2007 WESTERN BRIDGE ENGINEERS' SEMINAR

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INNOVATIVE RETAINING WALL SYSTEM FOR THE DALLAS HIGH FIVE PROJECT

by
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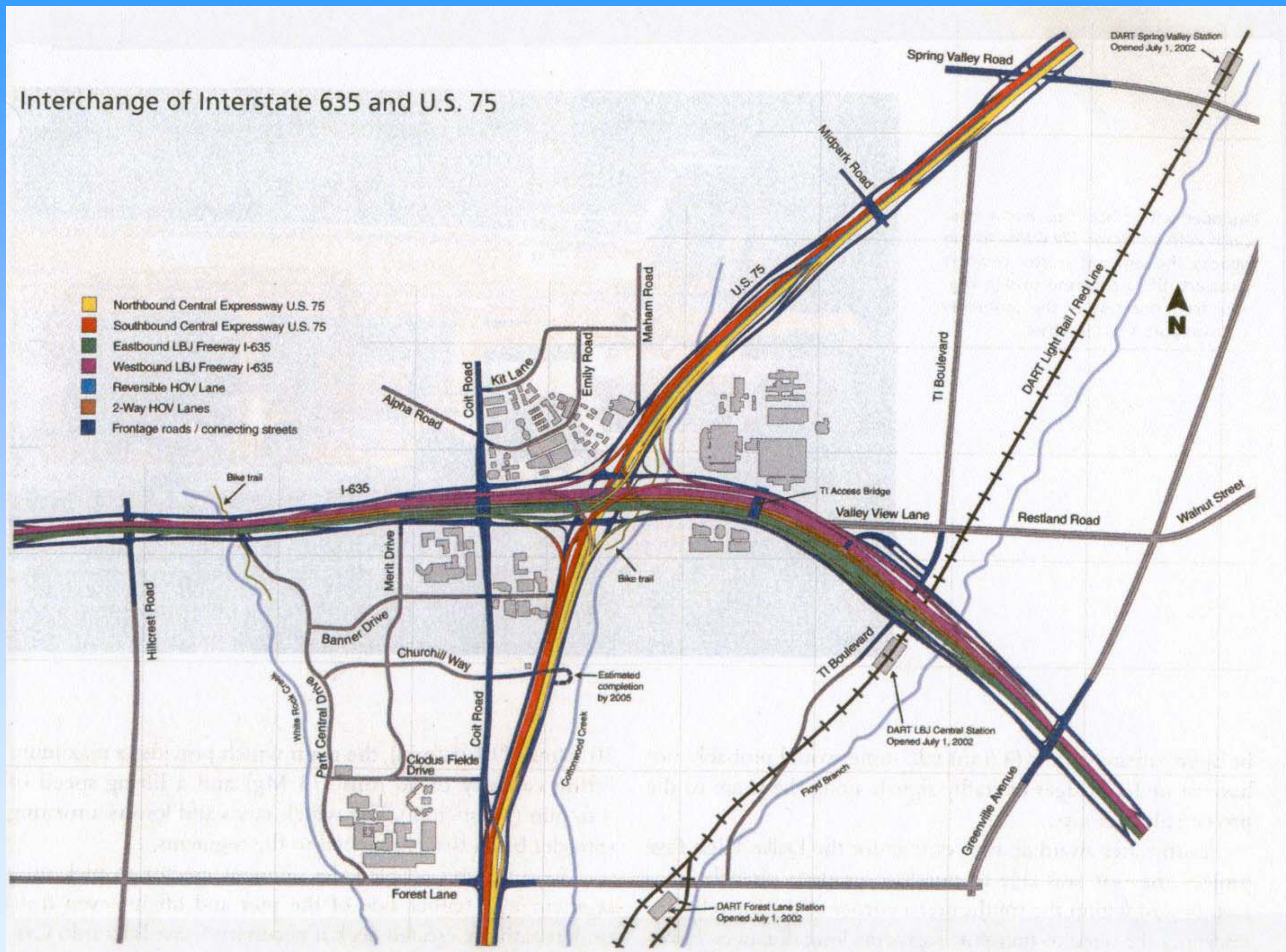
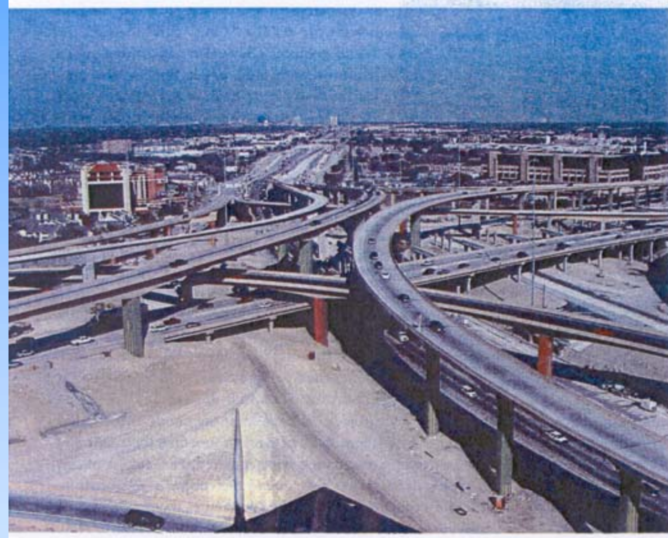
Project Overview:

- Replacement of a 3-level interchange at Highway 635 / US Highway 75 with a new 5-level interchange
- Owner: Texas Department of Transportation
- Engineer: HNTB Corporation
- General Contractor: Zachry Construction Corporation
- Retaining Walls: Designed and supplied by Foster Geotechnical (The Reinforced Earth Company after February 2006)
- Total Contract Value: $261 million
- Retaining Wall Materials, Coping and Traffic Barrier: $4.5 million
- Project was completed a year ahead of schedule
- Bonus for early completion: $11.5 million ($32,000/day with a maximum of 360 days)


Interchange of Interstate 635 and U.S. 75
Northbound Central Expressway U.S. 75
Southbound Central Expressway U.S. 75
Eastbound LBJ Freeway I-635
Westbound LBJ Freeway I-635
Reversible HOV Lane
2-Way HOV Lanes
Frontage roads / connecting streets
DART Spring Valley Station
Opened July 1, 2002
Spring Valley Road
Midpark Road
U.S. 75
Maham Road
Emily Road
Kit Lane
Colt Road
Alpha Road
TI Boulevard
DART Light Rail / Red Line
N
Bike trail
I-635
TI Access Bridge
Valley View Lane
Restland Road
Walnut Street
Merit Drive
Hillcrest Road
Banner Drive
Churchill Way
Estimated
completion
by 2005
Bike trail
TI Boulevard
DART LBJ Central Station
Opened July 1, 2002
Park Central Drive
White Rock Creek
Colt Road
Cottonwood Creek
Cladus Fields
Drive
Floyd Branch
Greenville Avenue
Forest Lane
DART Forest Lane Station
Opened July 1, 2002

A High Five For Dallas



Thanks to innovative contractual and construction measures, major work on an ambitious, five-level highway interchange in Dallas is expected to be complete by the end of the year, a full 12 months ahead of schedule. **By Jay Landers**

The redesigned interchange of Interstate 635 and U.S. 75, *above left*, features direct connectors that enable vehicles to pass quickly from one freeway to another rather than encounter bottlenecks on cloverleaf ramps and left-hand exits. Thirty-one bridges had to be demolished as part of the Dallas High Five project, and 35 concrete bridges, including those shown here, *center*, will have been built for the new interchange by the time it is completed. The future lanes of northbound U.S. 75 just north of I-635, *opposite*, are under construction. The tallest bridge is the reversible high-occupancy vehicle lane, and crossing beneath it is the direct connector from southbound U.S. 75 to eastbound I-635. The other lanes convey traffic from eastbound I-635 to northbound U.S. 75.

