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Route 22 over Liberty Avenue and Conrail Hillside Township, Union County, Monitoring of Tensar MSE Walls

FINAL REPORT
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Submitted by

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16. Abstract

This report discusses the application of Tensar geogrids as the reinforcement elements in the construction of mechanically stabilized earth (MSE) walls on the Route 22 over Conrail and Liberty Avenue bridge replacement project in Hillside, NJ. As this is a relatively new product to the New Jersey Department of Transportation, the geogrids were instrumented with strain gages and tiltmeters to allow performance monitoring of the MSE walls during and after construction. This report documents the results and findings of the monitoring data at the end of construction and after six months, as well as an optical surveying of the MSE wall faces to determine post-construction wall movement. The monitoring effort is in collaboration with the Federal Highway Administration's Long Term Bridge Performance Program.

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INTRODUCTION

The Route 22 over Conrail and Liberty Avenue Project is currently under construction. The project is located in a commercial area of Hillside Township in New Jersey. The area has been designated as an Urban Enterprise Zone (UEZ) which includes various commercial developments and businesses along the Route 22 corridor. Liberty Avenue functions as the main corridor through Hillside Township's Central Business District, and the Liberty Avenue/Long Avenue intersection is the commercial center of the township.

The existing bridge in Hillside spans over Conrail, Liberty Avenue, and a private access road which runs in a south-north direction from Long Avenue to the south to Shop-Rite on the north side of Route 22. The Conrail line under the bridge is active and serves several industries in the area. Liberty Avenue is a major local street linking Hillside north and south of Route 22, and the Access Road to Shop-Rite serves the local community by providing a direct access to the Shop-Rite Plaza without the need to enter Route 22.

The project is essentially a bridge replacement project for the structurally deficient and functionally obsolete existing bridge. In its final form, it includes the following features:

- A single span structure over the Shop-Rite Access Road supported on stub abutments on surrounding full-height Mechanically Stabilized Earth (MSE) walls.
- A pie-shaped 2-span (WB) and 3-span (EB) structure with a continuous multi-girder steel superstructure founded on full height reinforced concrete abutments spanning over Liberty Avenue and Conrail.
- Eight mechanically stabilized earth (MSE) walls inclusive of those supporting the Access Road Bridge stub abutments (see Figure 1).

The Contractor (Union Paving) proposed the use of the ARES system which utilizes Tensar polymeric geogrid as the reinforcing elements for construction of the MSE walls. Tensar walls are not on NJDOT's pre-approved list of allowable MSE walls for walls greater than 20 feet tall, or for walls that support spread footing abutments. NJDOT considered Union Paving's request that they be allowed for this project, and agreed to permit their use. Since it is a relatively new application of the product, NJDOT agreed to implement an instrumentation program to monitor the performance of two of the eight MSE walls during and after their construction. The Tensar ARES walls were designed by the Tensar International Corporation using the allowable stress design (ASD) method. The computer software MSEW v.3 developed by ADAMA Engineering, Inc. was used to perform the calculations. As per NJDOT requirements for this project, the ASD method was used for design of most of the geotechnical elements of the project.

The two instrumented walls are Walls 1 and 3 (see Figure 1). The instruments consist of the following:

- Eighteen strain gages attached to three geogrids (six per geogrid) at three different levels for each of the two walls.
- Two tiltmeters installed at two different levels on the facing of each of the two walls.
- Four optical prisms mounted on the face of each wall after construction

Geocomp Consulting, Inc of Boxborough, Massachusetts, provided the service for the MSE wall instrumentation installation and real-time monitoring during and after construction as part of the FHWA Long-Term Bridge Performance Program. Monitoring will continue after completion of this report to evaluate the long-term performance of the walls. In addition to collecting the strain gage and tiltmeter data in real-time, Geocomp performed an automated survey of the facing of the two walls to determine the post-construction movement at the locations of the optical prisms up to the time of preparation of the report. Rutgers University will continue to monitor and receive data to evaluate the MSE wall performance over time and report to NJDOT, also as a part of the FHWA Long-Term Bridge Performance Program. This contract is limited to the following:

- Review the monitoring program plans developed by Geocomp.
- Provide field consultation including the initial readings during construction.
- Evaluate the real-time monitoring data during and after construction (short-term).
- Prepare Interim and Final Data Reports shortly after construction and 6 months later, respectively, to evaluate the observed strains and movements of the walls and to compare with anticipated design values.

