Construction and Long-Term Performance of Innovative Geotechnologies

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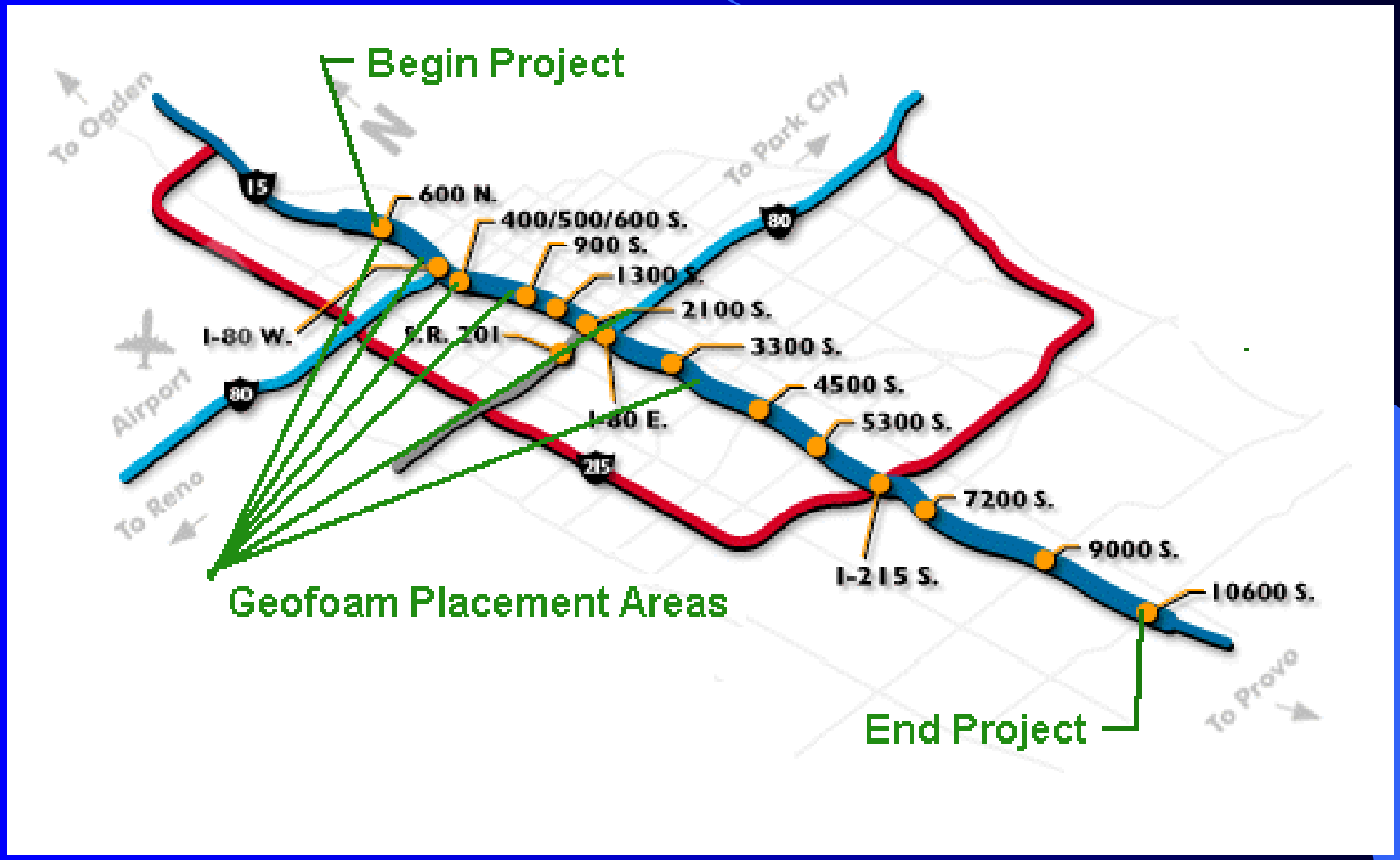
I-15 Project Limits



Approx. 100,000 cubic meters of geofoam was placed

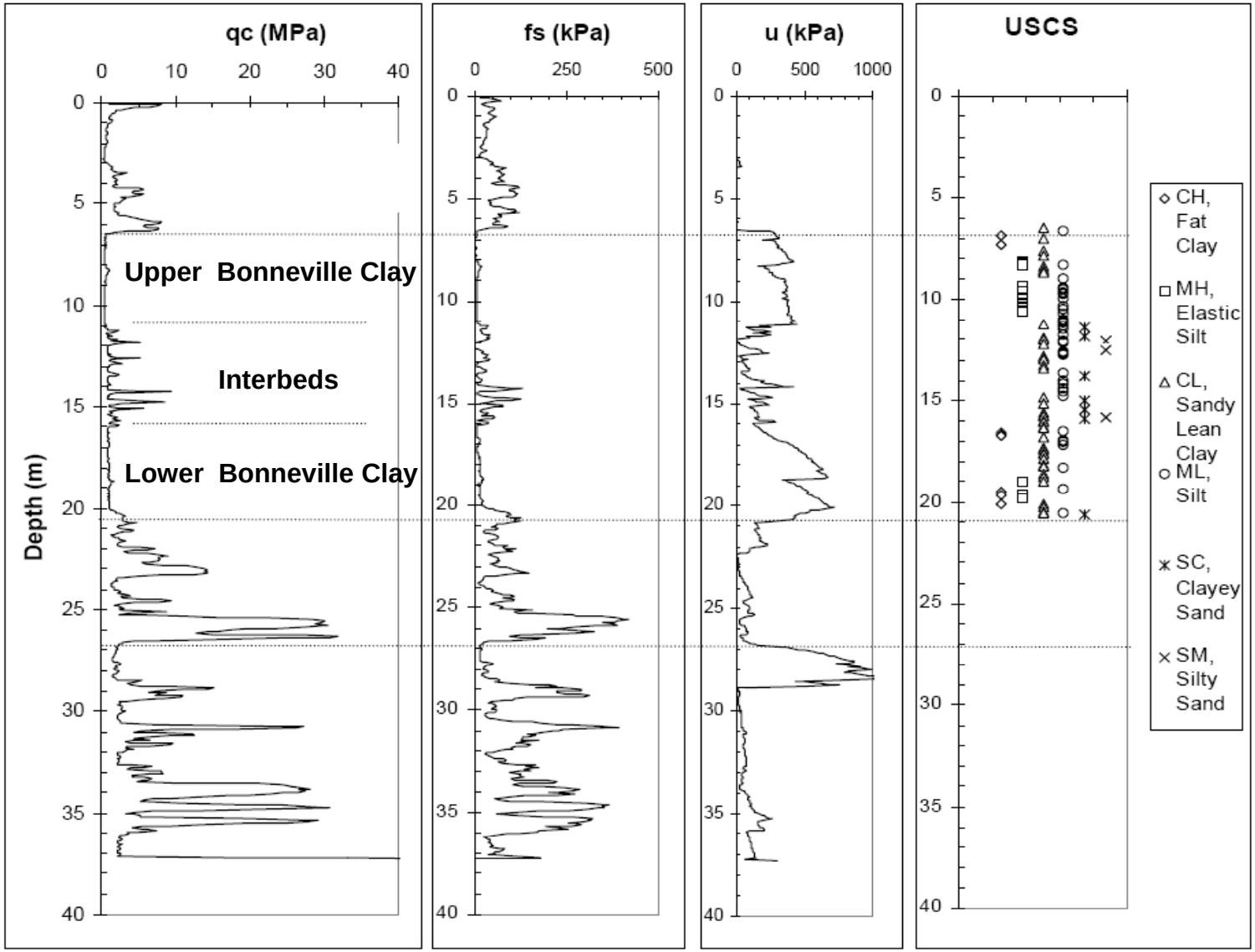
I-15 Reconstruction - Quick Facts

- **Single Largest Design-Build Highway Contract in U.S.**
- **17 Miles of Urban Interstate**
- **$1.5 Billion (Project Cost)**
- **Wasatch Constructors (Prime Contractor)**
- **4 Year Construction Duration (1997 - 2001)**
- **144 Bridges/Overpass Structures**
- **160 Retaining Walls (mostly MSE Walls)**
- **$350 K Embankment Study**

