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MONITORING THE TWO-PHASE WALL SYSTEM

MAJID DERAKHSHANDEH
TIM BOWEN
Colorado Department of Highways
4201 East Arkansas Avenue
Denver, Colorado 80222

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16. Abstract

Various reinforced earth retaining walls were constructed in Glenwood Canyon to accommodate for the possible large differential settlements of the foundation soils. The first time these walls were constructed with 10-foot wide, and 20-foot high fascia panels. These panels admirably withstood severe differential settlements. However, they did not meet the specifications for the final alignment due to the horizontal rotations associated with the vertical settlements. Therefore, it was decided to complete the construction of the walls in two phases. During the first phase, the walls were constructed with a temporary facing according to the standard construction procedures. Then the walls were allowed to settle under their own weights. Upon completion of the primary settlements, the permanent full-height fascia panels will be placed and connected to the front of the phase one walls, and the area between them will be filled with lean concrete.

The walls have been monitored since completion of the phase one construction, and the results are presented in this interim report. The results indicate that the primary settlements are completed and it is possible to begin the second phase of the construction. The full height fascia panels will be monitored and the results will be presented in a final report.

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MONITORING THE TWO-PHASE WALL SYSTEM

INTRODUCTION

The Glenwood Canyon project is a gap segment of I-70 located in western Colorado. Severe geologic, topographic, and environmental constraints require innovative designs and construction methods to complete the construction of the four-lane highway through this canyon.

An unexpected compressible, lacustrine silt/clay was discovered during the foundation investigations for a proposed rigid cantilever wall and pavement system. Thickness of the compressible layer varies from 0 to 60 feet along the wall profile line, and the depth to the clay also varies greatly. Therefore, a wall system that could handle differential settlements up to 3 feet and be architecturally compatible with canyon design parameters had to be found. Architectural guidelines and constraints developed over a ten-year period of very intense design effort by citizens, design consultants, FHWA, and the Colorado Highway Department left little latitude in selection of wall types to replace the obviously unsuitable rigid, precast, post-tensioned concrete cantilever wall and pavement system as standard design for the canyon project. The Reinforced Earth Company and the Retained Earth Division of the VSL Company provided designs for their respective walls which included 10-foot wide, full height facing panels. This was the first use of full height panels for either company. These panels admirably withstood severe differential settlement. However, they did not meet architectural specifications for the final alignment due to the horizontal rotation associated with the vertical settlement. The problem developed in attempting to place a modified bridge-rail guardrail on top of the wall. This railing is unique to the canyon and requires that the deviation of the top of a wall panel from planned final location be less than three inches.

A two-phase wall system seemed to offer the best possible solution to this unique problem. In order to obtain the required alignment at the end of primary consolidation, it was decided to construct the wall in two phases. The first phase would include a completed earth reinforced retaining wall with temporary facing. The second phase would include setting a permanent facing in front of the phase one wall, connecting the facing to the wall, and filling the void between them with lean concrete. This would assure exact final panel alignment and would then permit the guardrail to be located in its proper location.

OBJECTIVES OF THE STUDY

The objectives of this study are:

1. To experience the application of the two-phase wall system on highly compressible material.
2. To determine the practicality of this system by means of field monitoring.
3. To evaluate the cost difference between this system and the standard reinforced/retained earth walls.

PROJECT LOCATION AND GEOLOGY

Glenwood Canyon, located about 150 miles west of Denver, is a winding 12 mile long, steep-walled chasm cut by the Colorado River. The river, a railroad, and US. 6 thread their way through the narrow scenic canyon. The highway is being upgraded as the last link of I-70 across the State.

In order to accommodate four lanes of interstate highway, it is necessary to build retaining walls over the U.S. 6 embankment slopes and in the river. The subsurface material beneath the walls, as shown in Figure 1, consists of new fill averaging about 5-feet in thickness, ranging up to approximately 18