An interim report was submitted in July 2011 and included the monitoring data at the time of preparation of the report. This final report describes the instrumentation program and provides an update of the monitoring data.

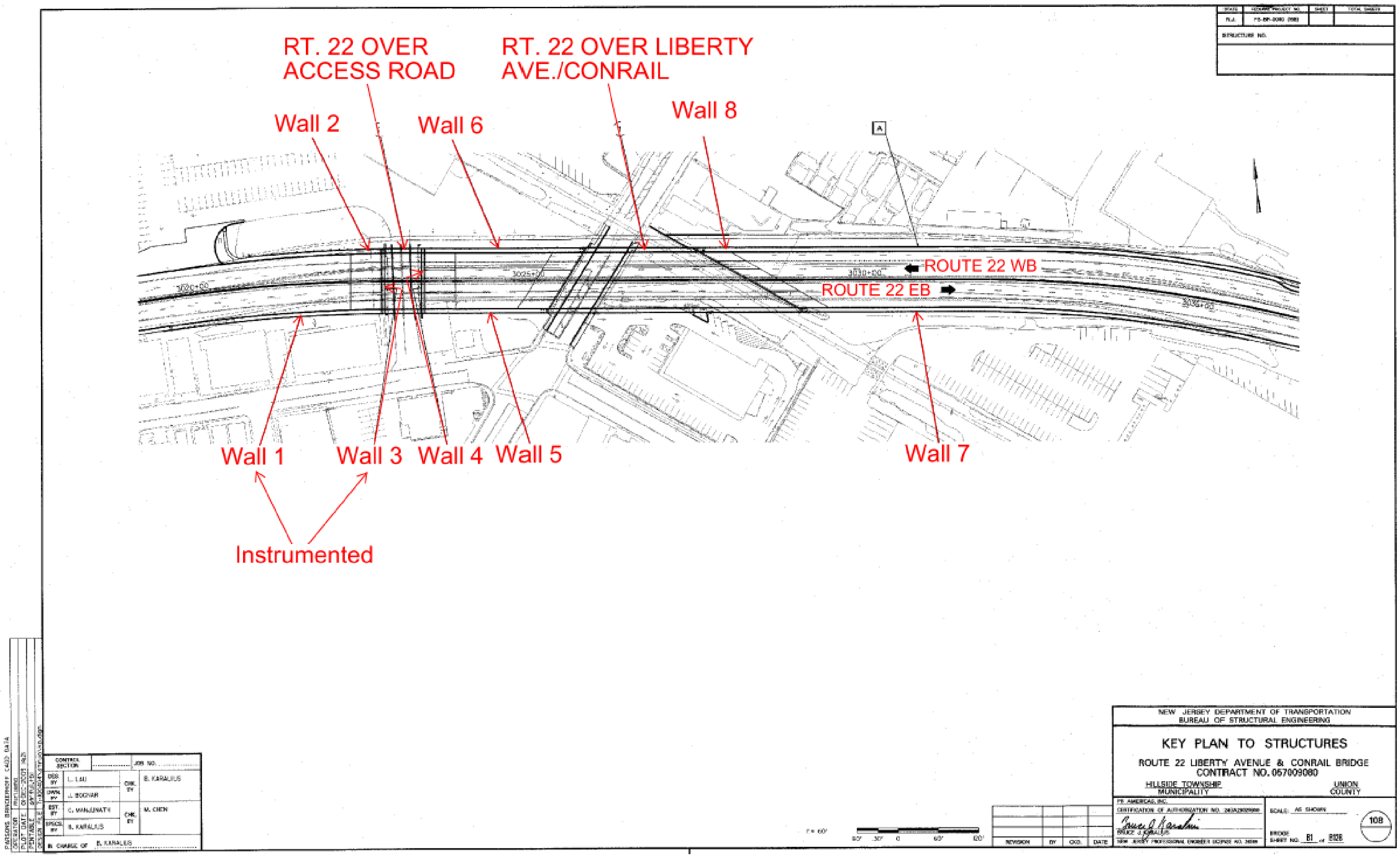


Figure 1. Route 22 over Liberty Avenue and Conrail Site Plan

MSE WALL GEOGRID REINFORCEMENT

Tensar geogrids are extruded from High Density Polyethylene (HDPE). The HDPE sheets are punched and drawn to generate the final geogrid structure, which consists of longitudinal ribs and elongated apertures. The geogrids used in the Route 22 Project are designated as UX1400MSE, UX1500MSE, UX1600MSE, and UX1700MSE, which have apertures and ribs about 18 inches long. Table 1 provides the geogrid design properties for a 100 year design life as obtained from the Tensar International Corporation.