Retaining Walls:

75 Retaining Walls specified in contract plans as MSE retaining walls

Total Wall Area: 265,000 SF

193,000 SF in fill

72,000 SF in cut

MSE walls were unattractive for several reasons:

- One-quarter of total area in cut, requiring additional lane closures to accommodate reinforced zone
- Walls in cut areas would also require expensive temporary shoring
- Contract documents specified the use of cement-stabilized backfill for MSE walls
- This would complicate wall construction by having to place MSE backfill and common embankment fill at the same time
- Unique artwork requiring precision in liner fabrication, panel casting, and erection in the field

The owner accepted a no-cost-change proposal that included:

- Two different (one for cuts; one for fills) innovative retaining wall systems instead of as-designed MSE walls
- These had the advantages of
  - simplifying construction in both cut and fill situations
  - reducing the impact on traffic flow during construction by significantly reducing time
  - use of large, full-height panels reduced the number of units to be handled in difficult access

The proposed retaining wall systems comprised the following:

- In cut situations

  Permanent tied-back soldier pile and lagging walls with 10-foot wide, full-height precast concrete fascia panels

  (Permanent lagging consists of CIP reinforced concrete)

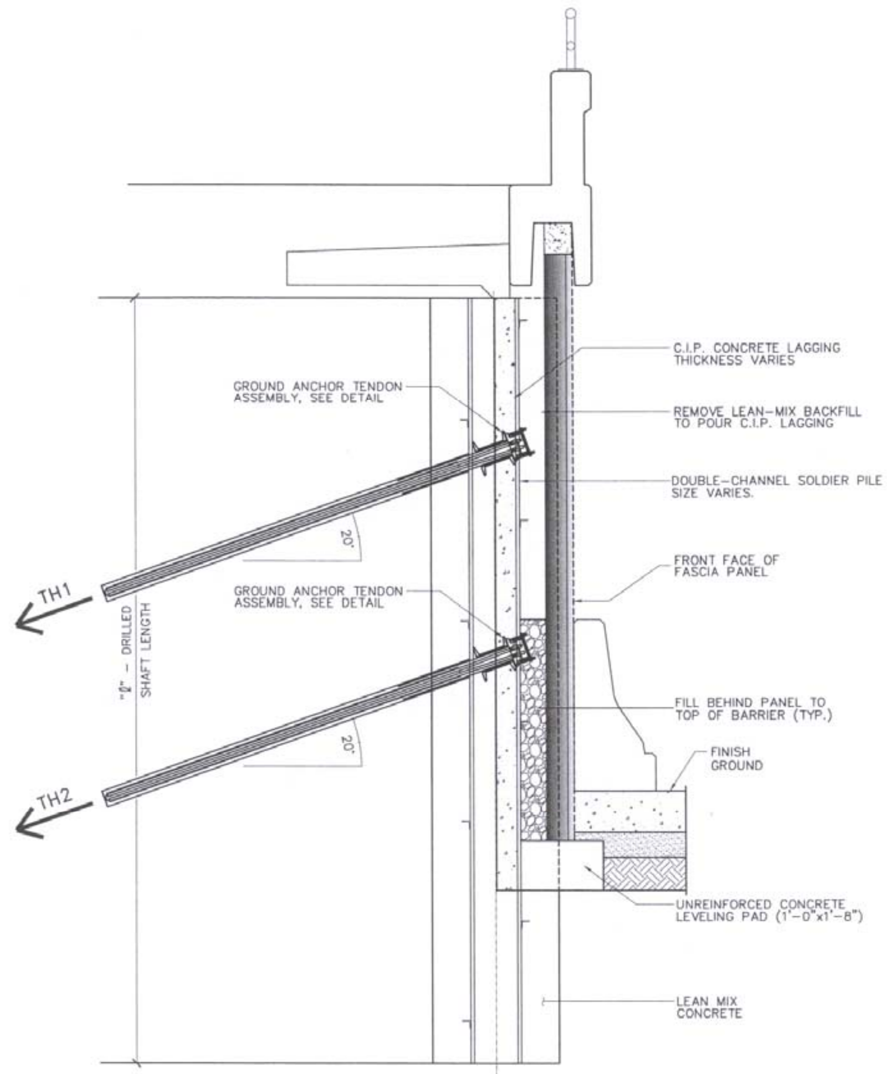
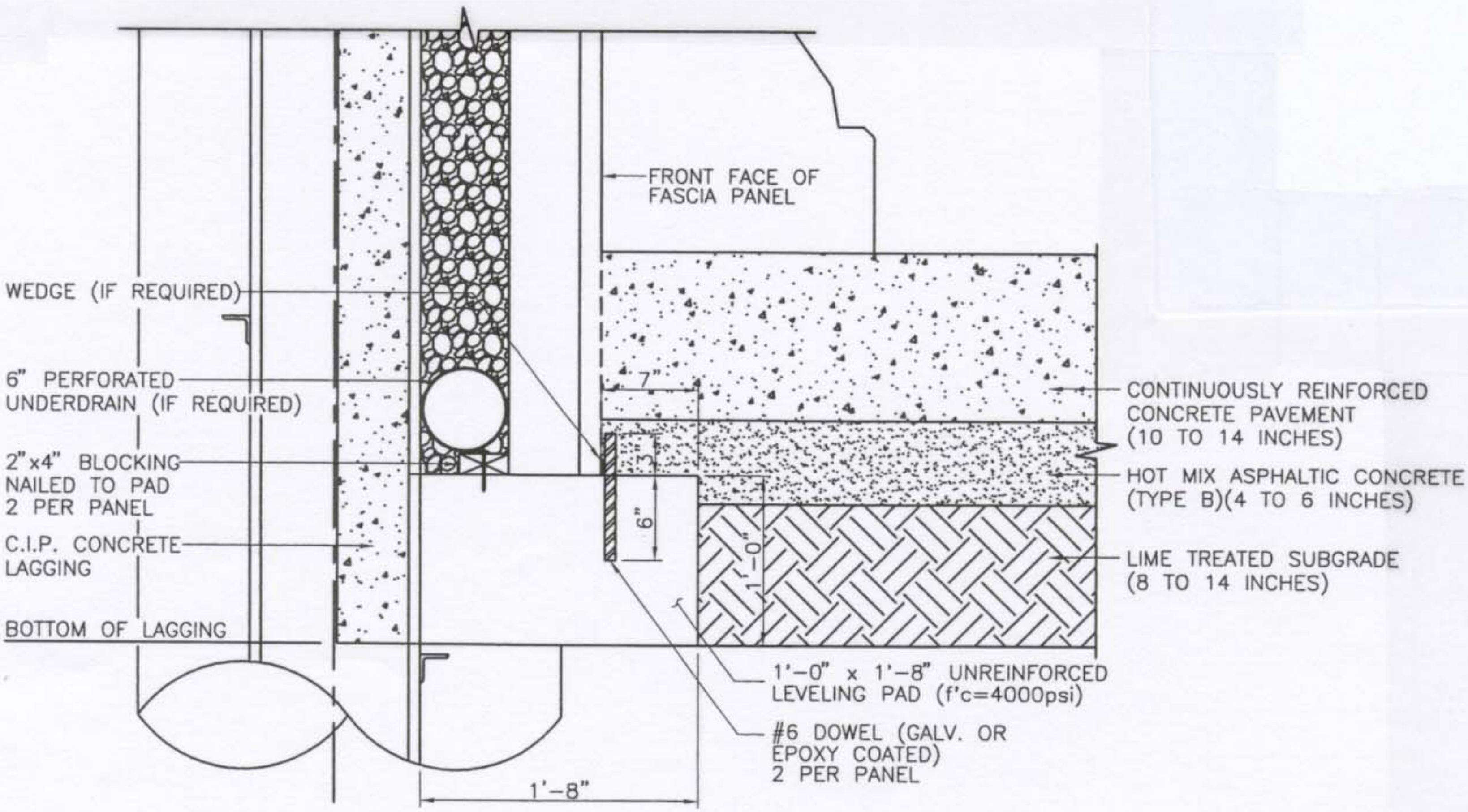