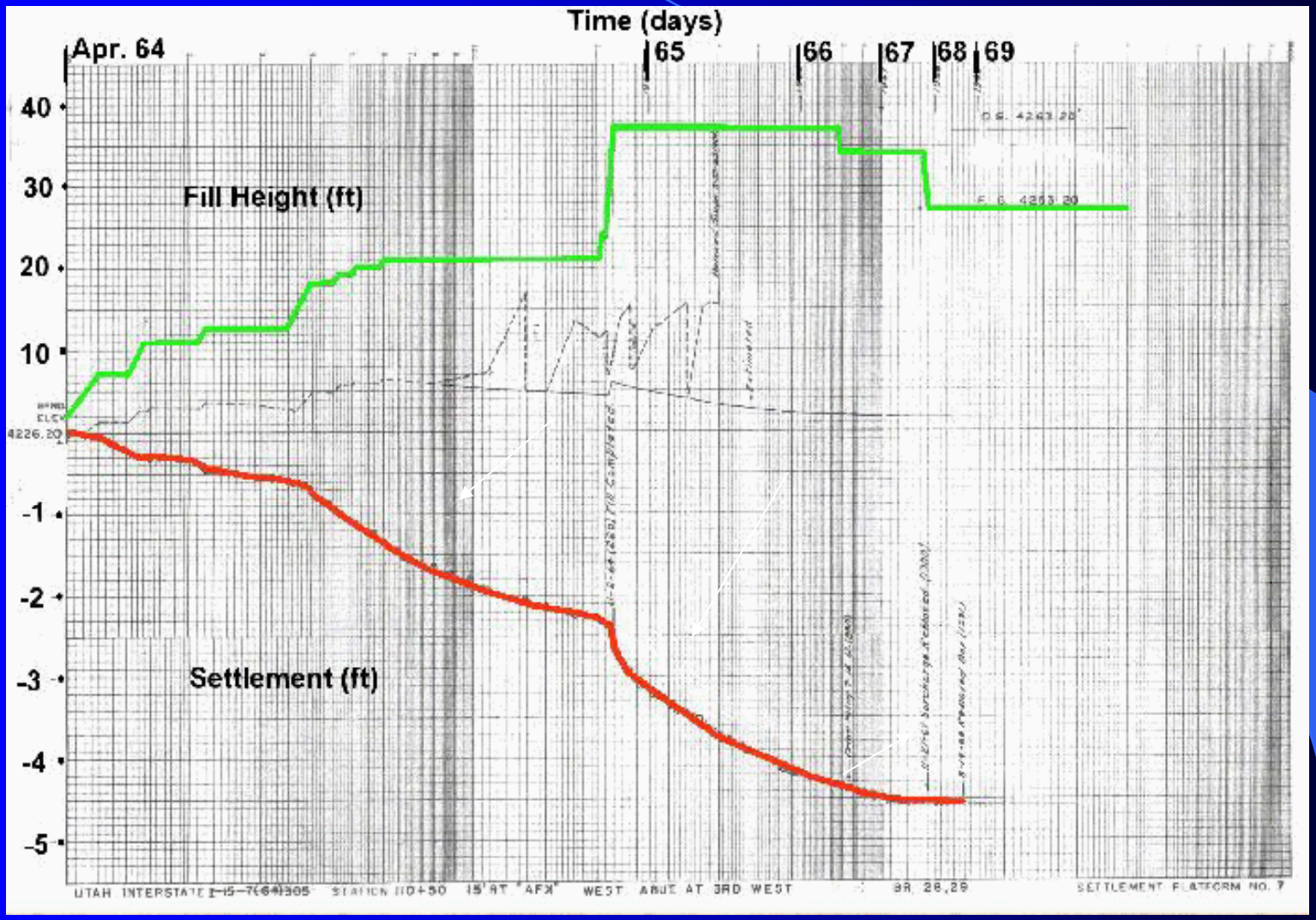
Geotechnical Issues

- Large Primary Consolidation Settlement (1 to 1.5 m)
- Time Rate of Consolidation (2 years to end of primary)
- Creep Settlement (Bump at Bridge)
- Foundation Stability (Large Embankments on Soft Soils)
- Schedule Constraints (two 2-year projects)
- Maintenance of Traffic (Had to be maintained)
- New Technologies and Development of Specifications

Subsurface Profile in Salt Lake Valley

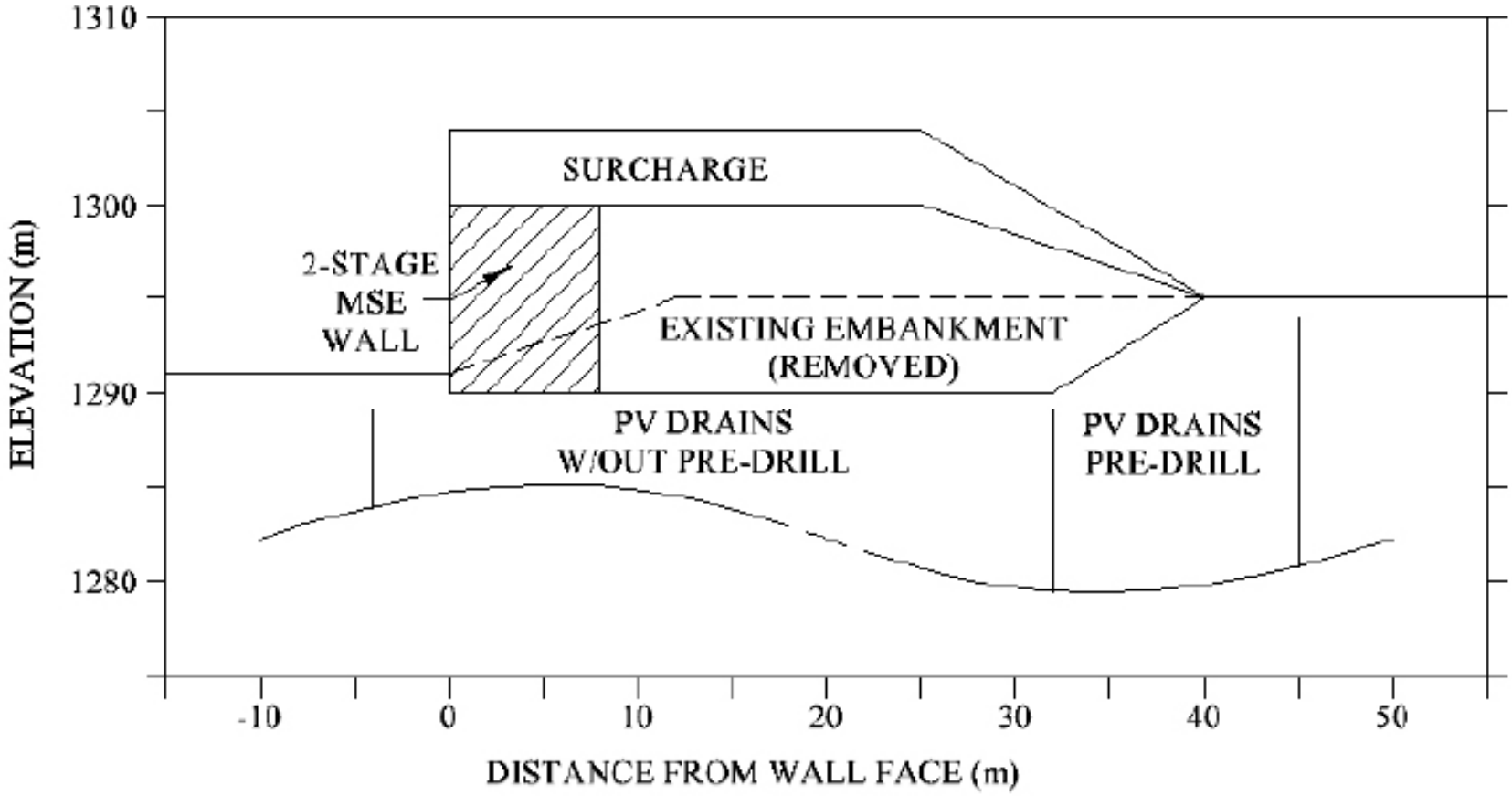


Settlement of Soft Clays in Salt Lake Valley



Approximate 2 years of primary settlement

I-15 Embankment Construction
2-stage MSE wall with surcharge



Prefabricated Vertical Drains

PV Drain Spacing 1.5 to 2.5 m triangular spacing

Installed drain

Placement of anchor bar

PV drain pushed into ground

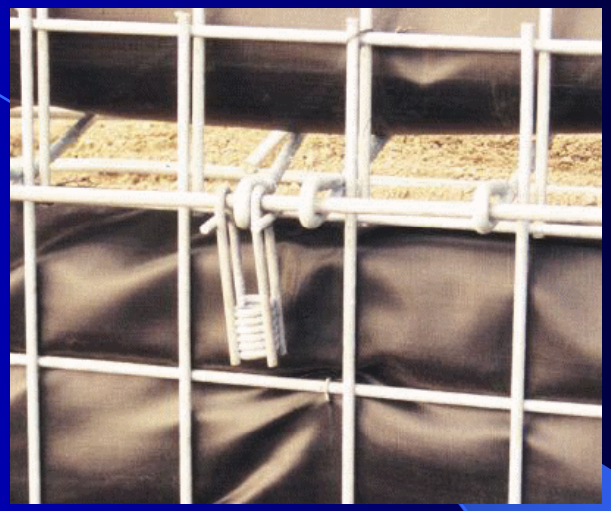
2-Stage MSE Walls

Right-of-way constraints required many slopes to be built vertically.