Table 1 – Geogrid design parameters

Geogrid Type	T_{ult} (lb/ft)	RF_{cr}	RF_{id}	RF_d	T_{all} (lb/ft)	C_i	Coverage Ratio (%)
UX1700MSE	11,990	2.58	1.25	1.10	3,380	0.8	89
UX1600MSE	9,870	2.58	1.25	1.10	2,782	0.8	89
UX1500MSE	7,810	2.58	1.25	1.10	2,202	0.8	89
UX1400MSE	4,800	2.58	1.25	1.10	1,353	0.8	89

The parameters listed in Table 1 are defined as follows:

T_{ult} = Tensile strength in a quick tension test, ASTM D6637
RF_{cr} = Reduction factor for creep
RF_{id} = Reduction factor for installation damage
RF_d = Reduction for chemical and biological degradation
T_{all} = Long-term design strength
C_i = Pullout interaction coefficient

As shown in Table 1, a coverage ratio of 89% was used in the instrumented walls. The load-extension curves measured according to ASTM D6637 for the four geogrid types are included in Appendix A. The tests were conducted at a strain rate of about 10% per minute.

INSTRUMENTATION CONFIGURATION AND MONITORING

The strain gage, tiltmeter and optical prism locations were selected by PB. Appendix B includes cross-section and elevation views showing the levels of the instrumented geogrids, the locations of the strain gages along the geogrids, and the locations of tiltmeters on the wall faces. Appendix B also includes the selected locations of the optical prisms. In order to capture the maximum tension in the geogrids, the locations of the strain gages were selected such that they are intersected by the theoretical line of maximum tension within the wall which corresponds to the plane of failure assumed in design. The strain gages were positioned at one third of the length of the longitudinal ribs rather than in the middle considering the fact that the width of the ribs is smallest in the middle and largest where they meet the transverse ribs. By doing so, two strain gages could be accommodated within a single rib where needed. As already mentioned, each of the two instrumented walls included three instrumented geogrids at three different levels with a total of six gages installed on each instrumented geogrid panel. All gages were installed at or near the center of the geogrid panel in the transverse direction. Installation of the strain gages was performed in GeoComp's laboratory in Boston, MA, before shipping the instrumented geogrid panels to the job site. The installation logs of the instrumented geogrids, prepared by Geocomp, are provided in Appendix C.

Two tiltmeters were installed on each of the instrumented walls during wall construction. In order to be able to correlate the tiltmeter and strain gage data, the tiltmeters were mounted on the column of panels to which the instrumented geogrids were attached. The installation logs of the tiltmeters are provided in Appendix D.

Automatic logging of the strain gages and tiltmeters was performed by Geocomp using a battery operated data logger that was mounted temporarily on the face of Wall 1 near the corner with Wall 3 (see last photograph in Appendix E). A solar panel provided energy to charge the battery. The data logger and solar panels were mounted on the side of the abutment supported by Wall 3 after completion of the construction activities. The data is transferred wirelessly through an iSite remote monitoring system via a proprietary Remote Area Network (RAN). The research team is granted automatic access to the data, which is provided in the form of charts and tables. All data is safely stored and backed up on redundant iSiteCentral servers.

INSTRUMENTATION DATA

Strain Data

Plots showing the variation of geogrid strain during construction since the time of installation are provided in Appendix E for all geogrids. Figures 2 and 3 provide the variation of strain along the instrumented geogrids for Walls 1 and Wall 3 respectively at the time of preparation of the Interim Report and the time of preparation of this Final Report. It can be seen that the maximum tension was captured by the strain gages. The data in Figures 2 and 3 indicate that the geogrids experienced some relatively small creep within the five month duration between the two sets of readings for both Walls.