FIG.1 TYPICAL SECTION AT PERMANENT TIED-BACK SOLDIER PILE WALL

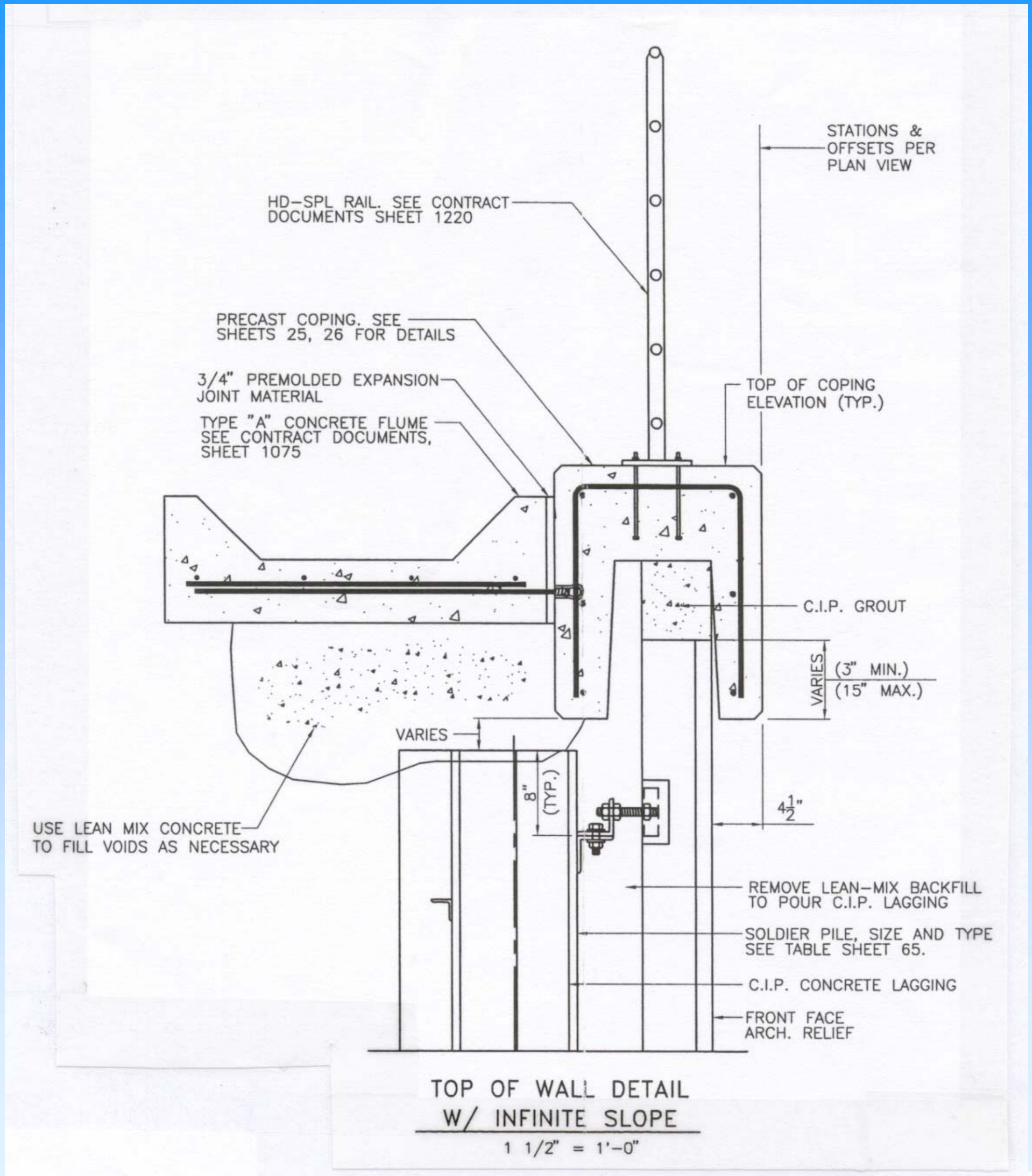
FIG. 2 TIED-BACK SOLDIER PILE WALL SHOWING CIP CONCRETE LAGGING

FIG. 3 FULL-HEIGHT FASCIA PANEL FOR SOLDIER PILE WALLS

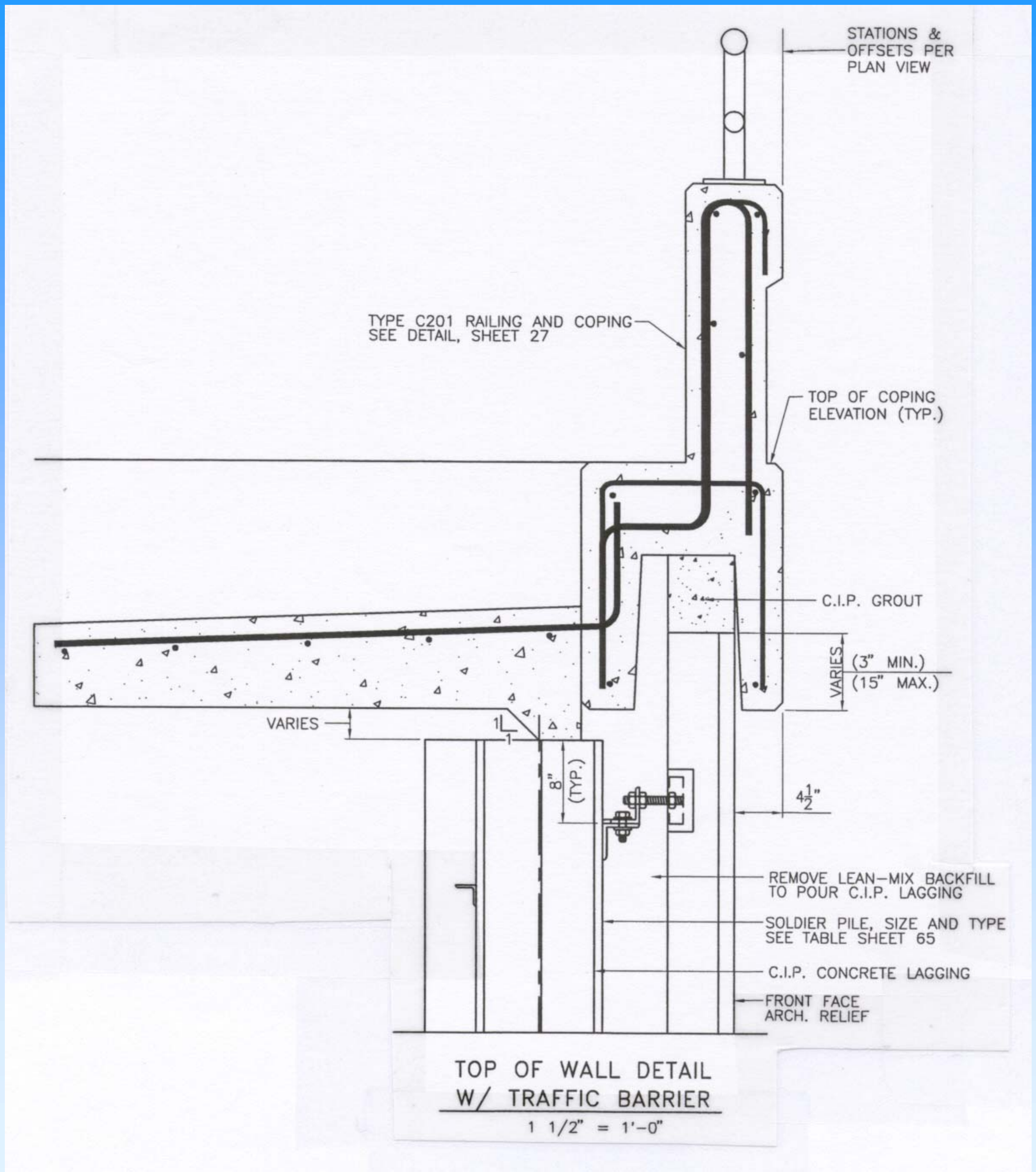


LEVELING PAD DETAIL FOR FULL–HEIGHT PANELS AT SOLDIER PILE WALLS

1 1/2" = 1'–0"



STATIONS & OFFSETS PER PLAN VIEW
HD–SPL RAIL. SEE CONTRACT DOCUMENTS SHEET 1220
PRECAST COPING. SEE SHEETS 25, 26 FOR DETAILS
3/4" PREMOLDED EXPANSION JOINT MATERIAL
TYPE "A" CONCRETE FLUME SEE CONTRACT DOCUMENTS, SHEET 1075
TOP OF COPING ELEVATION (TYP.)
C.I.P. GROUT
VARIES
(3" MIN.)
(15" MAX.)
VARIES
8" (TYP.)
USE LEAN MIX CONCRETE TO FILL VOIDS AS NECESSARY
REMOVE LEAN–MIX BACKFILL TO POUR C.I.P. LAGGING
SOLDIER PILE, SIZE AND TYPE SEE TABLE SHEET 65.
C.I.P. CONCRETE LAGGING
FRONT FACE ARCH. RELIEF
TOP OF WALL DETAIL
W/ INFINITE SLOPE
1 1/2" = 1'–0"


STATIONS & OFFSETS PER PLAN VIEW
TYPE C201 RAILING AND COPING SEE DETAIL, SHEET 27
TOP OF COPING ELEVATION (TYP.)
C.I.P. GROUT
VARIES
(3" MIN.) (15" MAX.)
VARIES
8" (TYP.)
REMOVE LEAN–MIX BACKFILL TO POUR C.I.P. LAGGING
SOLDIER PILE, SIZE AND TYPE SEE TABLE SHEET 65
C.I.P. CONCRETE LAGGING
FRONT FACE ARCH. RELIEF
TOP OF WALL DETAIL
W/ TRAFFIC BARRIER
1 1/2" = 1'–0"

In fill situations, the alternative wall type accepted by the owner comprised

- Precast concrete elements post-tensioned to cast-in-place strip footings
- All precast concrete elements are full-height ranging from about 2 feet high to almost 30 feet
- All elements are 10 feet wide, giving completed walls a uniform appearance regardless of whether they are in cut or in fill
- Three types of precast elements:

  L-panels (up to 70" high)

  Double-T panels (75" – 230" high)

  Triple-T panels (≥ 235" high)


338
140

FIG. 4 L-PANELS ON CIP CONCRETE FOOTINGS

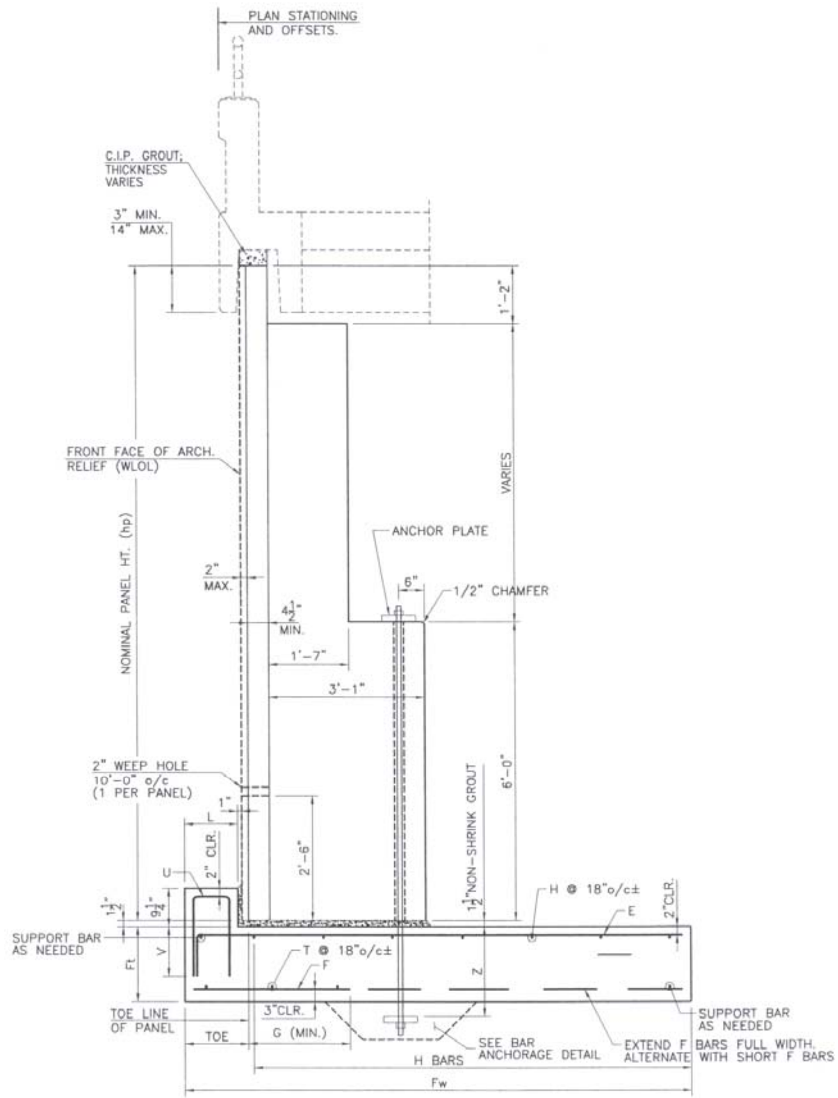


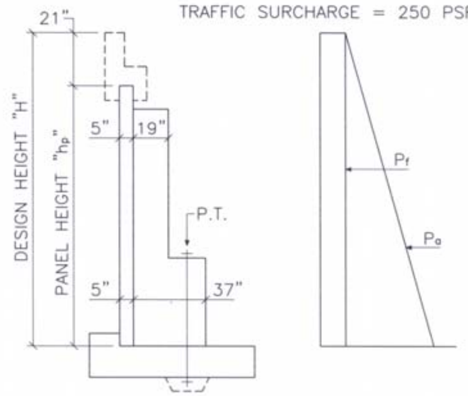
FIG. 5 TYPICAL SECTION AT DOUBLE-T PANEL

FIG. 6 TYPICAL DOUBLE-T PANEL

FIG. 8 TYPICAL TRIPLE-T PANEL

DOUBLE–T PANELS:

DESIGN PROCEDURE: PRECAST WALL STEMS AT BASE



1. ALL WALLS h_p>70" TO BE DOUBLE–T PANELS (OR TRIPLE–T AT h_p>230").

2. PANELS ARE CONNECTED TO FOOTING USING POST–TENSIONED BARS (f_y = 150 ksi) FOR MOMENT DESIGN AT BASE OF WALLS.

3. SHEAR AT BASE IS RESISTED BY "LUG" ON TOE OF FOOTING.

4. POST–TENSIONING FORCE IS SELECTED TO LIMIT CONCRETE STRESSES AT SERVICE LOADS TO MAXIMUM ALLOWABLE COMPRESSION AND TENSION LIMITS.

5. VERTICAL REINFORCING IS PROVIDED IN FACE PANEL TO RESIST TENSION STRESSES AT TRANSFER OF POST–TENSIONING FORCE. (BEFORE SOIL LATERAL LOADS)

6. CHECK ULTIMATE MOMENT CAPACITY.

7. DESIGN ANCHORAGE ZONE REINFORCEMENT FOR POST–TENSIONING FORCE.

8. DESIGN STEM ABOVE TRANSITION STEP AS CONVENTIONAL REINFORCED ELEMENT.

9. DESIGN FOUNDATION.

NOTE: DESIGN IS BASED ON ACTIVE EARTH PRESSURE CONDITIONS.

Date 09/20/05	SUBJECT	Foster Geotechnical
Designed by WJN	DOUBLE–T PANEL DESIGN PROCEDURE: PRECAST WALL STEMS AT BASE	A Division of L. B. Foster Company
Checked by WJN		

1372 Old Bridge Road, Suite 101, Woodbridge, VA 22192
Telephone: (703) 499–9818 / Fax: (703) 499–9348
SAN DIEGO, CA / WOODBRIDGE, VA / MELBOURNE, FL / CHICAGO, IL

FIG. 7 ERECTED DOUBLE-T PANELS

Erection of Panels:

- Anchor plate and locating nut are cast into the footing; specially designed steel-framed templates were used to position the anchor devices
- After placement, panels were shimmed and dry-packed with non-shrink grout
- The high strength all-thread bars were then installed through the preformed holes in the vertical stems into the footing and threaded into the nut on the underside of the anchor plate
- Post-tensioning force applied and locked off
- Assembly grouted in place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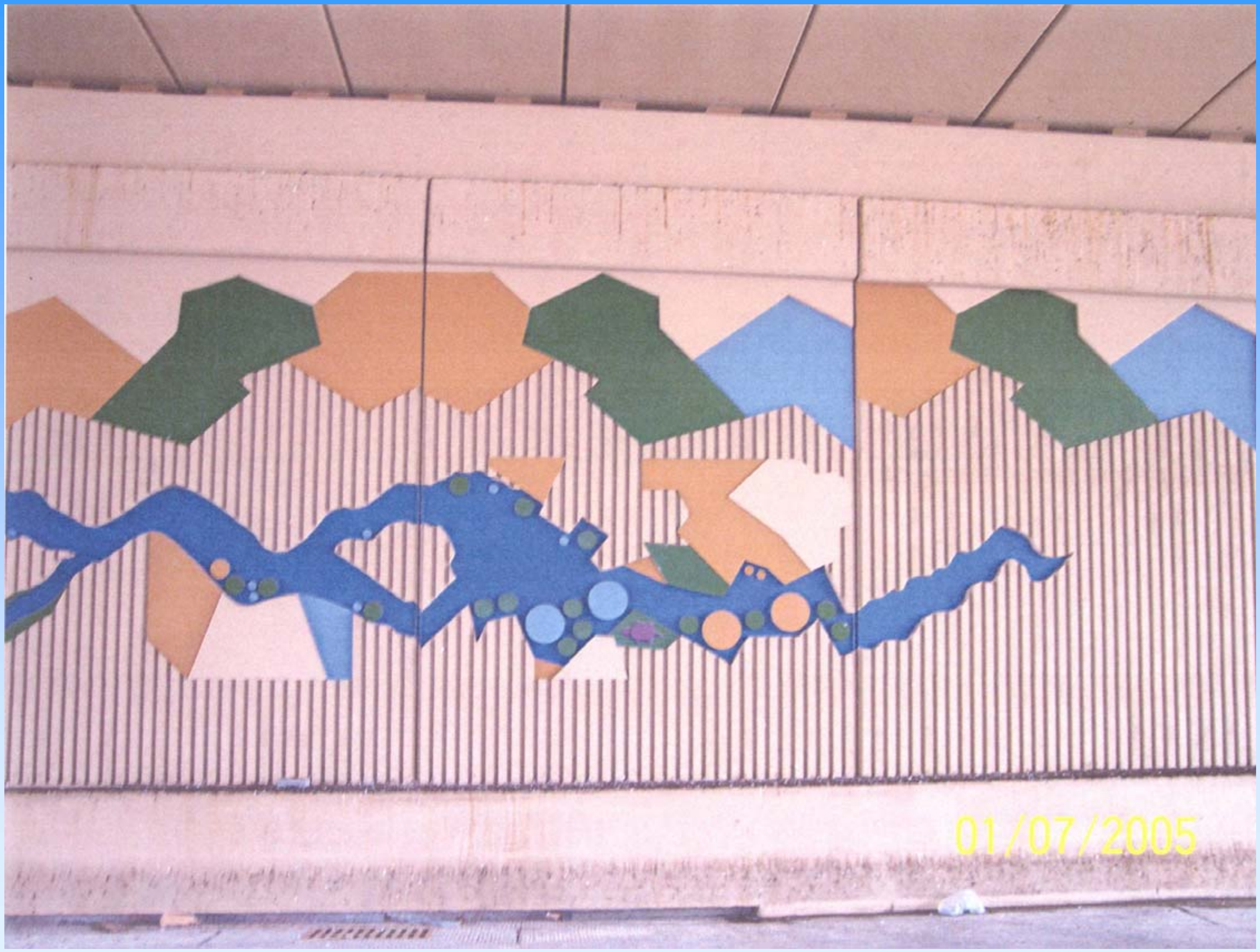
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Monitoring of Wall Displacements:

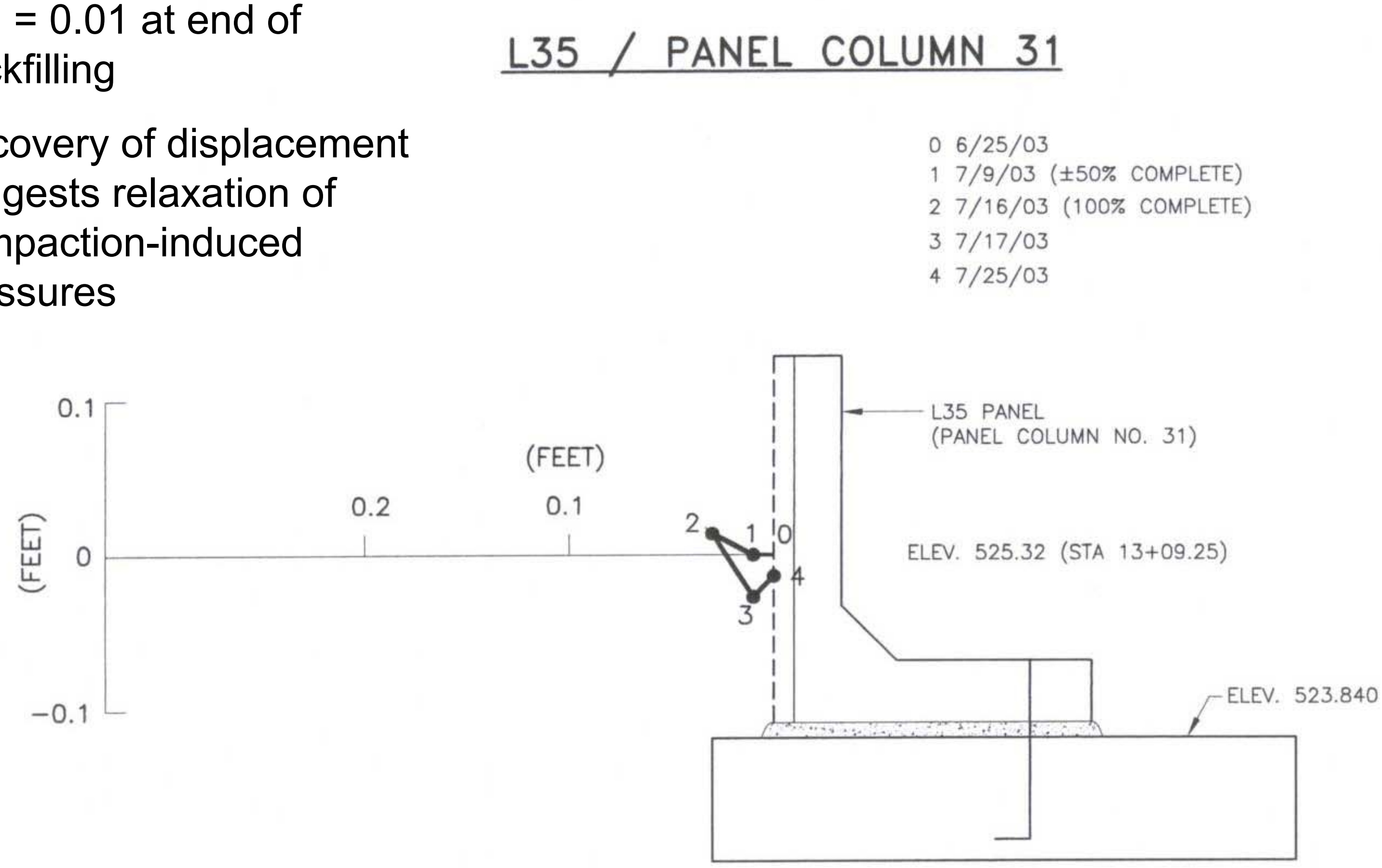
- Owner required data on wall displacements (both vertical and horizontal) both during and after backfilling
- Displacements to be monitored for at least 6 months under traffic loading
- Measurements were made on reflector-plate targets on a single vertical line on selected wall panels
- Initial readings were taken after panels were placed and post-tensioned
- Reflector-plate targets were installed on 29 panels, ranging from 3 feet to 29 feet high, in 6 different retaining walls

Earth Pressures and Movements:

- Earth pressures were not measured
- Designed as a gravity retaining wall
- Although seemingly relatively stiff it was judged that active conditions would develop
- Backfill comprised a low plasticity silty/sandy clay with an estimated drained friction angle of 30 degrees
- Movements to reach active (or passive) condition are roughly proportional to height
- A movement of no more than 1 inch in 20 feet, or Δ/H = 0.004, was considered sufficient to reach active conditions

Δ/H = 0.01 at end of backfilling

Recovery of displacement suggests relaxation of compaction-induced pressures



Measurements of pressures on relatively rigid retaining walls backfilled with clayey soils suggest that compaction-induced pressures can relax with time; e.g. Carder et al. (1980); Symons et al. (1989)

Perkins et al. (2000) measured lateral earth pressures on a 30-foot high massive counterfort wall with CL and CL-ML backfill. Significant stress relaxation occurred in top 10 feet within a few days of backfilling

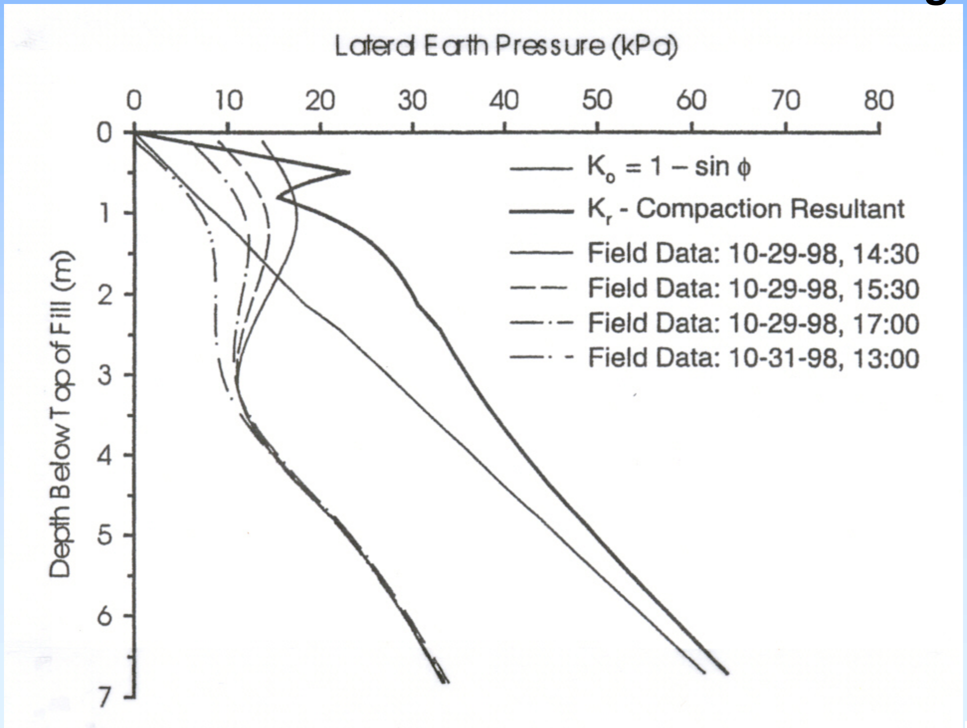


Table 1. Total Lateral Force on Stem for Various Backfill Heights

Backfill Height (m)	Lateral Force on Stem from EPCs (kN/m)	
	t = 0	t = 12 hr
3.7	97.0	75.2
5.5	122.2	109.9
6.1	159.0	142.8