Beginning of 2-stage MSE Wall

2-Stage MSE Wall Connections

Attachment of Panels with threaded rod



Female threaded rod coupler

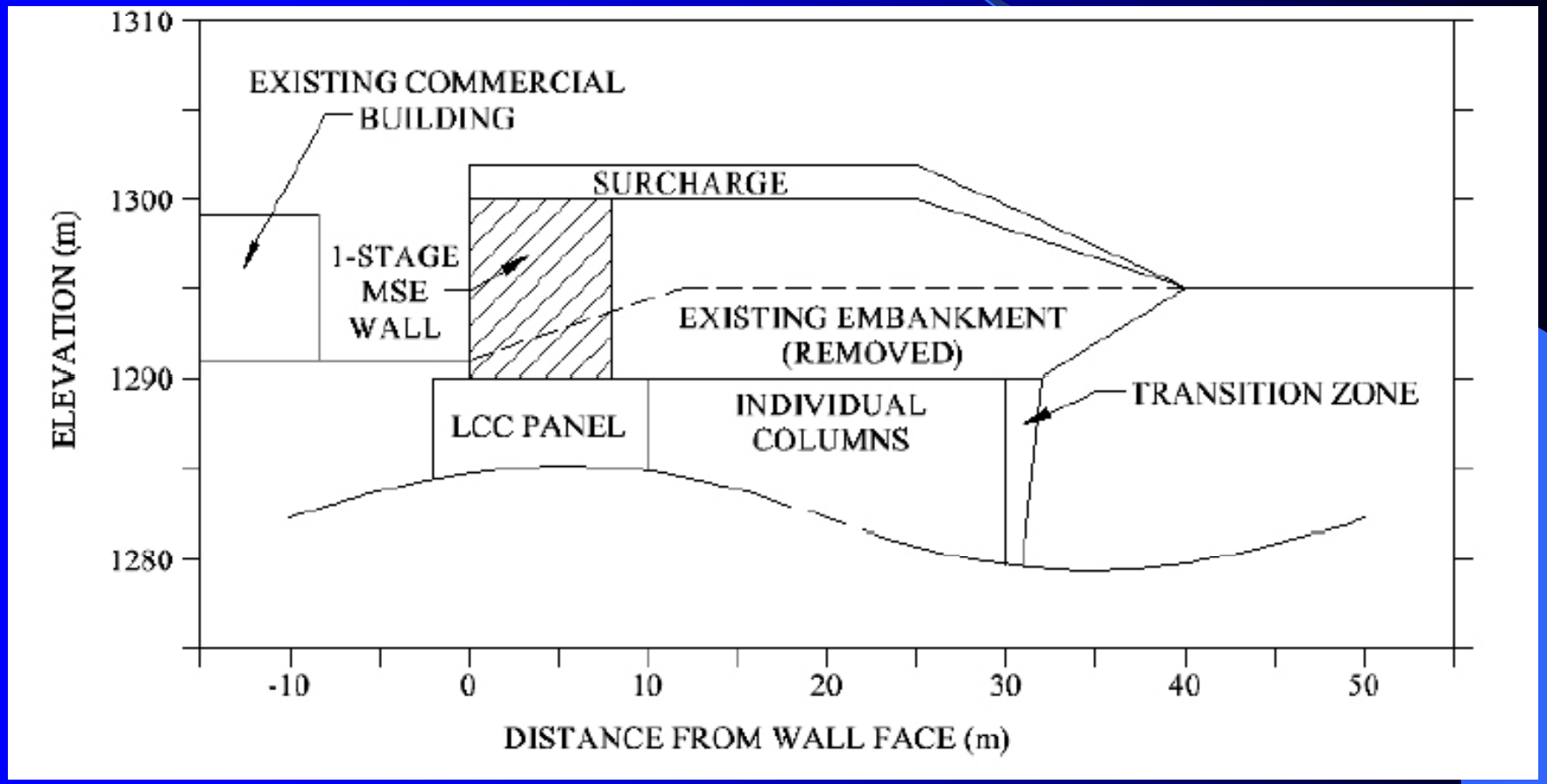
Concrete Fascia Panel

2-Stage MSE Wall with Prefabricated Vertical Drains Cost and Schedule Comparison

Two-Stage MSE Wall	Existing Embankment Removal *($6/m^3)*	$9,500	0.5
	Bedding Sand *($7/ton, 1 crew 2 days)*	$2,500	
	PV Drain Installation (1.5 m triangular spacing) *($1.5/m without pre-drilling, $3/m with pre-drilling)*	$14,000	1.5
	Wall/Embankment Construction and Settlement Time *($300/m^2 wall face, $9/m^3 embankment)*	$54,000	2
	3-stage Embankment Construction, Surcharging , Settlement Time, and Removal *(Placement - $9/m^3, Removal - $6/m^3)*	$20,000	10
	Total =	**$100,000**	**14**