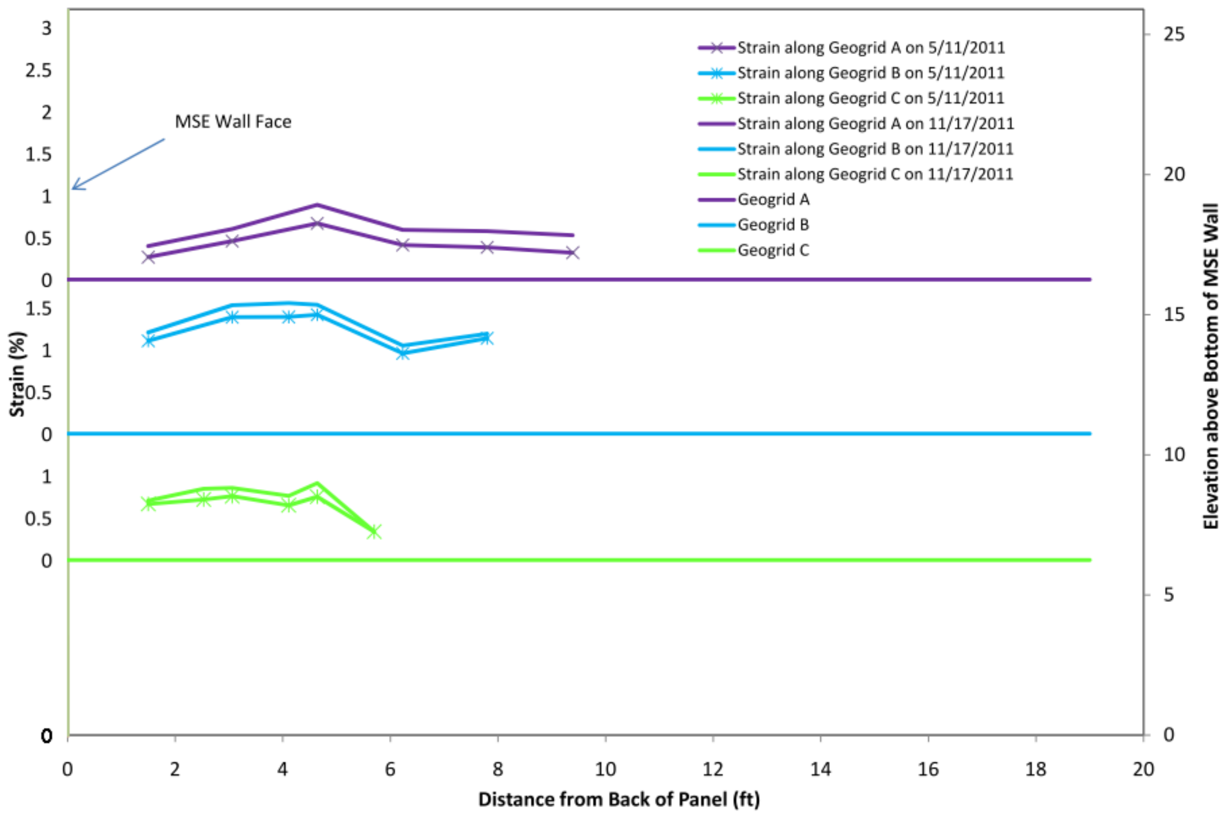


Figure 2. Variation of strain along geogrid at wall 1

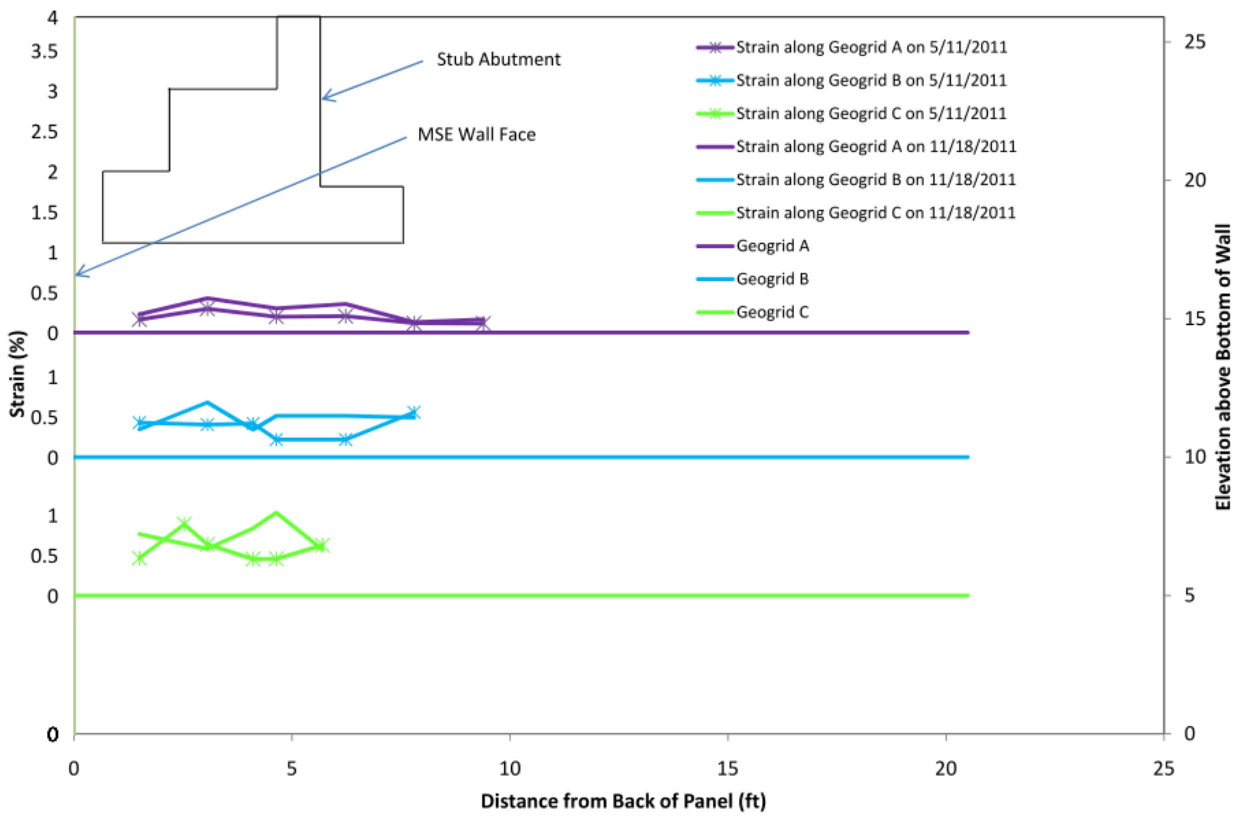


Figure 3. Variation of strain along geogrid at wall 3

The latest maximum strain detected for each instrumented geogrid is provided in Column 4 of Table 2. Geogrid A is the upper instrumented geogrid, Geogrid B is the intermediate instrumented geogrid and Geogrid C is the lower instrumented geogrid for both walls 1 and 3 (see Appendix B for geogrid locations within the wall).

The measured strains were used to estimate the tensions in the geogrids. However, evaluation of tension forces from the measured strains is complex for polymeric materials such as Tensar geogrids. Polymeric products are characterized by a load-extension behavior that is time dependent, i.e. susceptible to creep or stress relaxation. This is illustrated schematically in Figure 4 in a rather simplistic manner. The figure shows that the load-extension curve obtained from a quick test exhibits a higher stiffness compared to that obtained from a slow test. As can be seen, predicting the tension from the rapid load-extension curve for any measured strain would overestimate the tension force if the loading was performed at a slow strain rate which would be representative of the rate of construction of the wall. Since only quick test data using ASTM D6637 was available for the used geogrids, prediction of tension in the geogrids was performed using the quick load-extension curve and, hence, it can be postulated that the predicted tension is on the conservative side. Ideally, a series of creep tests are performed at different load levels and the creep data is used to develop the so-called isochronous curves from which a better correlation between load and strain can be made at any given load duration. Alternatively, a stiffness determined at a strain level of 2% after 1000 hours of loading is often used to represent the creep stiffness at low strains and at rates of strains representative of the rate of construction of MSE walls. The stiffness designated as J2% and referred to as Low Strain Creep Stiffness can be used to estimate the geogrid tension from the measured strains. Since the objective of this report was to determine whether the allowable geogrid tension is exceeded as part of checking the internal stability of the wall, it was sufficient to use a conservative approach to estimate the tension from the rapid load-extension test unless the estimated tension forces were sufficiently high to warrant a more rigorous analysis. Nevertheless, finite element analyses were performed using the Low Strain Creep Stiffness to evaluate the wall behavior. A brief discussion of the finite element analyses is provided later in this report.

