factor of safety of 1.5.
6. Conservative interpretation of geotextile strengths has a limited effect on economy because the cost of the reinforcing component is a small part of the total cost of the wall.
7. Full-scale wall tests to failure are needed to clarify the theory, develop appropriate factors of safety, and allow more rational, and perhaps more economical, designs.
8. Reduced fabric lengths in the lower portions

of fabric walls may be a safe, effective way of minimizing excavations in side-hill installations.

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The wall was constructed by Peter Kiewit and Sons Construction Company.

Note that the use of product, trade, proprietary, and company names in this paper is for clarity and does not imply endorsement or superiority to similar items.

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