Total cost is for 10 m length of embankment

I-15 Embankment Construction
1-stage MSE wall with lime cement columns



Lime Cement Stabilized Soil

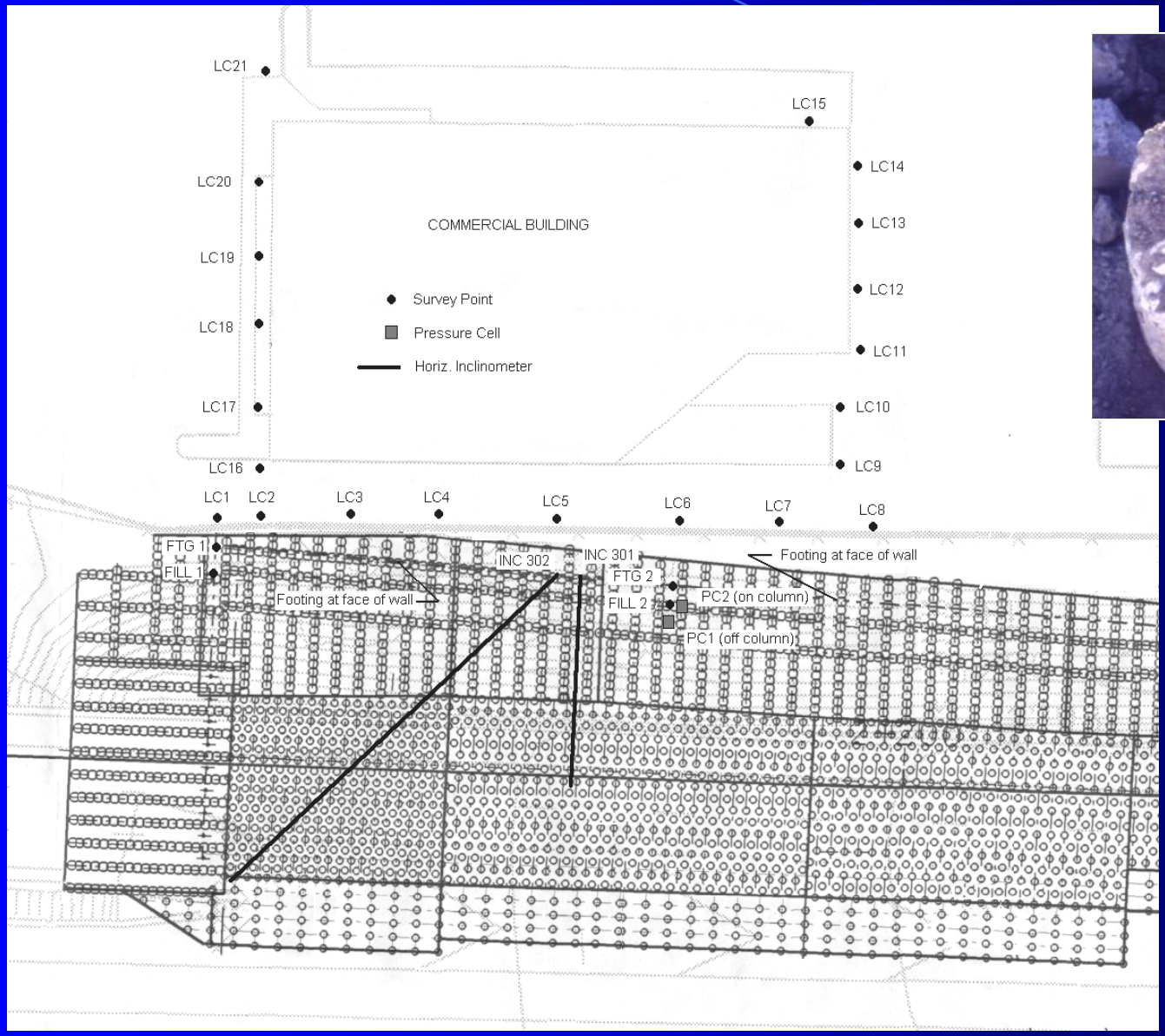
Lime Cement Column Rig

Auger / Mixer for Lime and Cement

125 kg/m^3 15% lime 85% cement

M = 30 Mpa (design); Su 300 to 400 kPa

Lime Cement Column Installation Pattern



1-Stage MSE Wall Construction

1-stage MSE placed over columns

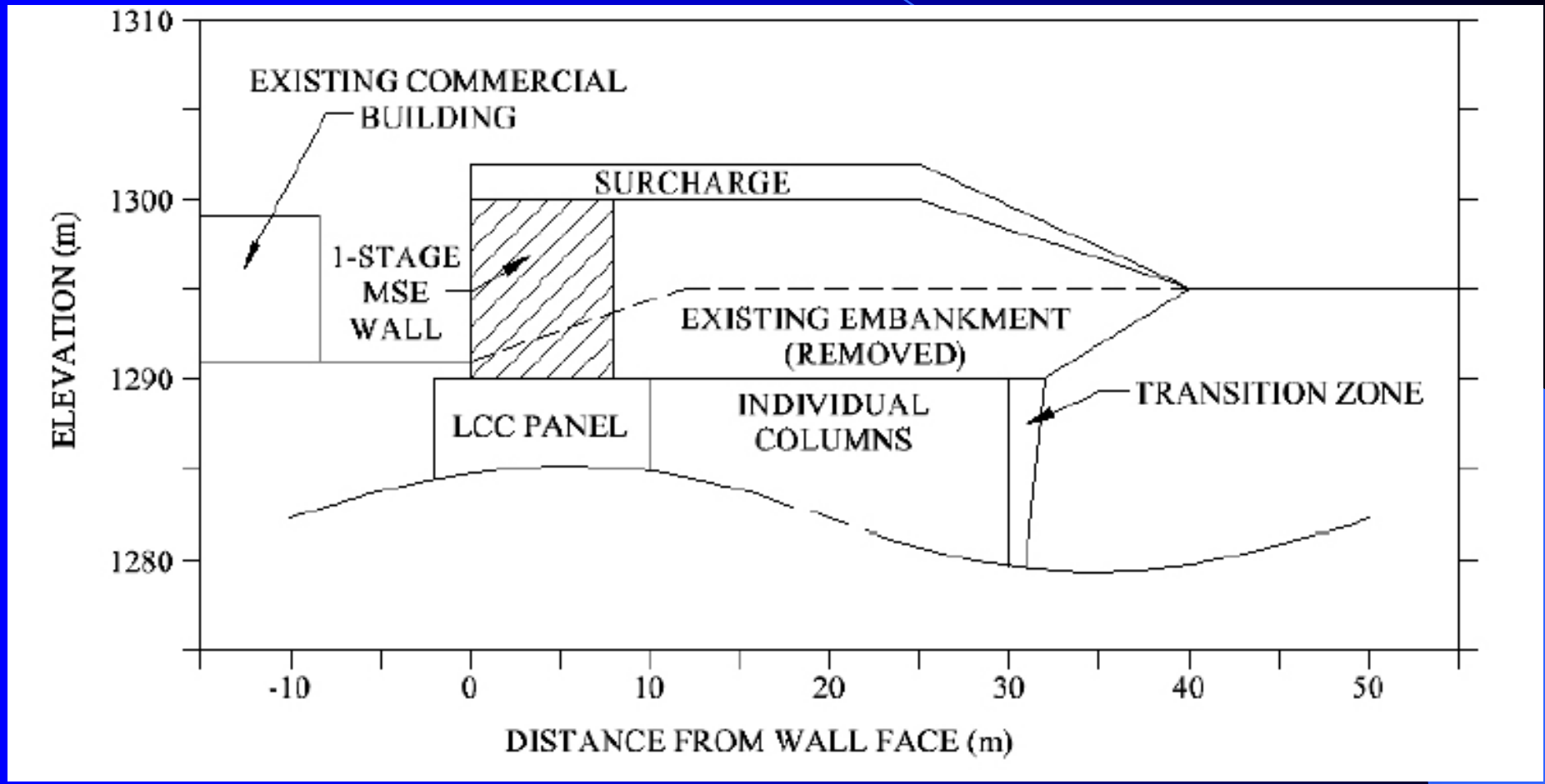
Finished MSE wall

1-Stage MSE Wall with Lime Cement Stabilized Soil Cost and Schedule Comparison

Geotechnology	Various Construction Activities *(With Typical Unit Cost)*	Associated Costs (Year 2000)	Time (months)
Lime Cement Columns	Existing Embankment Removal *($6/m^3)*	$9,500	0.25
	Lime Cement Column Installation *(0.8 m column - $17.5/m, 0.6 m column - $16/m)*	$97,000	2
	One-Stage MSE Wall/Embankment Construction *($200/m^2 wall face)*	$43,500	1
	1-stage Embankment Construction, Surcharging, Settlement, and Removal *(Placement - $9/m^3, Removal $6/m^3)*	$10,000	8.75
	Total =	**$160,000**	**12**

Total cost is for 10 m length of embankment

I-15 Reconstruction
Geofoam Embankment



I-15 Reconstruction Geofoam Properties

Physical Property	ASTM Test Procedure	Type VIII Accepted Value	Type II Accepted Value	Tolerances
Density	D1622	18 kg/m^3	22 kg/m^3	± 10 %
Compressive Resistance	D1621	90 kN/m^2	104 kN/m^2	minimum @ yield or 10 percent axial deformation
Flexural Strength	C203	208 kN/m^2	276 kN/m^2	Minimum
Water Absorption	C272	3	3	< % by volume

Table 2. Properties of Type VIII Geofoam Specified for the Reconstruction I-15 Project.

*** I-15 used 1.25 pcf density exclusively (i.e., type VIII geofoam)**

Geofoam (I-80 State Street to 200 West St.)

Geofoam Embankment Construction

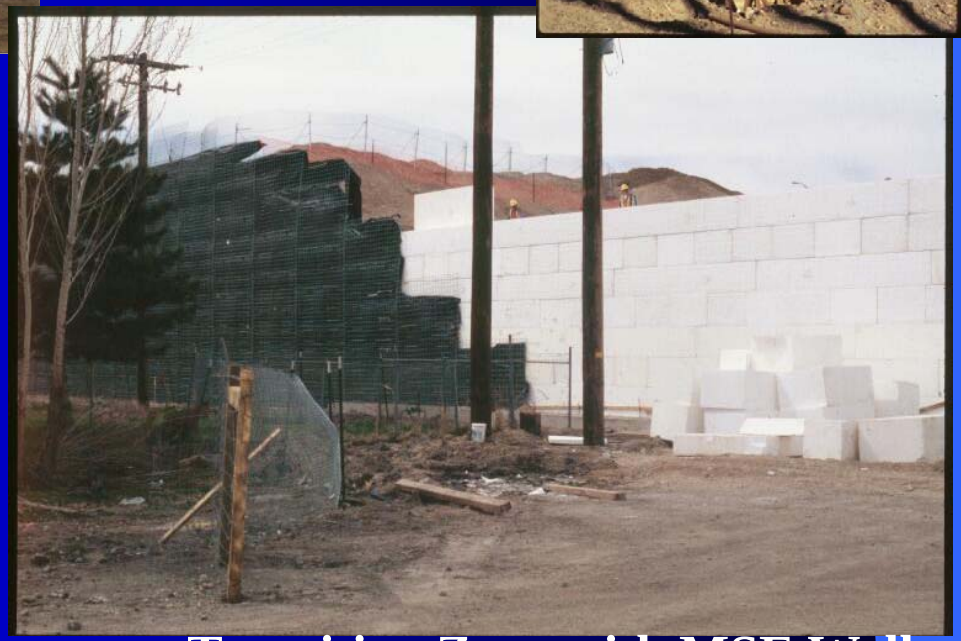
Base Sand

Footing for Panel Wall and Block Placement

Geofoam Embankment Construction

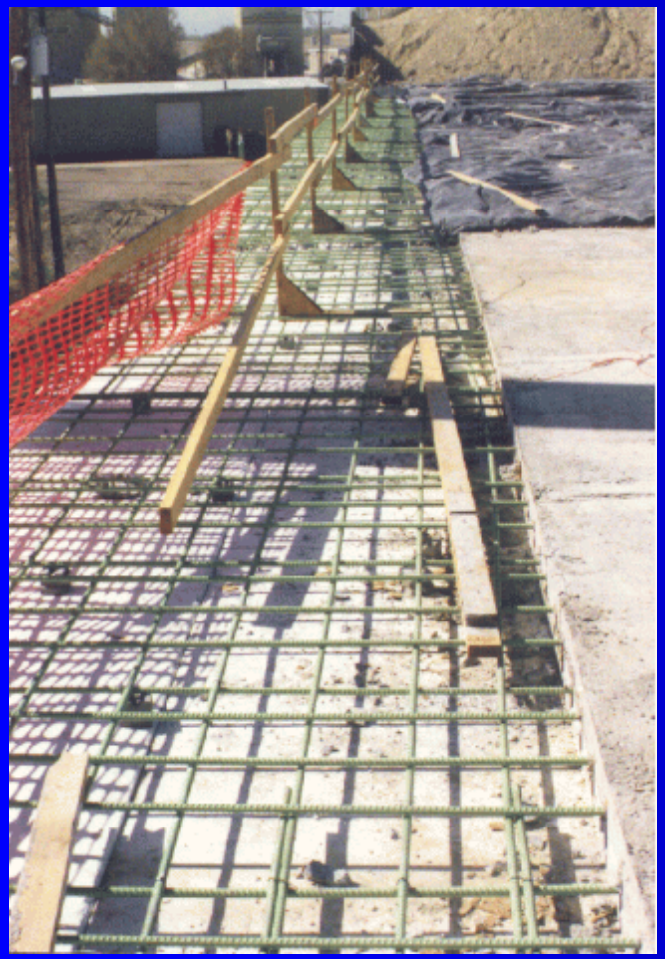
Nearly Completed Geofoam Embankment with Vertical Face