Table 2 – Tensile strains and forces in instrumented geogrids

1	2	3	4	5	6	7	8
Wall No.	Geogrid No.	Geogrid Type	Maximum Strain (%)	T_{max} based on quick load-extension curves (lb/ft)	T_{max} from MSEW calculation (lb/ft)	Long-term Design Strength (LTDS) (lb/ft)	Maximum Allowable Design Load (LTDS/1.5) (lb/ft)
Wall 1	A	UX1500MSE	0.89	805	1,014	2,202	1,468
	B	UX1600MSE	1.55	1,660	1,450	2,782	1,855
	C	UX1700MSE	0.91	1,156	1,889	3,380	2,253
Wall 3	A	UX1700MSE	0.41	523	1,611	3,380	2,253
	B	UX1700MSE	0.66	836	1,863	3,380	2,253
	C	UX1700MSE	1.00	1,262	1,647	3,380	2,253

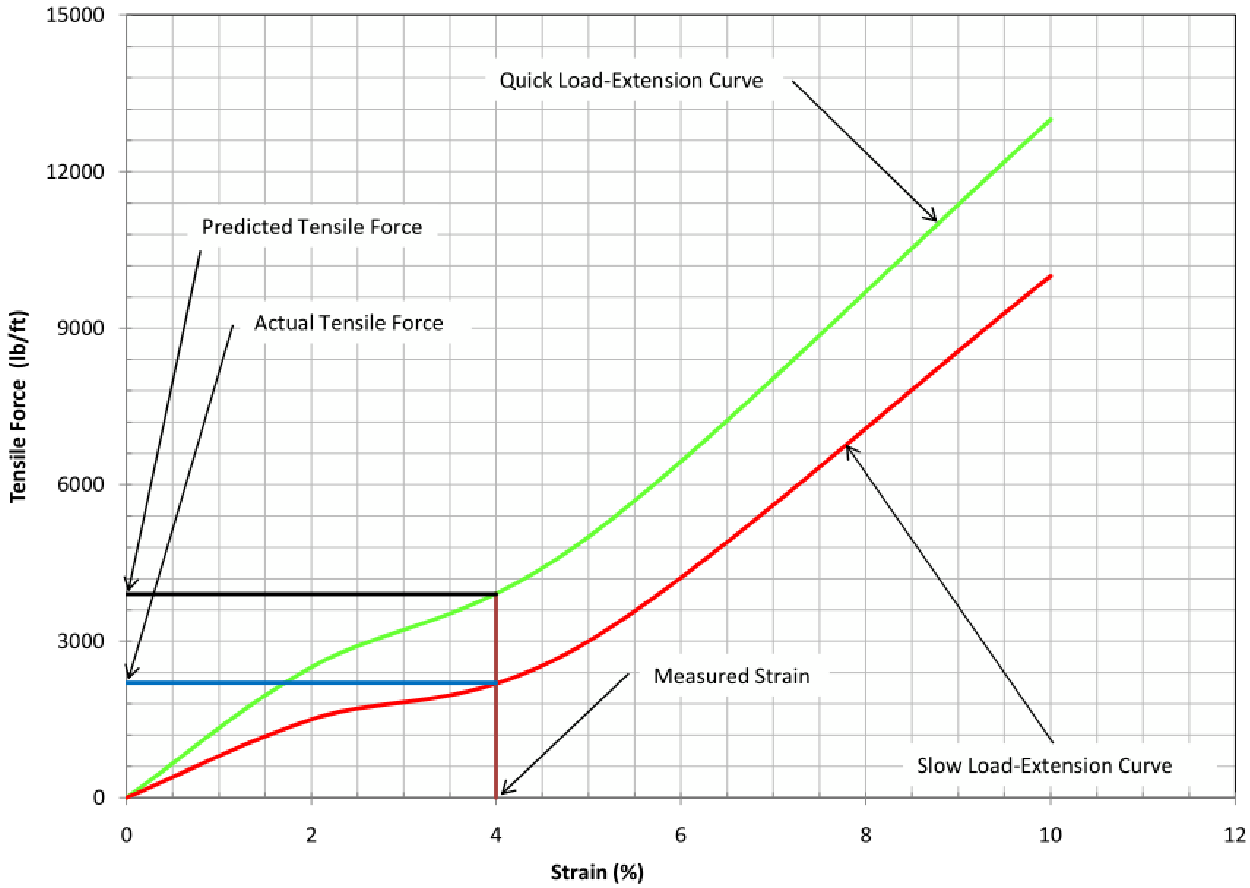


Figure 4. Conservatism in estimating geogrid tension force

The maximum tension deduced from strains and based on quick load-extension tests (Column 5 in Table 2) are compared with the allowable tension (column 8), which is equal to the long term design strength (LTDS, Column 7) divided by a factor of safety of 1.5 as typically assumed in the allowable stress design (ASD) method. It can be seen that in all cases, the maximum estimated tension is less than the maximum allowable tension. This, in addition to the fact that the tension is conservatively estimated from the strains, as already discussed, indicates that there is sufficient safety factor against tension failure for all the instrumented geogrids. For completeness, the maximum tension forces in the geogrids as obtained using the software MSEW V.3 developed by Adama Engineering, Inc. and based on limit equilibrium method are provided in Column 6. By comparison with Column 8, it can be seen that the design tension forces are less than the maximum allowable tension indicating that some conservatism was used in design.

Tiltmeter Data

Plots showing the variation of facing tilt during construction since the time of installation are provided in Appendix F for all tiltmeters. The maximum tilts measured in May and November of 2011 at the four tiltmeter locations are summarized in Table 3. It is to be noted that the tilts reported in the interim report were overestimated due to the fact that the reference initial readings were not