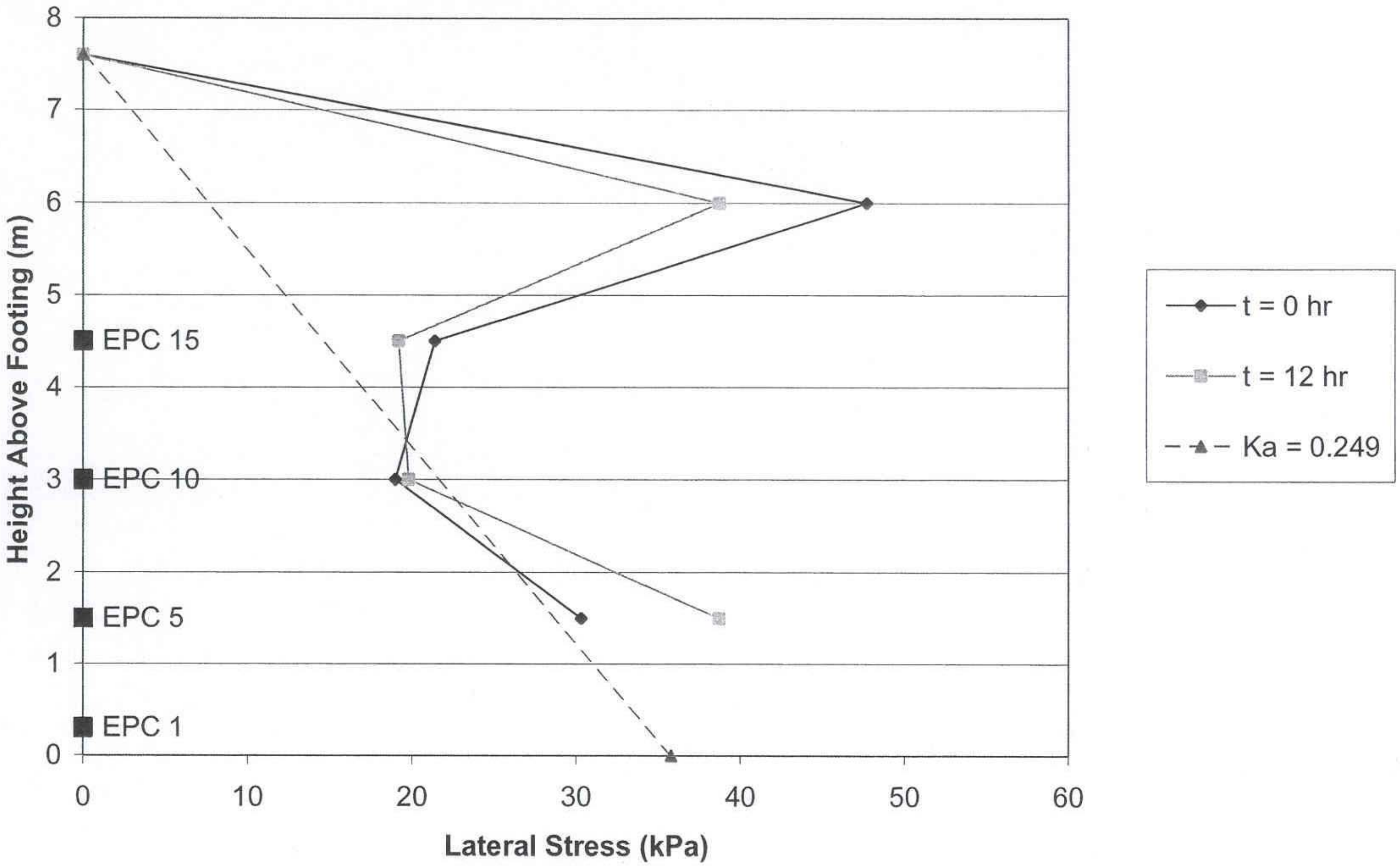


Fig. 2. Estimated compaction-induced lateral stresses for backfill height of 7.6m

Panel translated 0.02' during backfilling.

Over the next 3-4 months there was settlement of 0.05', giving a final Δ/H of 0.008

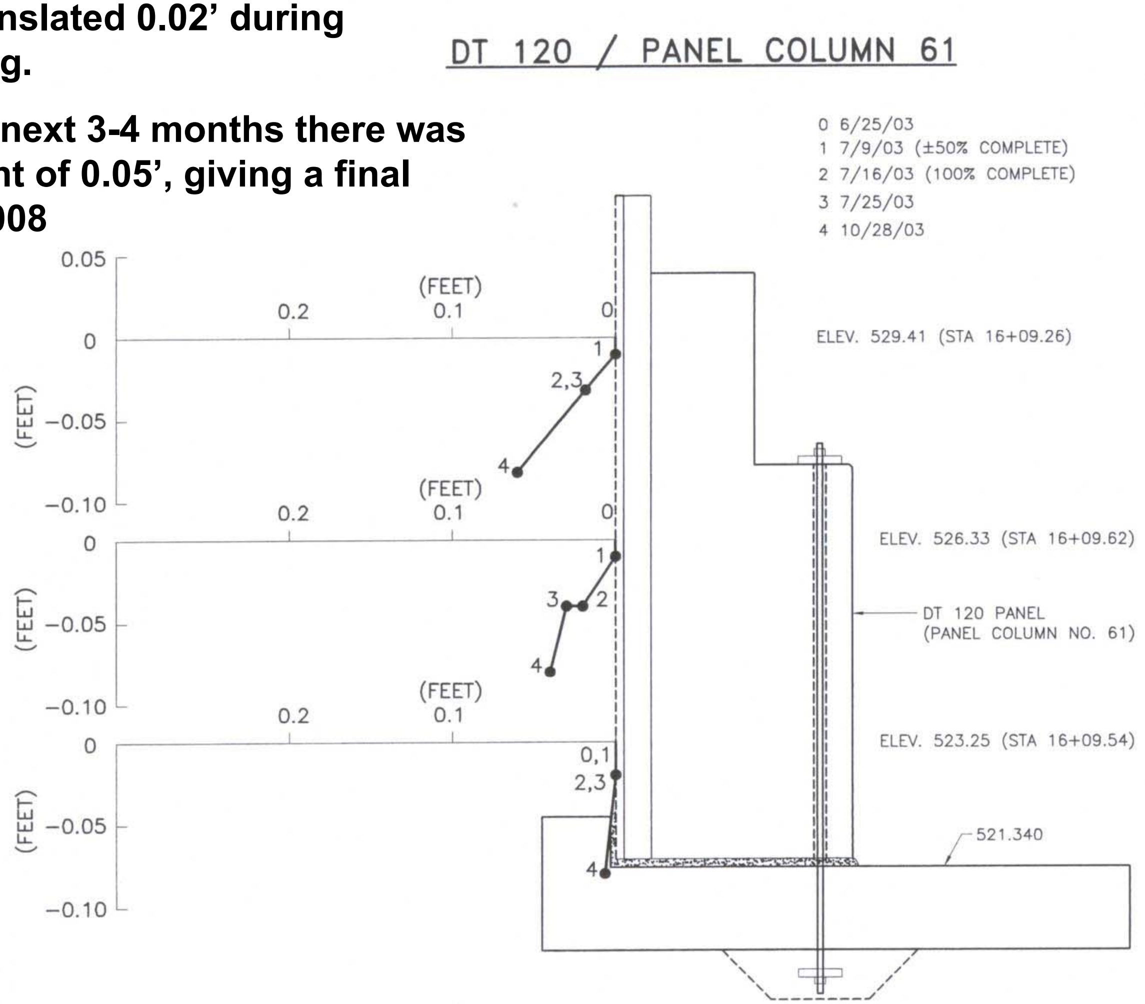
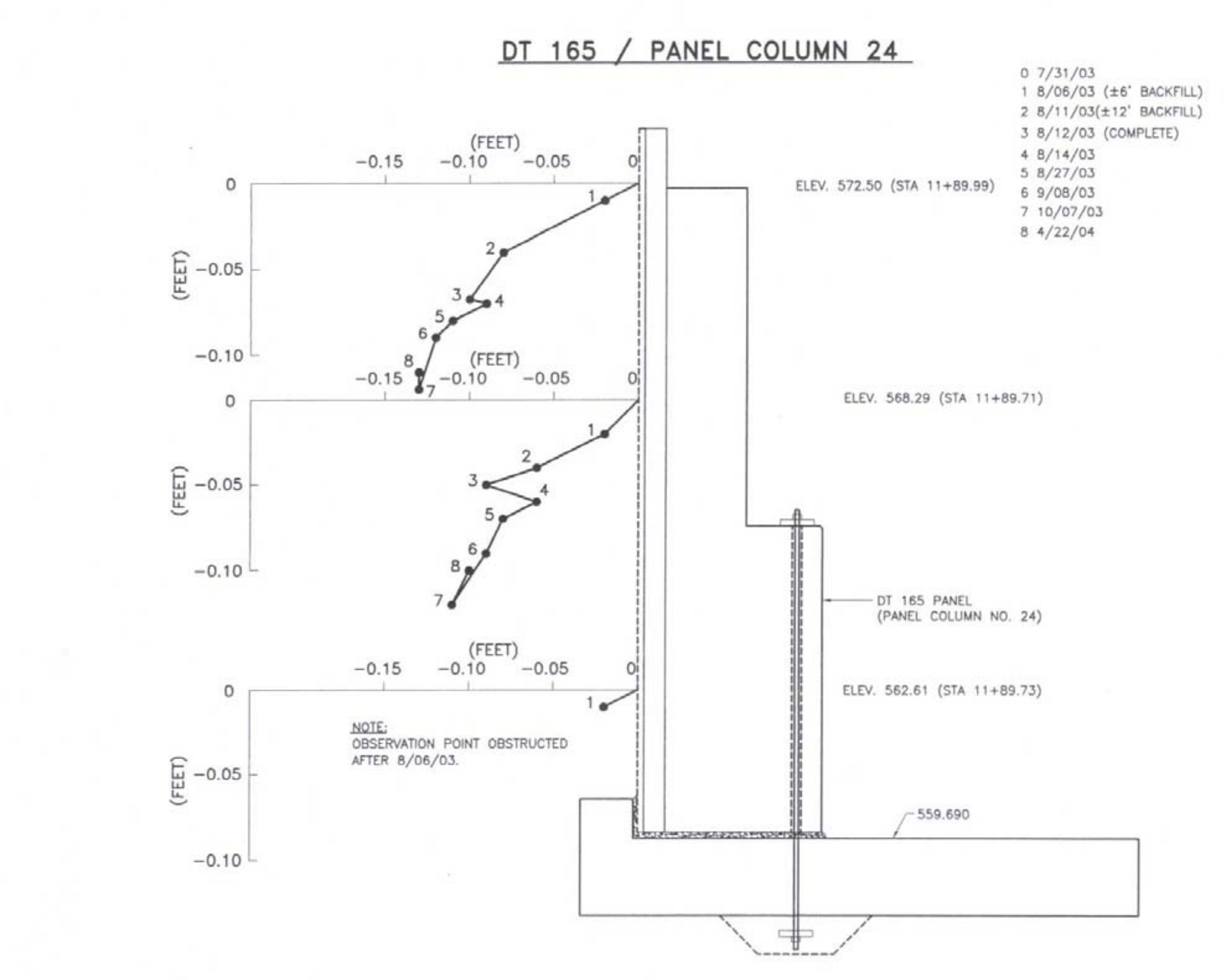