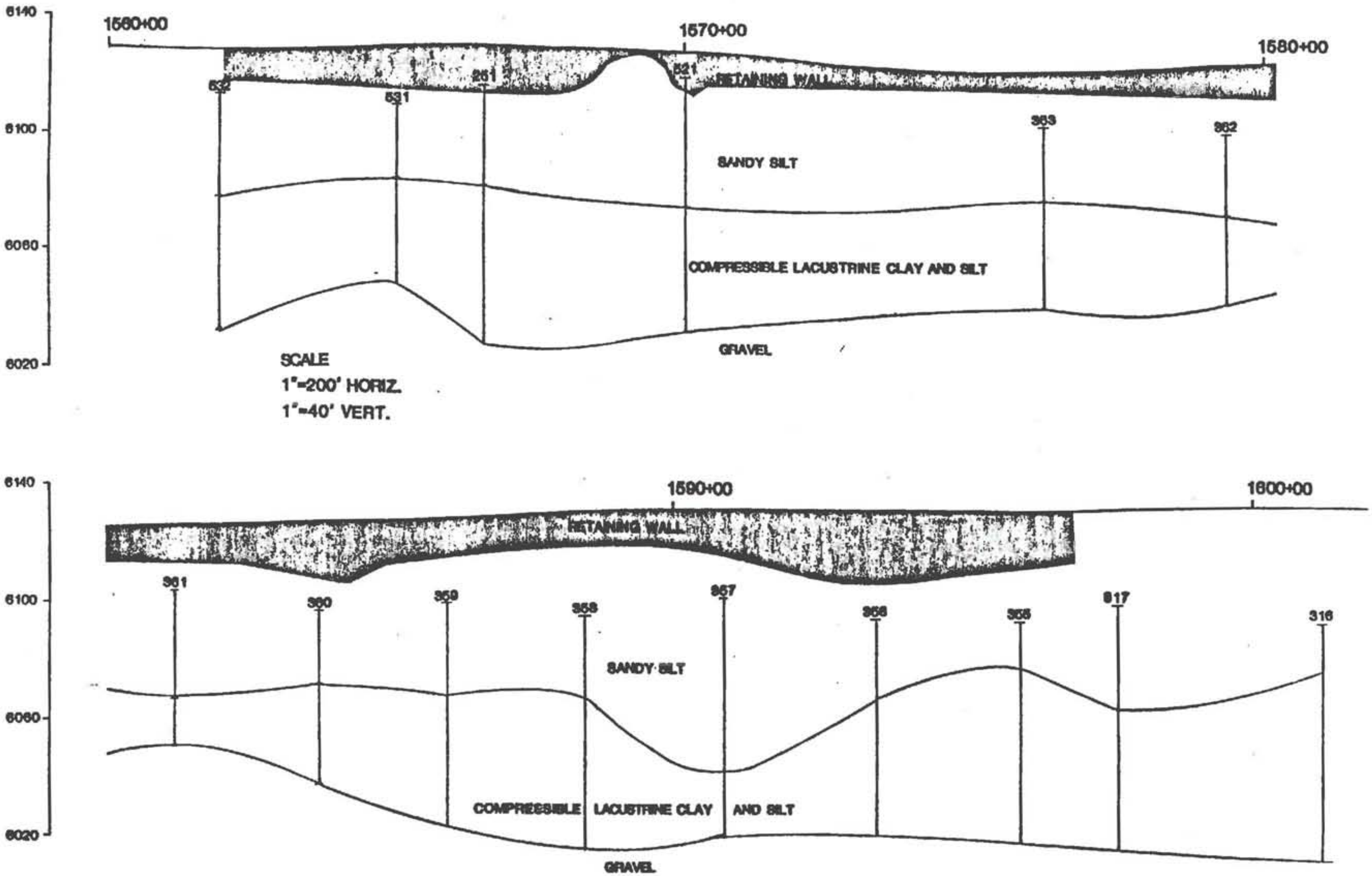


FIGURE 1- PROFILE OF THE TWO PHASE WALL SYSTEM WITH THE DISTRIBUTION OF THE COMPRESSIBLE CLAY SOIL BELOW THE GROUND SURFACE

feet, underlain by the present highway embankment which in turn is underlain by 20 to 60 feet of sand, gravel and boulders intermixed in some places with clay and silt. The sand and gravel is, in turn, underlain by varying amounts of soft gray silt and clay, known locally as the "gray layer" which has been encountered at most other locations in this part of the canyon. The gray layer thins out and disappears laterally across the canyon beneath the existing road. The walls along the eastbound lane are located on various amounts of new fill along its entire length. Between Stations 1563 and 1571+50, the layer of fill is relatively thin and is underlain by river terrace material consisting of sand, gravel, clay and silt ranging in thickness from 16 to 60 feet. Soft layers and pockets of clay-silt mixtures are common near the ground surface through this interval, particularly between Stations 1563 and 1567. Beneath the sand and gravel is the gray zone, which ranges from 13 to 57 feet in thickness, averaging 38 feet. The gray zone is underlain by sand, gravel and boulders. Deposits of soft, silty muck ranging from 2 to 10 feet in thickness and averaging 4 feet were found on the river channel bottom at 40% of the locations drilled.

LABORATORY TEST RESULTS

During the geologic investigation various samples were obtained and tested to determine the engineering properties of the foundation material.

Triaxial compression tests were performed on the soft silty material underlying the site. The results indicated an angle of internal friction of 11.2 degrees and cohesion of .04 psi for the total stresses and a corresponding 14.9 degrees and .65 psi for the effective stresses. These values were then used to determine the safety factors against shear failure. The analysis based on the total stresses produced a safety factor equal to

.878. This defined the situation which would exist if the loads were imposed instantaneously. On the other hand, the safety factor based on the effective stresses was determined to be 1.362. This represented the condition where the soil was allowed to consolidate fully under the proposed wall load. Results of the consolidometer tests performed on similar material from the adjacent Bair Ranch Rest Area site indicated that consolidation should occur fairly rapidly, probably on the order of several weeks. This suggested that it would be possible to construct the roadway section without failure if the construction proceeds gradually, allowing the materials to progressively consolidate under successive applications of load.