Geofoam cut and placed around piling at bridge abutment



Transition Zone with MSE Wall

Geofoam Embankment Construction



Reinforced Concrete
Load Distribution Slab

Completed Load Distribution Slab

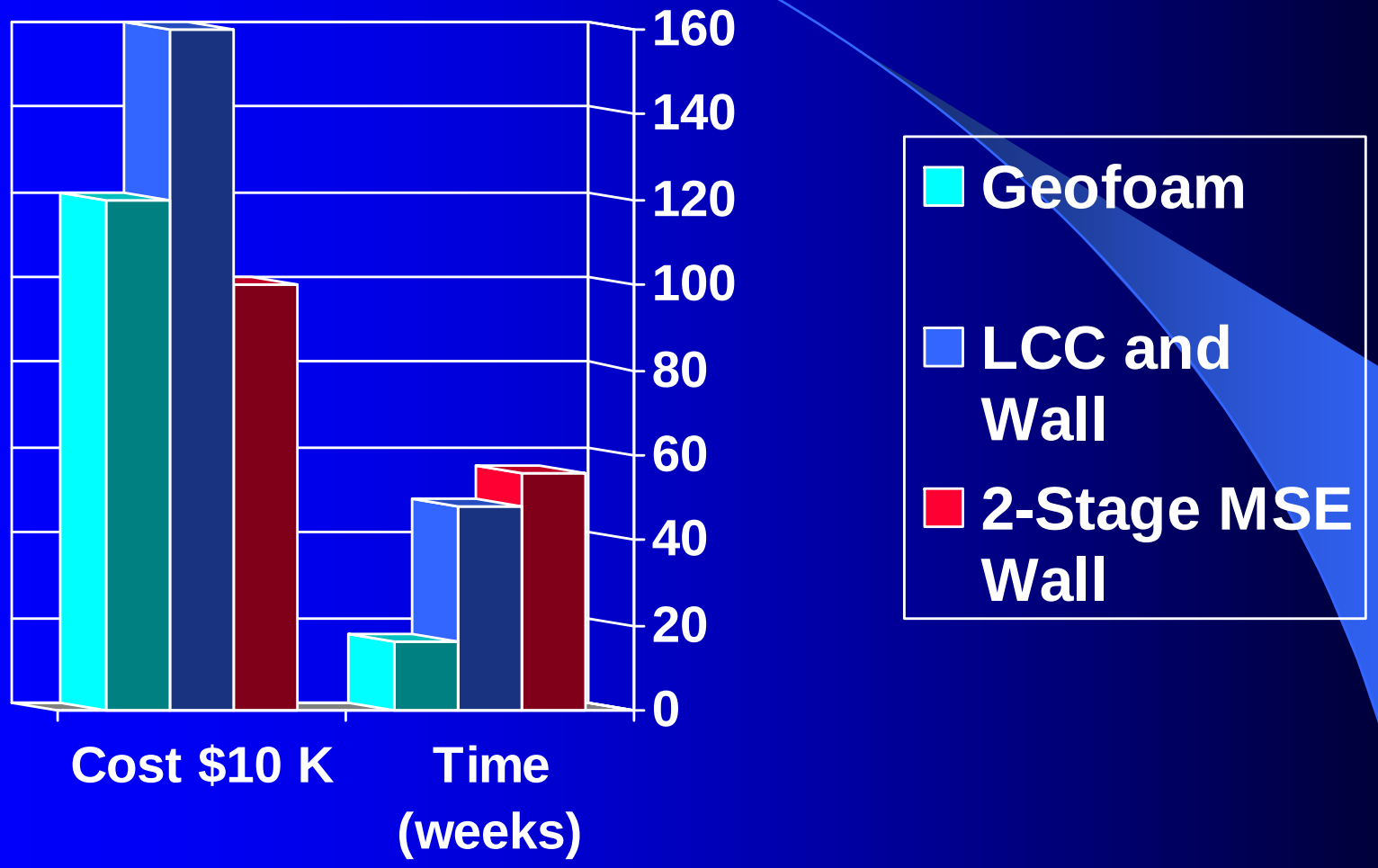
Geofoam Embankment Finished

Geofoam Embankment with Tilt-up Panel Wall Cost and Schedule Comparison

Geofoam	Existing Embankment Removal *($6/m^3)*	$1,500	0.25
	Bedding Sand *($7/ton, with 1 crew 1 week)*	$5,500	0.25
	Geofoam Embankment *($45/m^3)*	$65,000	2
	Tilt-up Panel Wall *($200/m^2 wall face)*	$20,000	0.75
	Load Distribution Slab *($60/m^2 surface area)*	$23,000	0.5
	Embankment Above Geofoam *($9/m^3)*	$5,000	0.25
	Total =	**$120,000**	**4**

Total cost is for 10 m length of embankment

Final Cost and Schedule Comparison

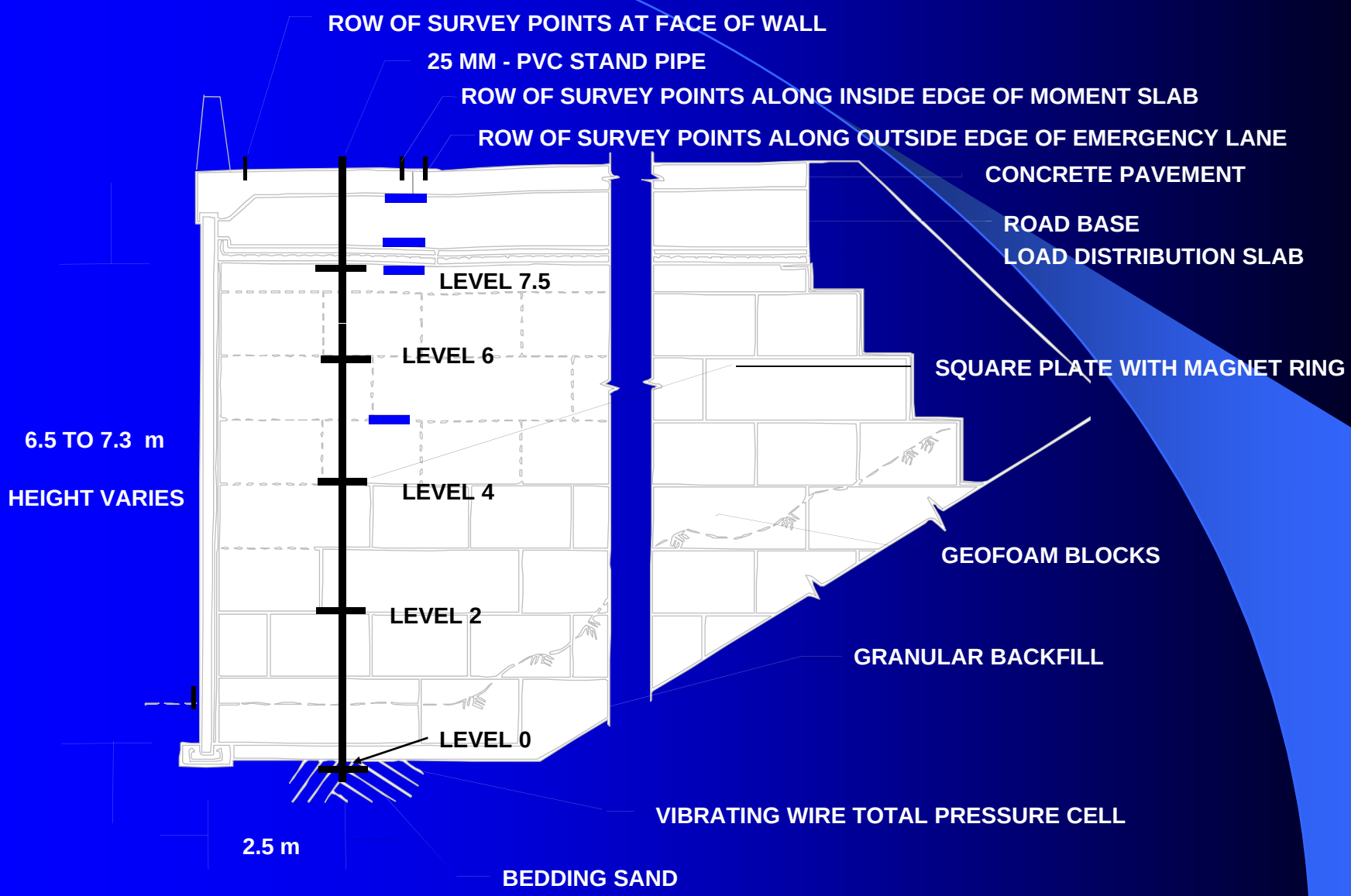


Cost represents total construction costs for each system for a 10-m long reach of interstate. Construction time is typical for embankments built on the I-15 Reconstruction Project.