FIG. 10 OBSERVED DISPLACEMENTS OF 120-INCH HIGH DOUBLE-T PANEL (WALL 635C)



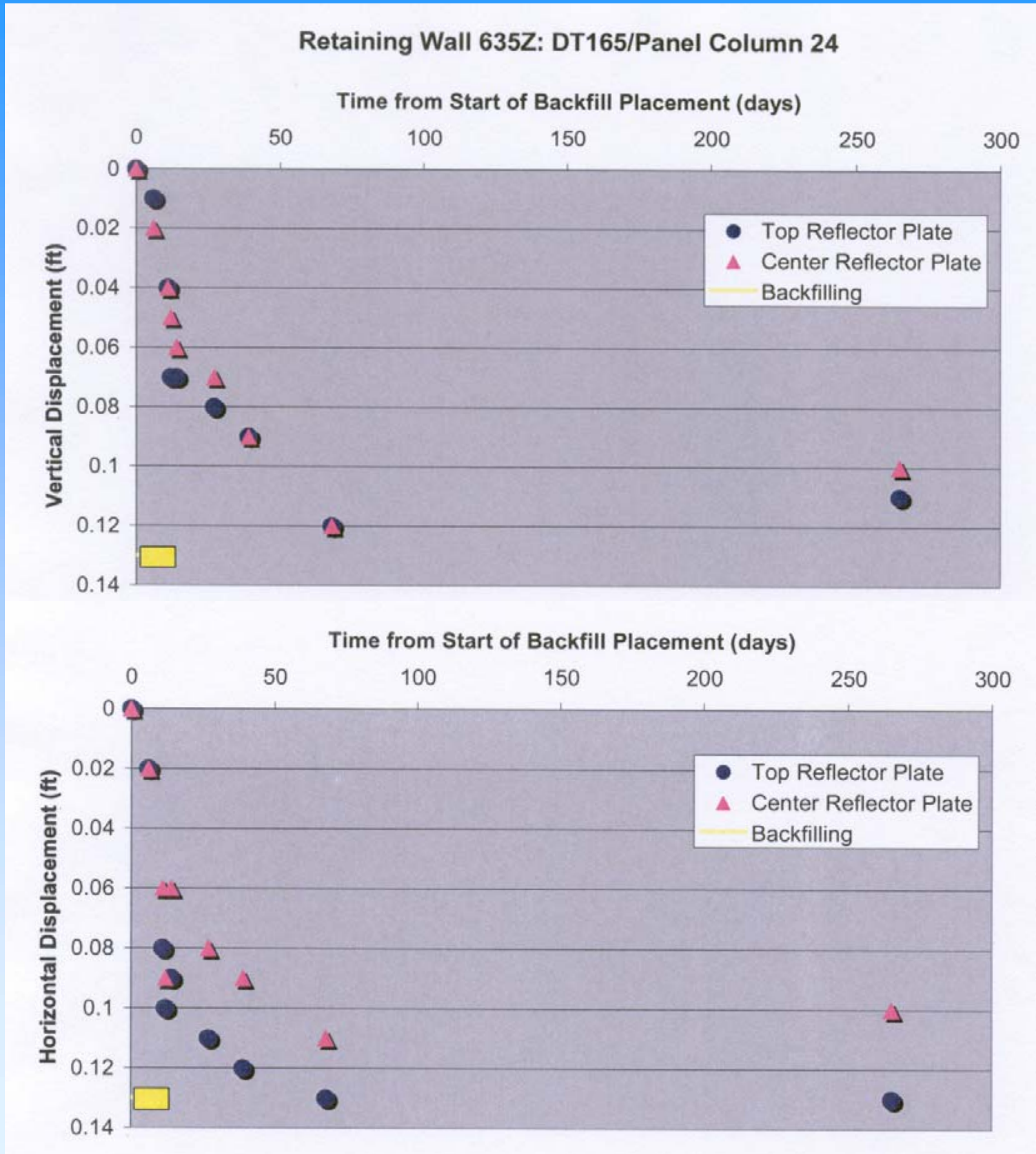
Founded on thick clay layer above limestone.