CONSTRUCTION

Construction of the two-phase wall between stations 1560+20 and 1590+70 started on September, 1983 and was completed in August, 1984. The Reinforced Earth Company provided the design and Eagle West, a subsidiary of Flatiron Structures, built the first phase of the construction. The construction of the second phase is scheduled for the Fall of 1989.

Construction of the first phase was carried out in accordance with the Reinforced Earth Company's standard construction procedures. The only exception was the use of a temporary wall face consisting of a wire mesh backed with fabric material to retain the backfill soil during the consolidation period.

The foundation for the reinforced earth structure was graded level for a width equal to or exceeding the length of the reinforcing strips. The foundation soil was compacted to a depth of 0.5 ft. according to AASHTO specifications. Wire mesh facing backed with filter fabric was then placed vertically as shown in the plans of Appendix A. Bracing was used to maintain verticality during backfilling. The horizontal-facing support bars, with attachment clips installed, were placed in position and connected to the reinforcing strips.

At each reinforcing strip level, the backfill soil was roughly leveled before placing and bolting the strips. The reinforcing strips were then placed normal to the face of the wall and inserted in the attachment clips. The free end of the strips extended a minimum of 6-inches past the attachment clips. Then a layer of backfill soil not exceeding 8-inches was placed on top of the reinforcements and compacted based on AASHTO specifications. Light mechanical tampers were used to compact the soil close to the face of the wall.

The above procedure was continued for each layer of reinforcement until the erection of the wall was completed.

Figures 2 through 8 show the erection of the reinforced earth-wall with the temporary facing. The actual plans and specifications on the temporary wall facing are presented in Appendix A.

MONITORING PROGRAM

Settlements were measured by standard surveying techniques. Eight survey stations, as shown in table one, were used to monitor two 300-ft. sections of the wall. Survey readings were initiated when backfill was at the 17-ft. high level. Readings have been taken with frequency diminishing from three times per week to four times per year. Figure 9 shows one of the survey stations used in this project.

In order to safely construct the reinforced earth wall over the clayey silt between stations 1563 and 1567, it was necessary to carefully monitor the pore water pressures in the underlying soil. This was accomplished by piezometers installed under the proposed location prior to construction and

FIGURE 2 - SETTING UP THE TEMPORARY FACING BY INSTALLING WIRE MESH ON THE WOODEN FRAME

FIGURE 3 - NAILING THE REQUIRED GEOTEXTILE FABRIC TO THE FASCIAL WOODEN FRAME

FIGURE 4 - PLACING A LAYER OF REINFORCEMENT STRIPS AND CONNECTING THEM TO THE TEMPORARY FACING

FIGURE 5 - PLACING BACKFILL SOIL TO COVER THE REINFORCING STRIPS

FIGURE 6 - CLOSE UP OF THE BACKFILL MATERIAL

FIGURE 7 - COMPACTING THE SOIL PLACED IN FRONT OF THE REINFORCED EARTH WALL TO PROVIDE STABILITY AND THE NECESSARY AREA FOR THE FUTURE BIKE-PATH PLATFORM.

FIGURE 8 - COMPLETED WALL AT THE END OF PHASE ONE CONSTRUCTION. THE TEMPORARY FACING IS CLEARLY ILLUSTRATED.

FIGURE 9 - REBARS STICKING OUT OF THE REINFORCED EARTH WALLS WERE USED AS SURVEY STATIONS

monitored daily throughout construction. To prevent failure, it was estimated that the observed pore pressure at any time should not be allowed to exceed 10% of the total load imposed by the installed embankment.

In addition, the wall was inspected periodically to determine the performance of the temporary facing and the overall safety of the retaining wall structure.