Performance Monitoring
Objectives of Geofoam Arrays

- Measure Creep Settlement of Geofoam Mass (10 yr.)
- Measure the Pressure Distribution within Geofoam
- Measure Differential Settlement in Transition Zones
- Measure Lateral Earth Pressure at Abutments
- Monitor for Differential Icing at Geofoam / Embankment Transition Zones
- Model Stress / Strain Behavior

Typical Geofoam Array



3300 South Geofoam Array Installation

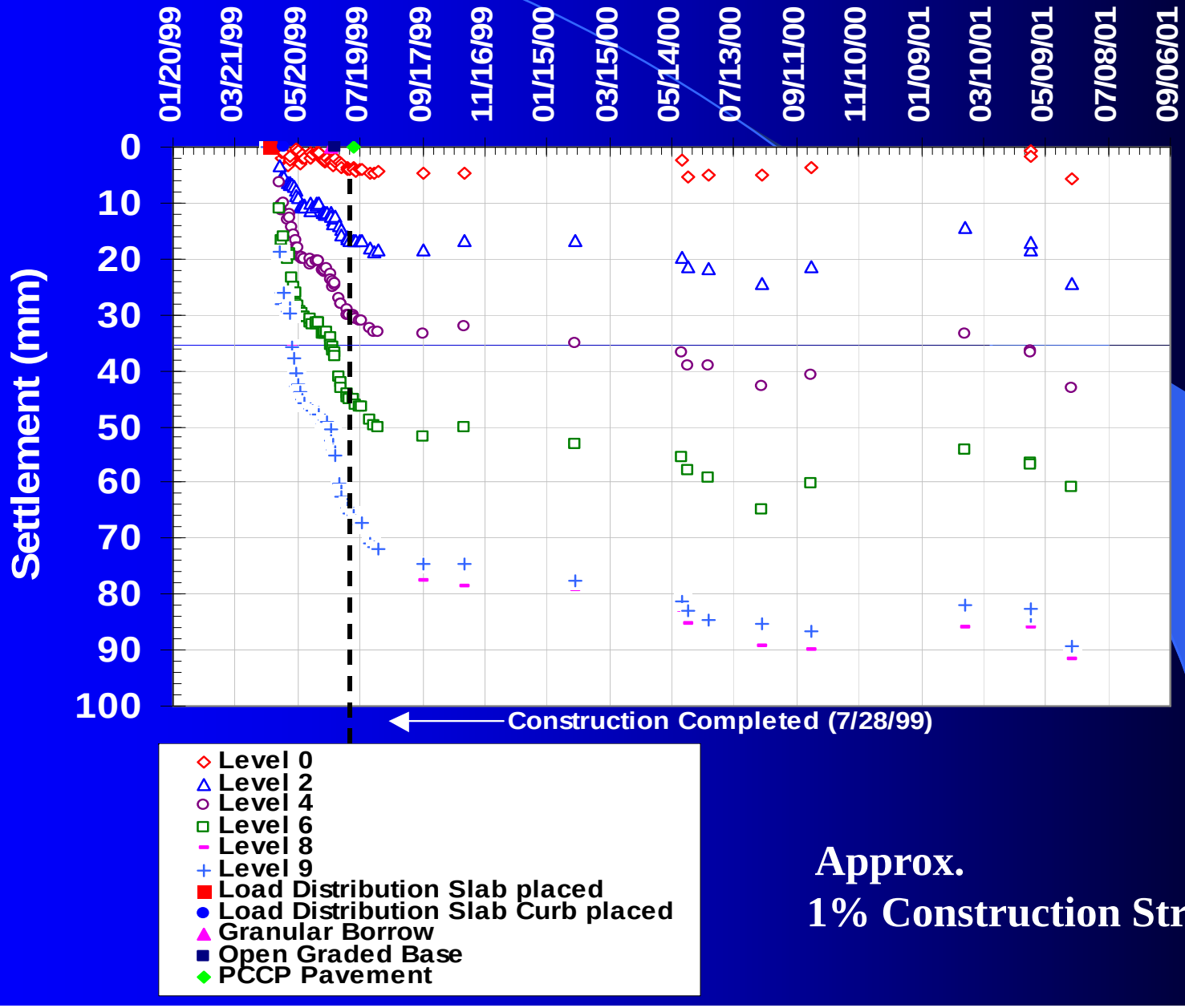
Magnet Extensometer and Pressure Cell Installation

Hotwire Cut for Pressure Cell

Pressure Cell Cast in Bridge Abutment

Pressure Cell in Base Sand

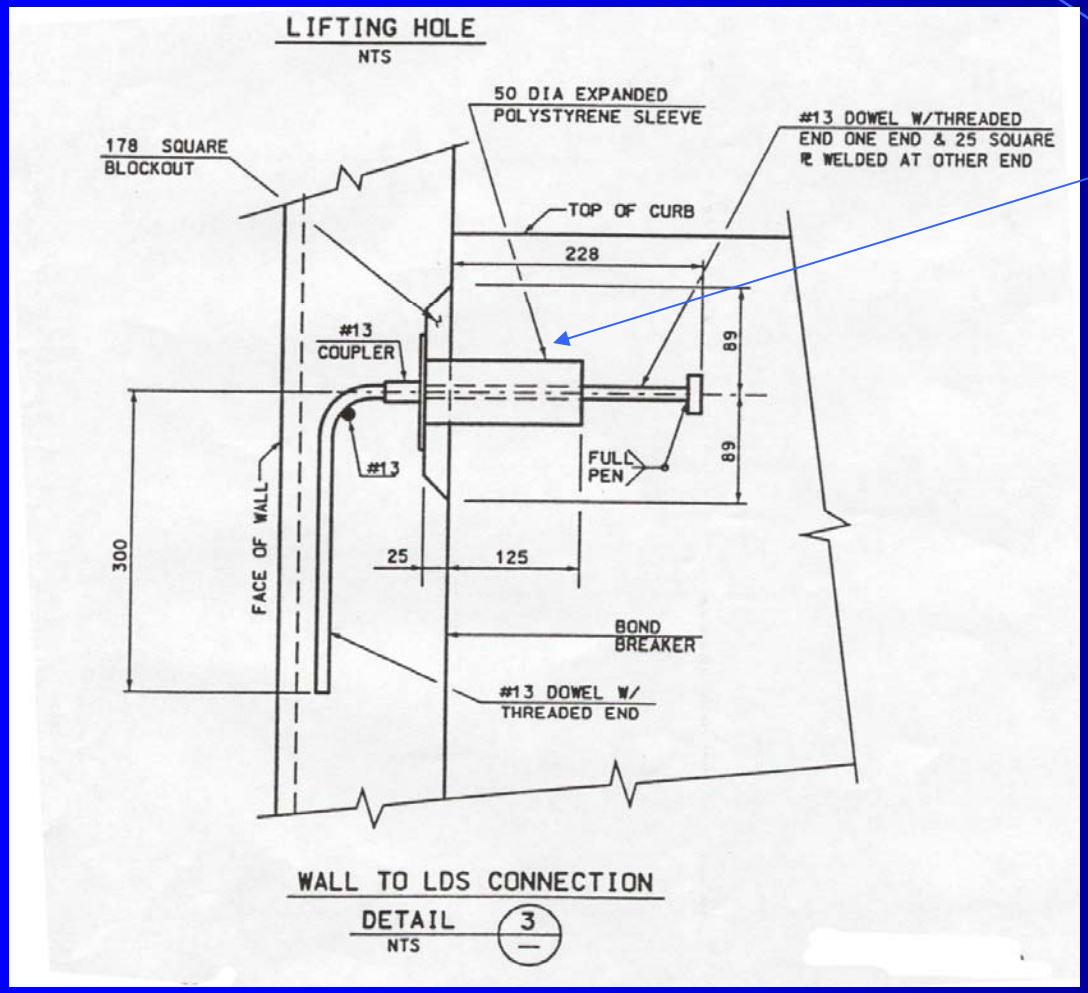
3300 South Array Settlement Data



Approx.
1% Construction Strain

3300 South Geofoam Array

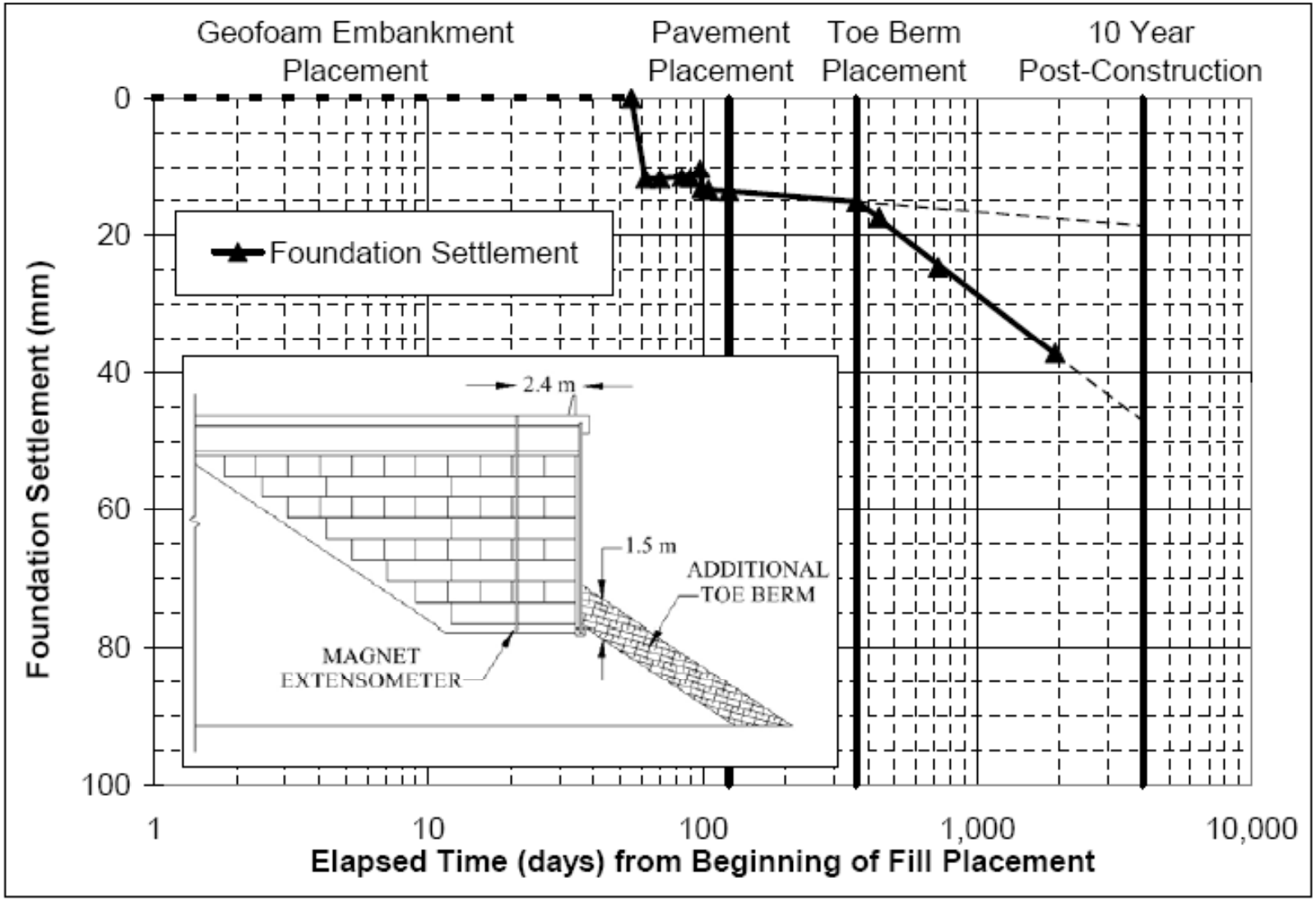
Damage to Connections During Construction Loading