representative of the stabilized values. Proper zeroing after stabilization of the initial readings is reflected in the present results. Table 3 indicates an increase in tilt over a period of 6 months after construction of the wall which is to be expected since the geogrids experienced some additional strain due to creep.

Table 3 – Tiltmeter measurement

Wall No.	Titlmeter Number	Maximum Tilt (radians)		Average Tilt (radians)	
		5/11/2011	11/17/2011	5/11/2011	11/17/2011
Wall 1	1-1 (Upper)	0.003	0.010	0.002	0.007
	1-2 (Lower)	0.001	0.004		
Wall 3	3-1 (Upper)	0.008	0.015	0.009	0.016
	3-2 (Lower)	0.011	0.018		

FHWA publication FHWA-NHI-024, 2009 provides an empirical estimate of the ratio of maximum lateral movement to the wall height for different L/H values where L is the reinforcement length and H is the wall height. The maximum lateral deformation can be obtained from Figure 5, which is reproduced from Figure 2-15 of the FHWA manual. The same figure is also provided in the 2010 AASHTO LRFD Bridge Design Specifications (Figure C111.10.4.2.1). Using Figure 5, the ratio of maximum lateral movement to wall height would be equal to 0.013 for Wall 1 and 0.010 for Wall 3. These values are of the same order of magnitude of the values in Table 3. However, all values should be viewed in light of the fact that direct comparison between the average measured tilts and the empirical ratio of maximum lateral movement to wall height obtained from Figure 5 is not strictly valid since the maximum displacement does not necessarily occur at the top of the wall. If, for example, the maximum lateral movement occurs in the middle of the wall, then the maximum tilt along the wall would be double or more than double the ratio of maximum lateral movement to wall height from Figure 5. It may be mentioned that there was an increase in tilt of Tiltmeter 1-2 on April 14, 2011, which corresponded to construction activities involving heavy equipment on the wall.

Based on the order of magnitude of the wall tilt, it can be concluded that the wall deformation is not excessive and comparable to typical MSE wall behavior.