RESULTS

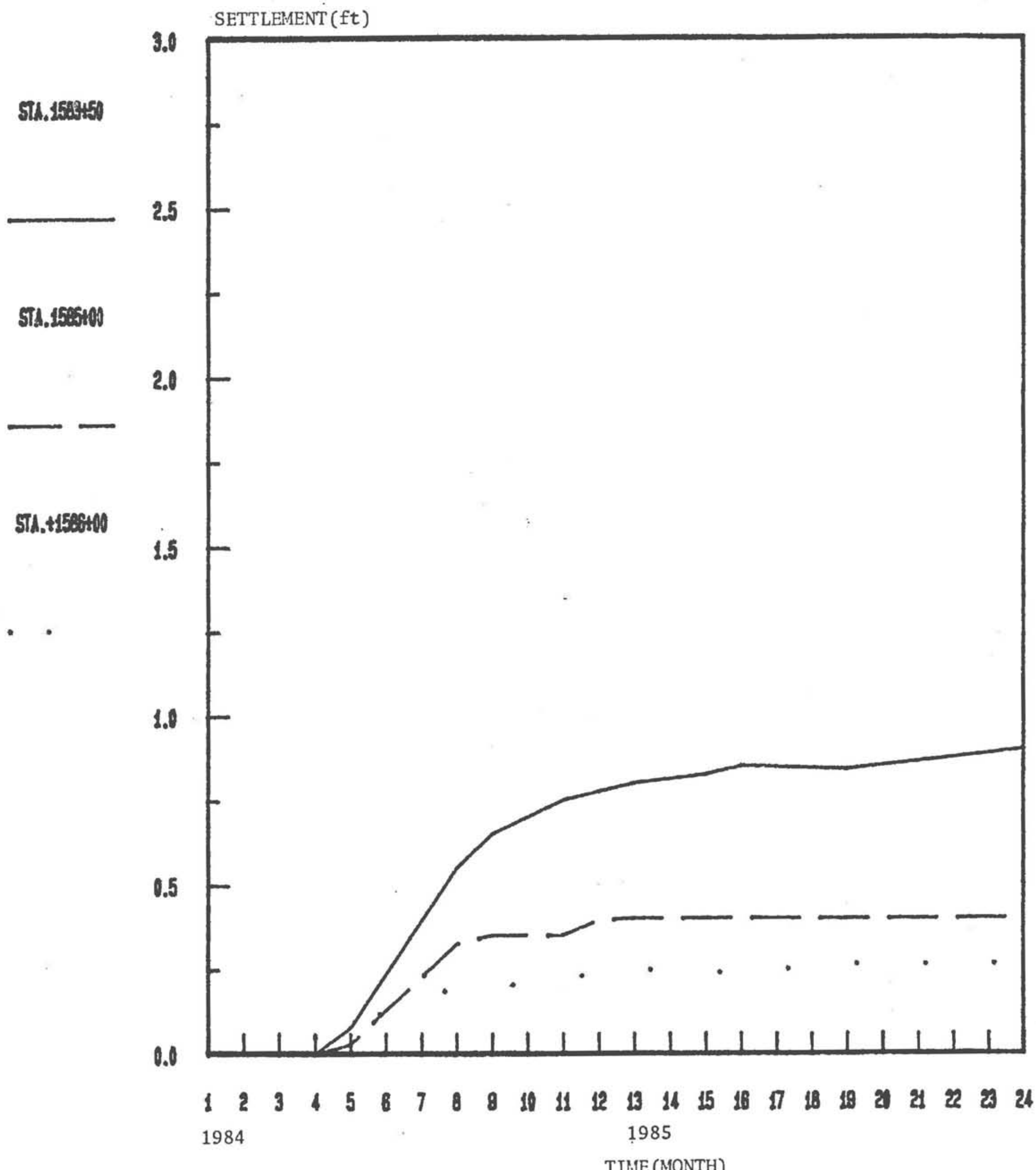
The performance of reinforced earth walls on highly compressible foundation soils has been well established from the previous studies conducted in this part of the canyon. Differential settlements as high as two feet were predicted to occur prior to construction of the two-phase walls. This was evaluated by monitoring the survey stations after completion of the walls.

The consolidation process was detected by taking periodic readings and plotting the time-settlement curve for each of the stations. The results are presented in Figures 10 and 11. According to these figures, all stations show the progress of the secondary consolidation processes. This means that most of the settlements are completed and the remaining settlements will be minimal, predictable, and at very slow rates.

In addition, the wall settlement profile underneath the wall between stations 1583+50 and 1596+25 was plotted to evaluate the magnitudes of the differential settlements. Figure 12 shows the total settlements at each station according to the last survey data obtained on July, 1985. The results indicate that maximum and minimum settlements of 2.28 (ft) and 0.27 (ft) had occurred at stations 1593+17 and 1586+00 respectively. This means that this section of the wall has experienced over 2 (ft) of differential settlement and this may have played a big factor in performance of the full height fascia