Damaged Connection

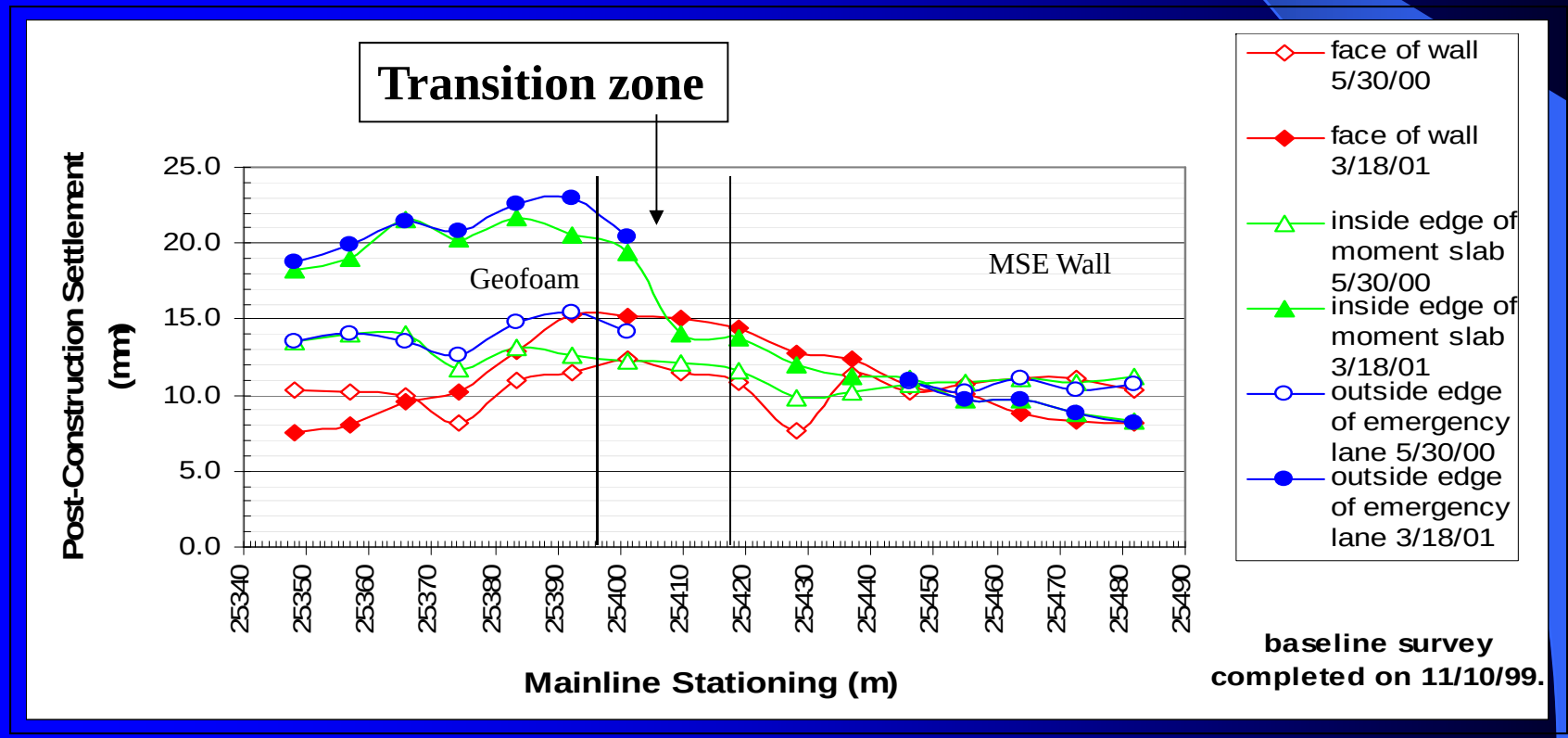
- **Approximately 1% loading strain can be expected.**
- **Strain due to seating of untrimmed block and elastic compression.**
- **Damaged connection was later repaired by dowels.**
- **Rigid connect should be avoided.**