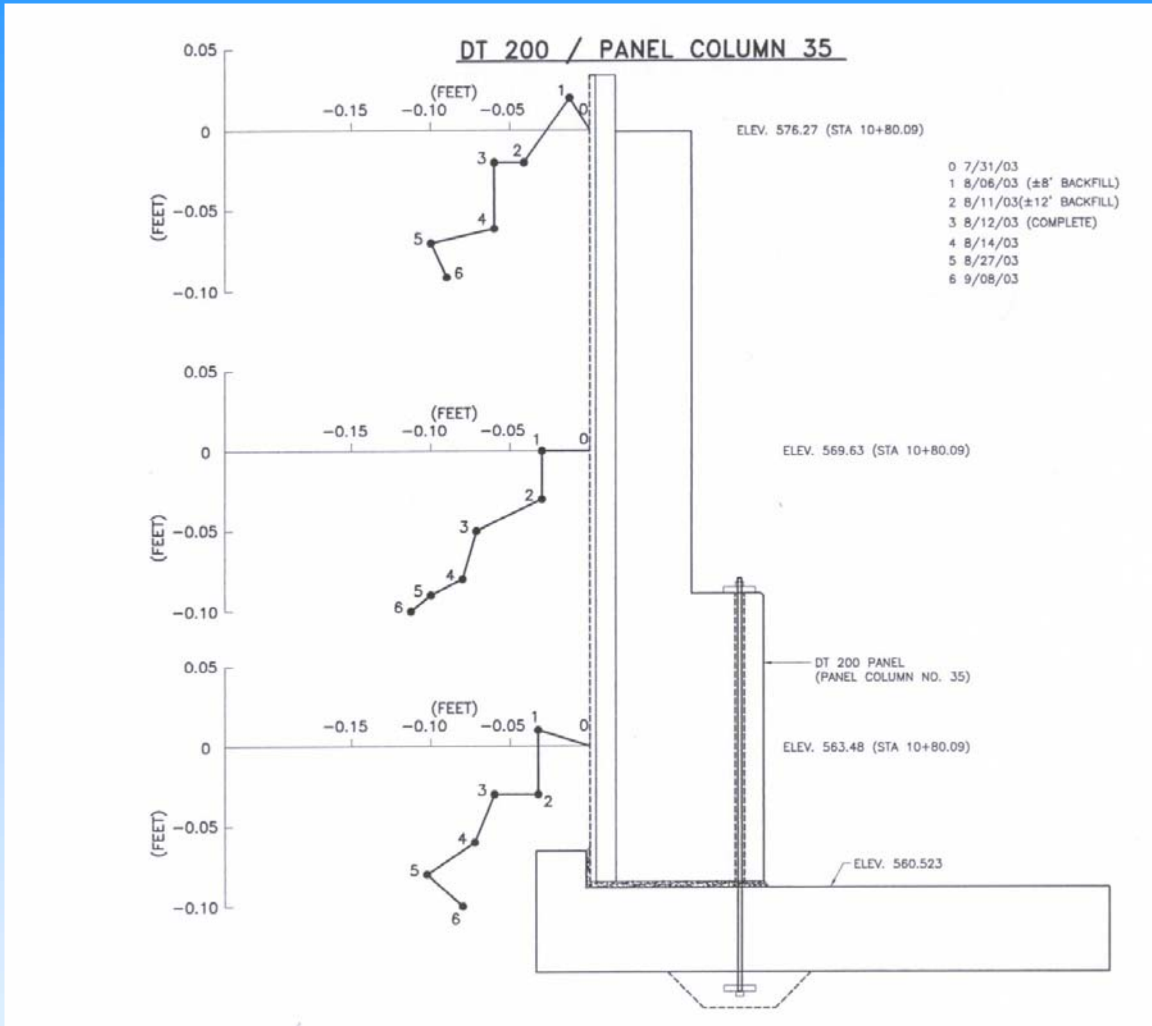
After backfilling, panel translated 0.1' or Δ/H = 0.007

Movements continued for 2 months, but at a decreasing rate.

6 months under traffic loading produced almost no additional movement

FIG. 11 OBSERVED DISPLACEMENTS OF 165-INCH HIGH DOUBLE-T PANEL (WALL 635Z)

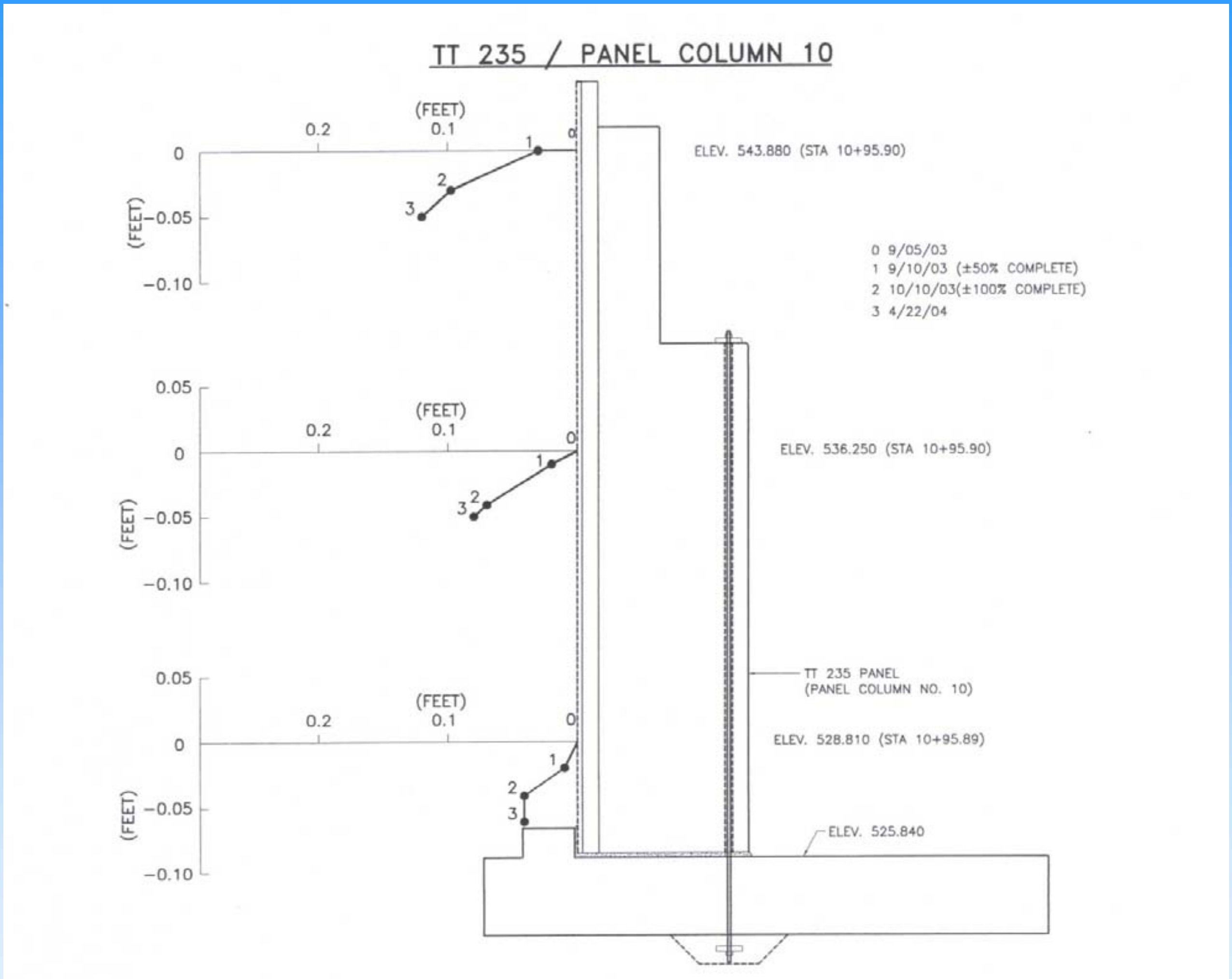

Retaining Wall 635Z: DT165/Panel Column 24
Time from Start of Backfill Placement (days)
0
50
100
150
200
250
300
Vertical Displacement (ft)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
Top Reflector Plate
Center Reflector Plate
Backfilling
Time from Start of Backfill Placement (days)
Horizontal Displacement (ft)
Top Reflector Plate
Center Reflector Plate
Backfilling



Located at a bridge abutment on 20' stiff clay over bedrock.

Backfilling resulted in a translation of 0.06' or $\Delta/H = 0.004$

FIG. 12 OBSERVED DISPLACEMENTS OF 200-INCH HIGH DOUBLE-T PANEL (WALL 635Z)



This 20-foot tall Triple-T panel is a good example of combined translation and rotation. At end of backfilling, $\Delta/H = 0.004$.

Six months under traffic loading increased movements by a maximum of 0.02 feet.

FIG. 13 OBSERVED DISPLACEMENTS OF 235-INCH HIGH TRIPLE-T PANEL (WALL 75J1)

Conclusions:

- Two innovative retaining wall systems were accepted as a no-cost-change to the specified MSE walls
- The concept of the post-tensioned wall system was accepted on an experimental basis
- Field monitoring of almost 30 individual wall elements
  - Short (< 6 feet) L-panels
    - **small movements (0.02 – 0.03 feet)**
    - **Δ/H = 0.004**
    - **recovery of outward displacements**
  - Double-T panels
    - **shorter panels behaved much the same as L-panels, including displacement recovery**
    - **movements were combined translation and rotation with Δ/H > 0.004**

Conclusions:

- Triple-T panels
  - **maximum horizontal displacement after backfilling was 0.1 feet**
  - **under 6 months of traffic loading, both horizontal and vertical displacements increased only 0.02 feet**
- Although the largest measured vertical displacement of 0.12 feet occurred over a 9-month observation period, there was no evidence of any damage or function impairment
- Since measured displacements are similar to those of other conventional retaining systems, including MSE walls, the post-tensioned wall system was released from experimental status by TxDOT in January 2005.