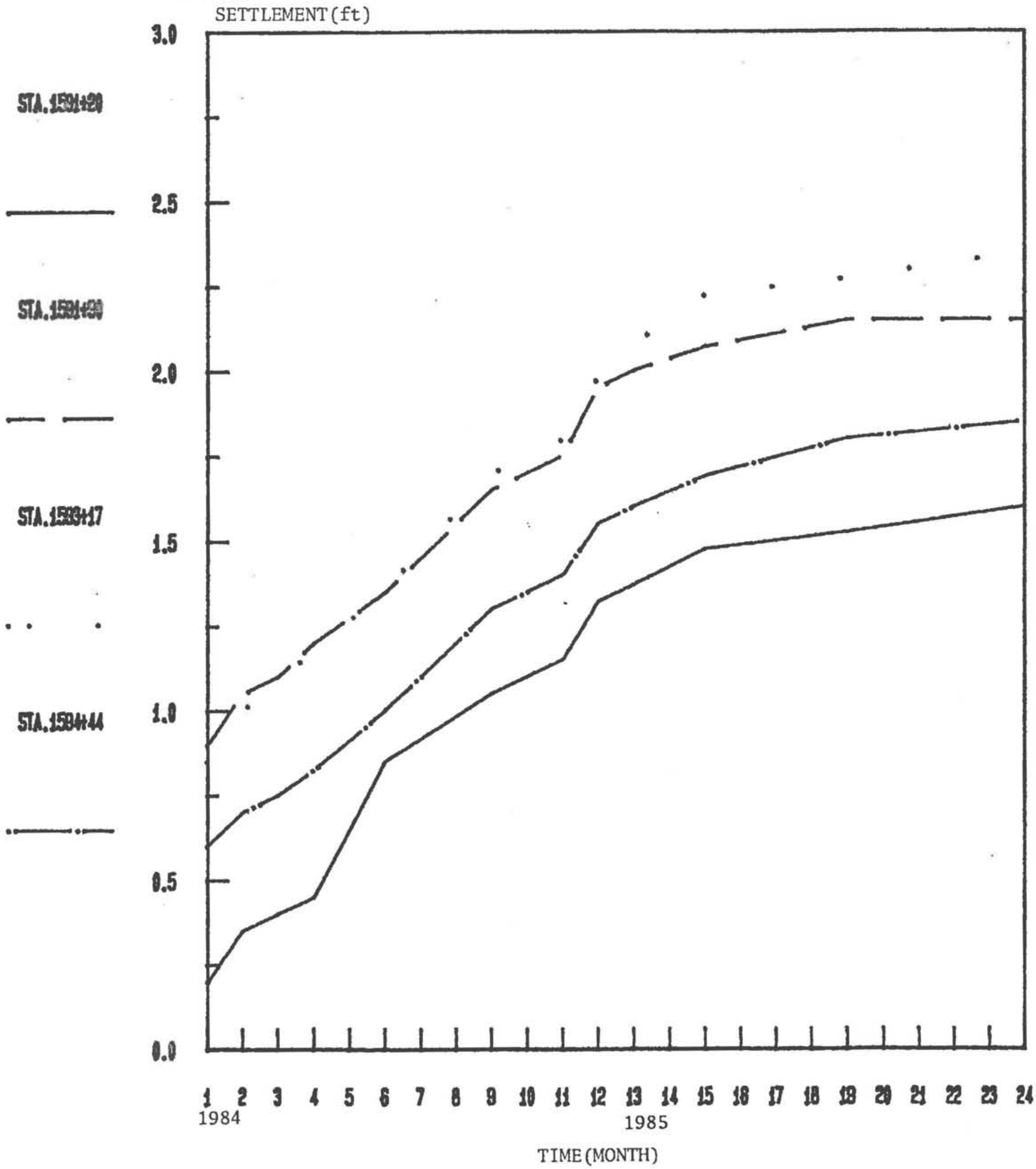
SETTLEMENT CURVES

FIGURE 10 - SETTLEMENT VERSUS TIME CURVES FOR THREE STATIONS ON THE TWO PHASE WALLS



SETTLEMENT CURVES

FIGURE 11- SETTLEMENT VERSUS TIME CURVES FOR THE REMAINING STATIONS ON THE TWO PHASE WALLS



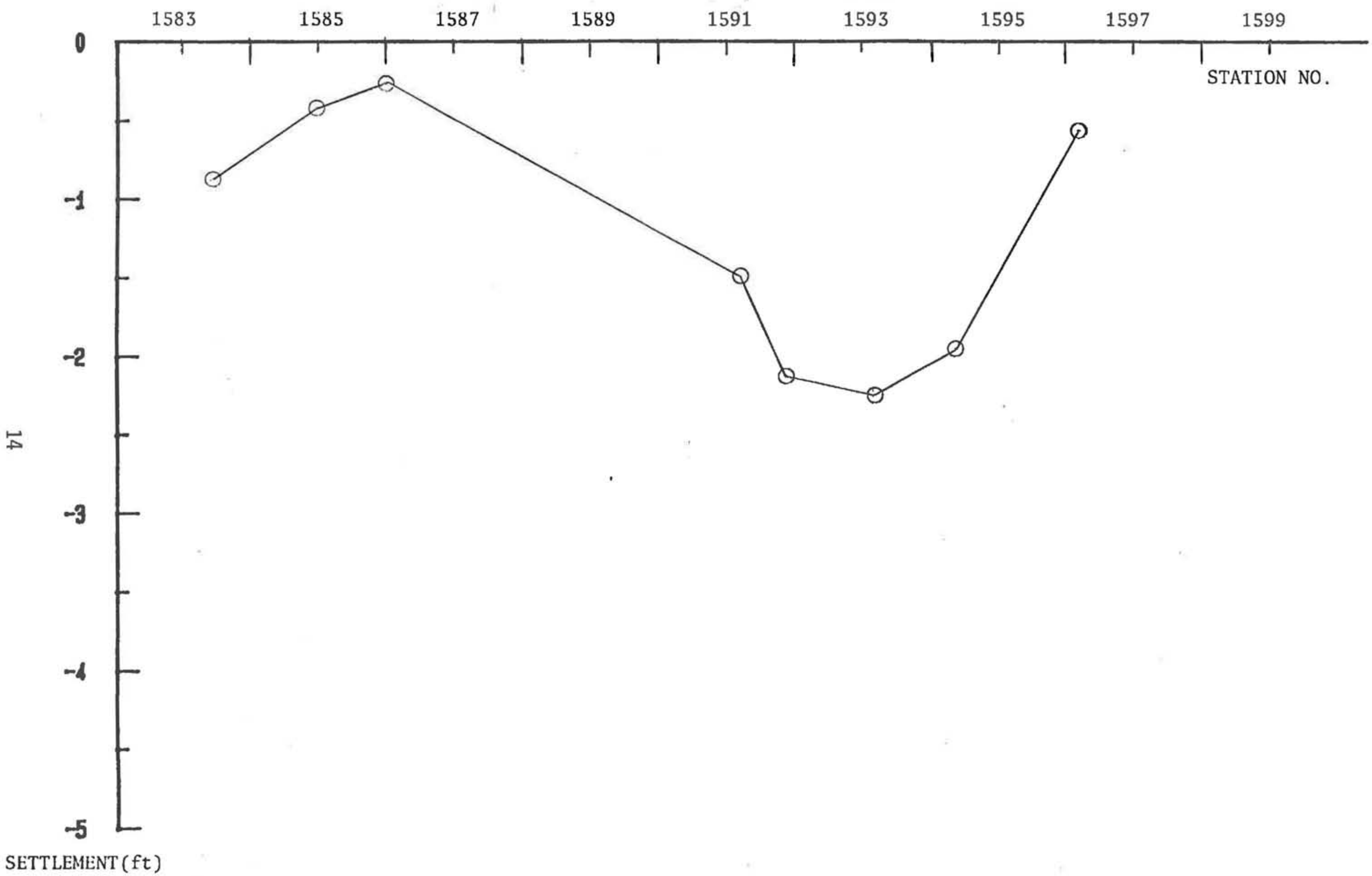


FIGURE 12 - SETTLEMENT PROFILE UNDERNEATH THE TWO PHASE WALLS

panels as they were erected prior to consolidation of the foundation soils. A summary of the total settlements is presented in Table 1.

CONCLUSION

The construction of Phase I of the two-phase wall was carried out according to the original plans and without much difficulty.

The performance of the reinforced earth retaining wall has exceeded the expectations. The wall has experienced fluctuating differential settlements of up to 2.3 feet without any apparent adverse effects.

The road on top of the reinforced earth wall was immediately paved upon completion of the retaining structure. The road was then opened to public to avoid any traffic congestion in the east end of the canyon. Some pavement cracks, as shown in Figures 13 and 14, were observed shortly after completion of the wall. These cracks were attributed to the differential settlements of the retaining structure and were patched immediately. According to survey data, the primary settlements across the wall profile have ceased and most likely secondary consolidation will occur in the future. These settlements are expected to be too small to damage the wall or the present pavement.

The temporary facing of the retaining structure has also performed well, and no major difficulty has been associated with it. During the construction, as the lifts were placed, some outward deformation of the temporary facing occurred. This bulging resulted from placement and compaction of fill near the wall face. Thus, there was inadequate confinement of the restrips to resist movement of the temporary facing.

The fabric portion of the temporary face seems to be functioning well. It has retained the fine portions of the backfill material and has kept its integrity against ultraviolet radiation.

Table 1. Summary of Total Settlement to Date, July, 1985

Eastbound Station	Settlement to Date, July, 1985 (ft.)
1583+50	0.84
1585+00	0.39
1586+00	0.27
1591+20	1.45
1591+90	2.11
1593+17	2.28
1594+44	1.90
1596+25	0.62

FIGURE 13 - CLOSE UP VIEW OF THE PAVEMENT CRACKS

FIGURE 14 - PAVEMENT LONGITUDINAL CRACKS ON TOP OF THE TWO PHASE WALLS

The construction of the second phase is scheduled for the Fall, 1989. At that time, the major portion of the secondary consolidation will be completed. As a result, the permanent facing panels will experience minimal movements due to the remaining settlements, and the alignment problem will be considerably reduced.