Settlement at Toe of Wall

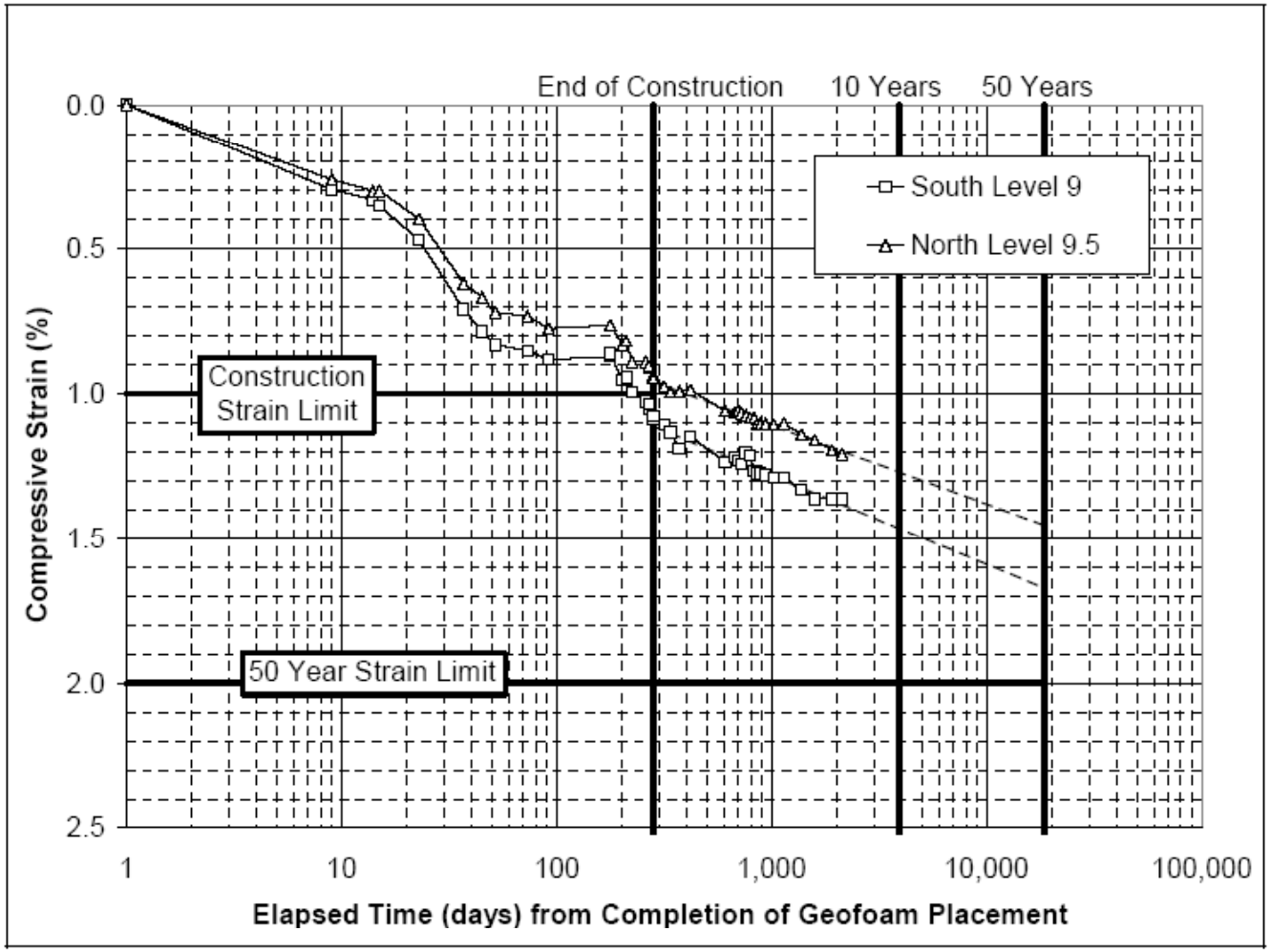


Geofoam Transition Zones
Post-Construction Settlement

Transition slope
3.5 H : 1 V

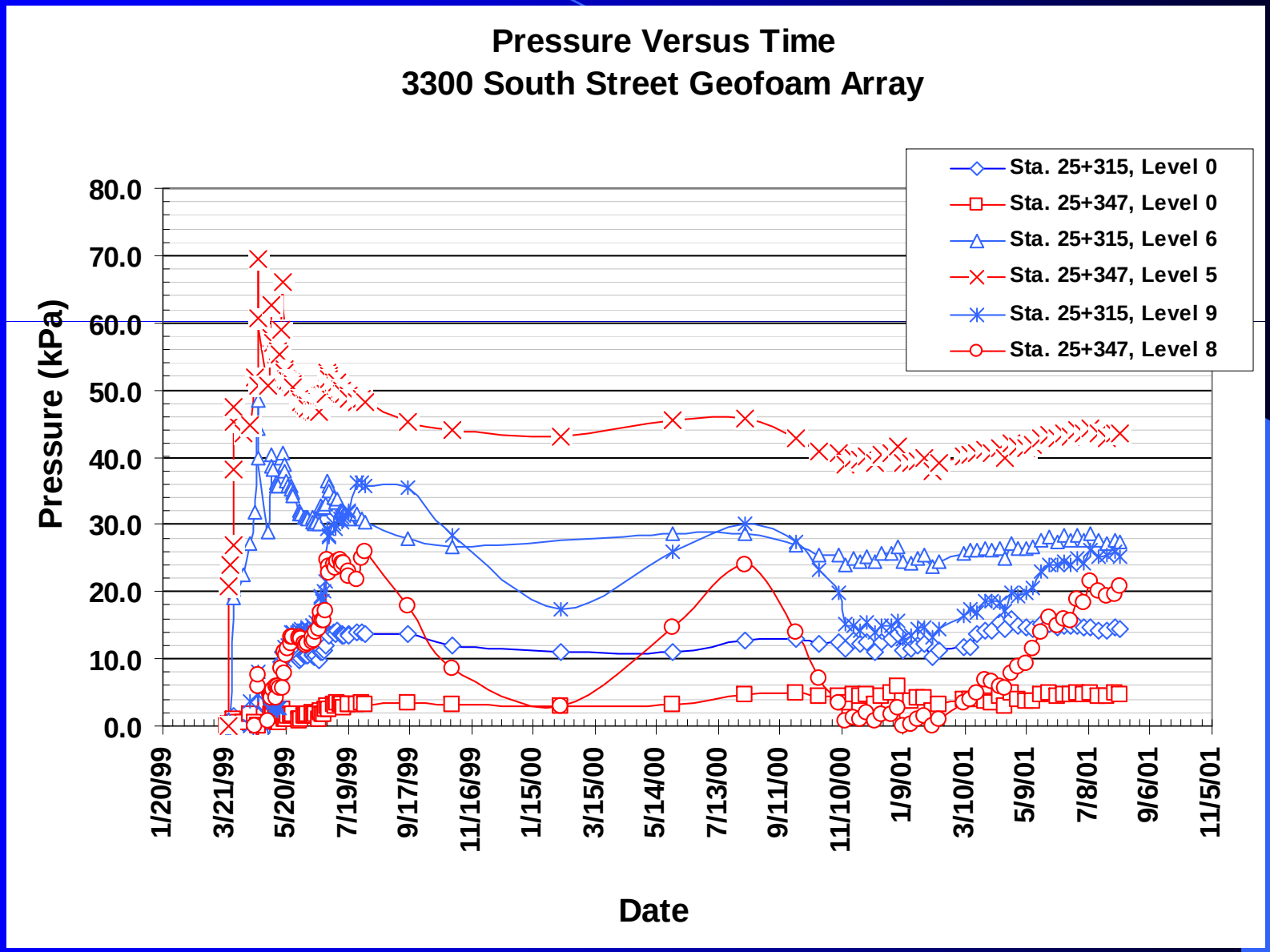


Settlement Monitoring 100 South Street



1% construction strain **projected 0.5 % additional 50 yrs.**

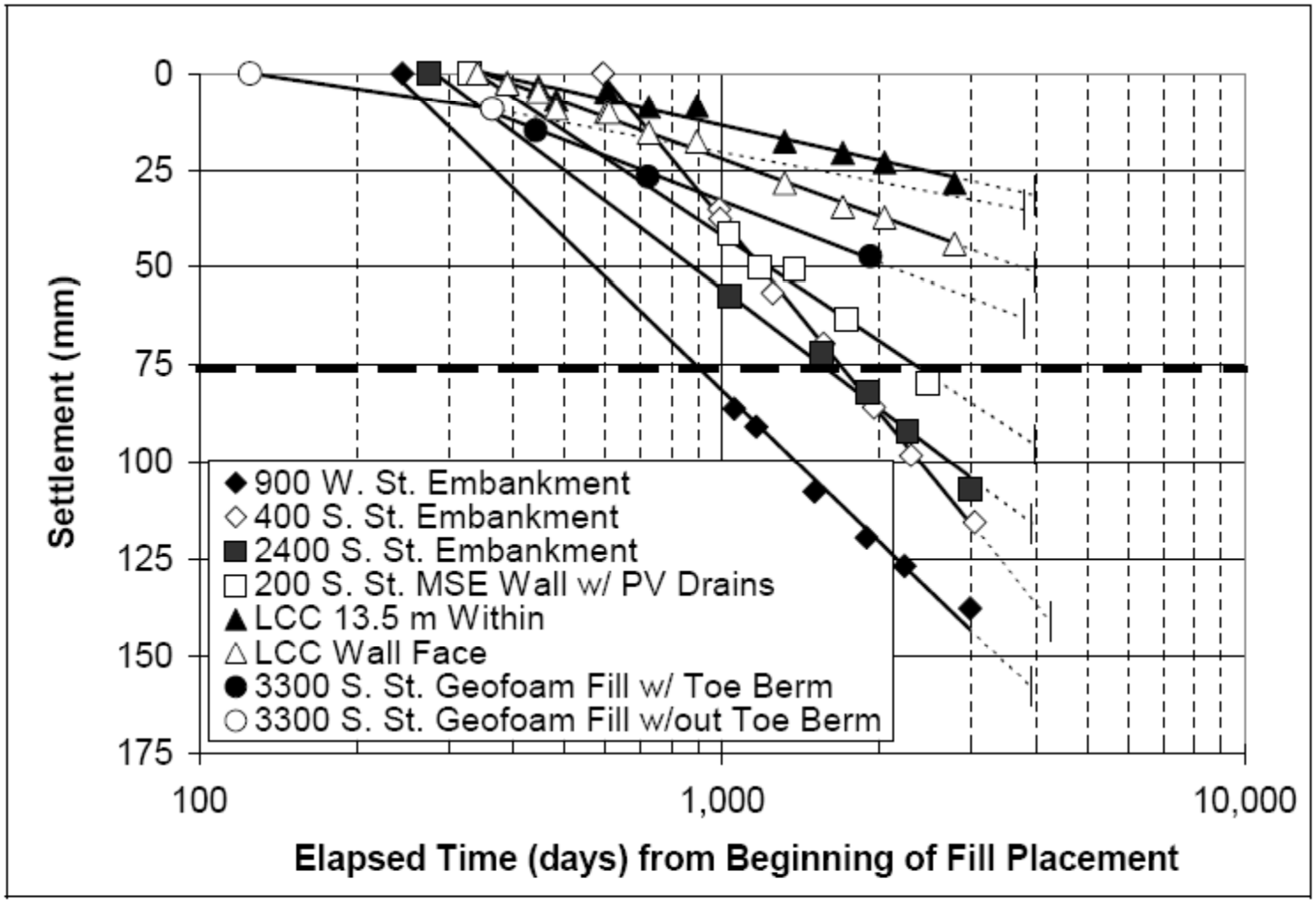
Pressure Cell Measurements in Geofoam



Geofoam Performance Summary

1. Geofoam fills are performing as expected
2. Approximately 1 percent vertical strain occurred during construction.
   a. Strain due to seating and compression of geofoam.
   b. This strain can damage rigid connections.
3. Approximately 0.3 percent creep strain (15 mm) has occurred in the geofoam for an 8-year post construction period. This is acceptable and within the expected performance.
4. The vertical stress distribution that develops in a geofoam wedge fill is complex, but generally diminishes with depth.
5. Pressure cell measurements suggest that approximately 45 kPa of vertical stress has developed in the center of the geofoam mass. This is approximately 50 percent of the compressive strength of the geofoam.

Settlement Comparison
I-15 Geotechnologies



Settlement Conclusions
I-15 Geotechnologies

- Geofoam has met the 75 mm (3 inch) in 10-yr settlement goal in all cases.
- LCC Treated soil has met the 75 mm in 10-yr settlement goal.
- 2-Stage MSE Walls have not met the 75 mm in 10-yr settlement goal for the MSE wall and embankments monitored. The expected range of settlement for these system is 100 (4 in) to 150 mm (6 in) for a 10-year post construction period.

Principal Investigators

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Published Reports

Farnsworth C. F., Bartlett S. F., Negussey, D. and Stuedlein A. 2008, "Construction and Post-Construction Settlement Performance of Innovative Embankment Systems, I-15 Reconstruction Project, Salt Lake City, Utah," Journal of Geotechnical and Environmental Engineering, ASCE (Vol. 134 pp. 289-301).

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