The construction of a reinforced earth wall in two phases costs approximately $5.00 per square foot more than one phase construction. It also takes longer than the standard procedures. But its major advantage is that it eliminates most of the problems associated with the alignment of the full-height facing panels due to settlements.

The conclusion of this interim report is that the two-phase wall construction, although more expensive and time consuming, is a good alternative for a project such as this one in Glenwood Canyon. It is a safe method and it provides an alternative to meet all the objectives of the Canyon project.

A final report will be prepared and distributed upon completion of the second phase of the construction. This report will discuss the details of the second phase of the construction, additional wall settlements, and a cost comparison between a standard Reinforced Earth wall and a two-phase wall.

APPENDIX A

Actual Plans and Specifications on the Wall Facing

The construction details of the Wall Facing are presented in Figures A-1 and A-2. These two figures illustrate details on the selection of the temporary steel facing and the alternate wire mesh facing.

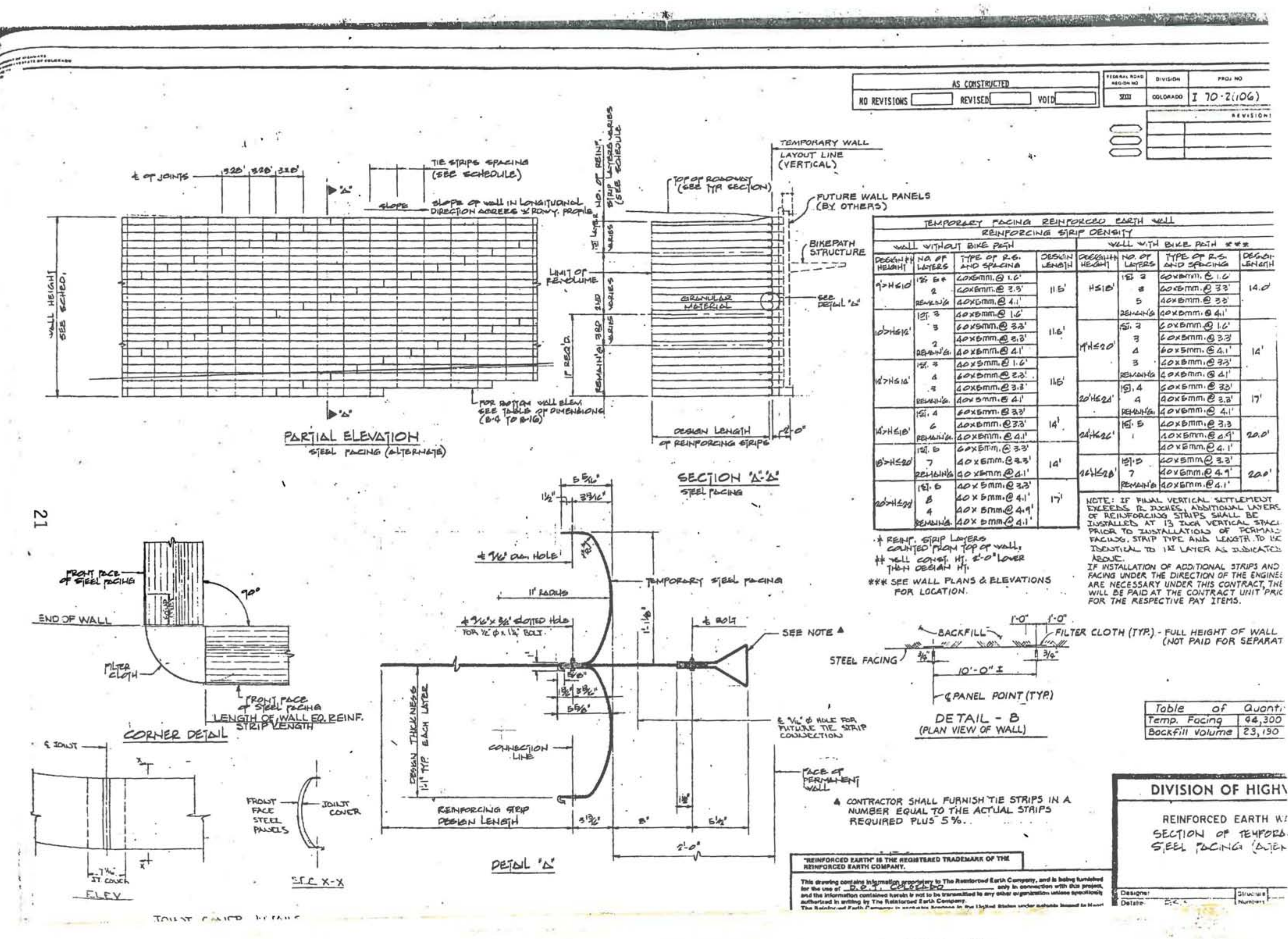


FIGURE A-1 DETAILS OF SELECTIG THE TEMPORARY STEEL FACING FOR THE TWO PHASE WALLS

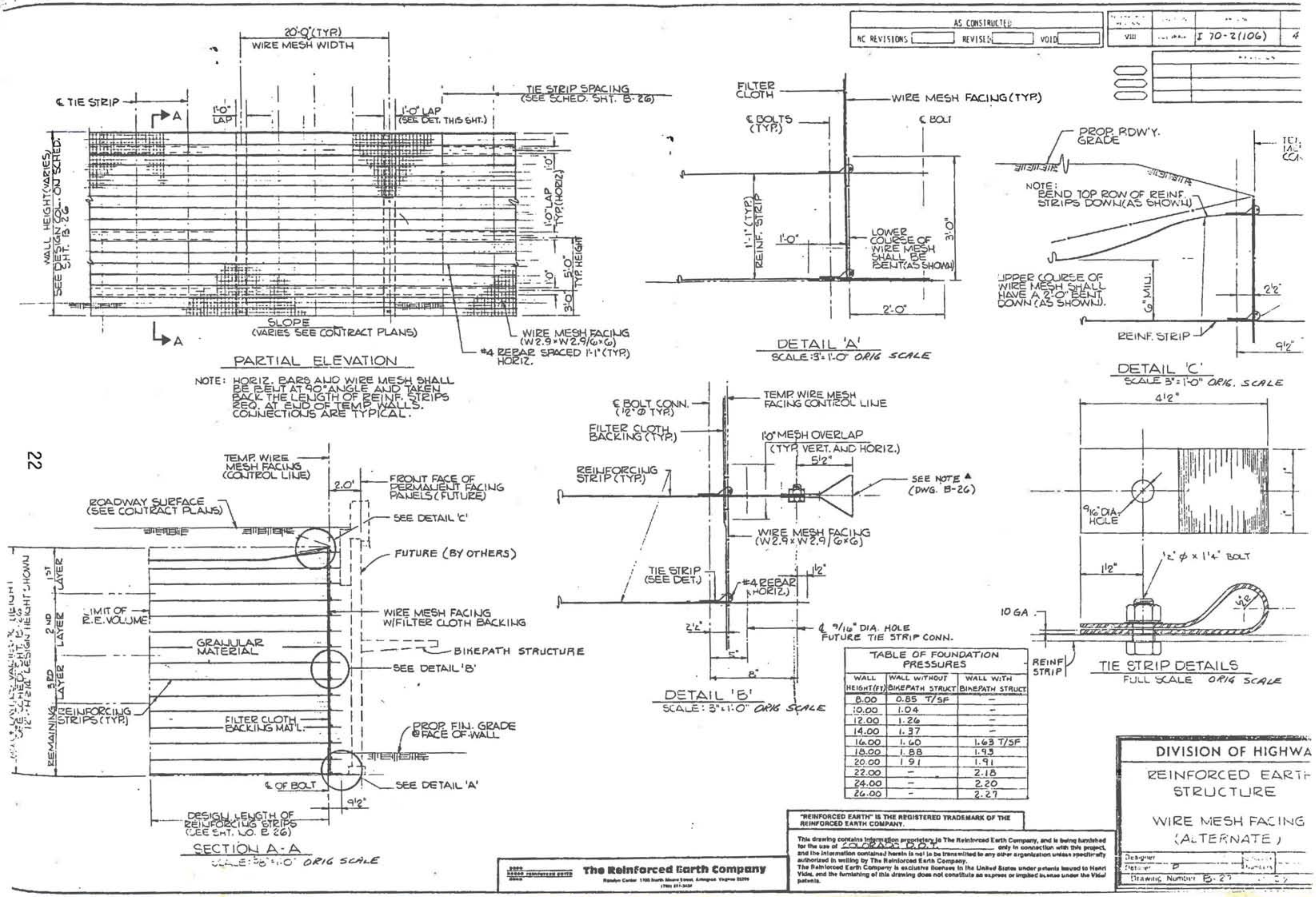


TABLE OF FOUNDATION PRESSURES

WALL HEIGHT (FT)	WALL WITHOUT BIKEPATH STRUCT.	WALL WITH BIKEPATH STRUCT.
8.00	0.85 T/SF	–
10.00	1.04	–
12.00	1.26	–
14.00	1.37	–
16.00	1.60	1.63 T/SF
18.00	1.88	1.93
20.00	1.91	1.91
22.00	–	2.18
24.00	–	2.20
26.00	–	2.27

FIGURE A-2 DETAILS OF WIRE MESH FACING SELECTED FOR THE TWO PHASE WALLS