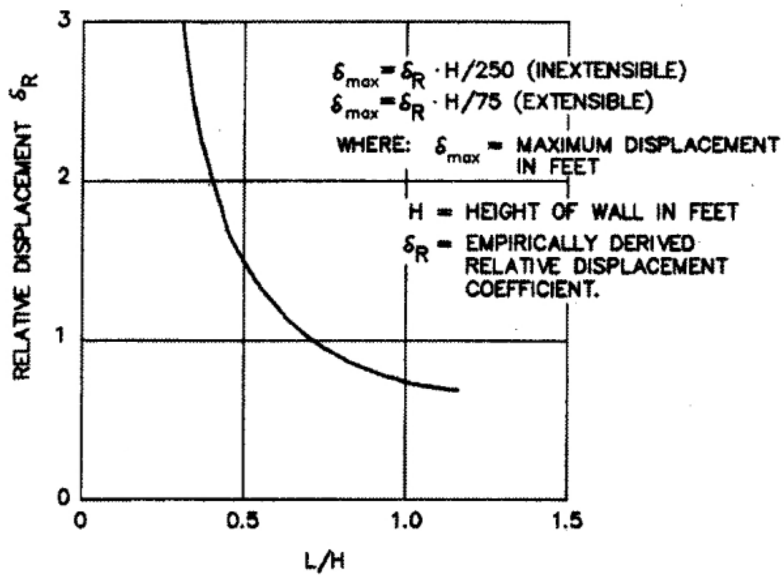


Figure 5. Empirical curve for estimating lateral displacement during construction for MSE walls (after FHWA RD 89-043 {Christopher et al., 1990})

Optical Prism Data

Five sets of survey readings were taken by Geocomp on June 30, 2011 to establish the average and standard deviation for the northing, easting, and elevation for each optical prism. Another survey was performed October 28, 2011 to determine the changes in northing, easting, and elevation between the two dates (about four months). Inspection of the data which are included in Appendix F indicates that in almost all cases the final values of the northing and easting fall within the range between the minimum and maximum of the corresponding initial values indicating that the measured displacements in the north and east directions are within the range of accuracy of the initial survey data and hence could not be accurately evaluated. This, in addition to the fact that the deduced out of plane displacements of the wall at several prisms were toward the inside of the wall which is not practically possible, leads to the conclusion that the wall face displacements are too small to be accurately evaluated with the survey equipment.

The changes in elevation data of the optical prisms indicate that the maximum measured vertical movement of all prisms for each wall is relatively small being equal to 0.22 inch for Wall 1 and 0.38 inch for Wall 3. The subsurface conditions encountered at the two walls generally consist of layers of predominantly coarse grained soils alternating with layers of predominantly fine grained soils. It is reasonable to assume that settlement occurring after wall construction would be due to possible compression with time of the fine grained soil layers.

FINITE ELEMENT ANALYSES

As already mentioned, finite element analyses were performed to evaluate the wall behavior. The computer software Plaxis (2008) was used to conduct the analyses which were performed in stages to model the actual construction sequence in terms of placement of soil lifts, geogrid layers and facing panels, construction of the stub abutment and application of the bridge loads. Only the maximum tension in the geogrids can be obtained from limit equilibrium analyses such as those performed using the program MSEW v.3 while tension distribution as well as wall deformation can be estimated using the finite element method. It is beyond the scope of this report to present the results of the finite element analyses. However, it is worth mentioning that the geogrid tensile loads based on both limit equilibrium and finite element methods and those deduced from measured strains are less than the allowable design strength demonstrating that the geogrid load levels are within allowable limits.

SUMMARY

1. Design of the MSE walls was performed according to the allowable stress design (ASD) method. There was some conservatism in design in that the calculated geogrid tension was less than the long-term design strength (LTDS) of the used geogrids divided by the global factor of safety of 1.5.
2. Geogrid tensions were determined using the quick load-extension tests (ASTM D6637) which are performed using a strain rate of 10% per minute. Hence, it can be postulated that the tension is overestimated since it does not consider the potential creep at the slow rate of loading during construction.
3. The geogrid tension deduced from the quick load-extension tests is less than the long-term design strength (LTDS) divided by the global factor of safety of 1.5, indicating that the geogrid load levels are currently within allowable limits. This is also the case based on the results of the finite element analyses.
4. The wall facing deformation is typical of MSE wall behavior based on comparison with published empirical data.
5. The overall behavior of the two instrumented walls does not indicate overstressing of the geogrid reinforcing elements or excessive facing deformation, which indicates stability of the walls during and after construction until the present time.
6. A survey of the optical prisms mounted on the facing of the two walls was performed after construction of the wall and four months later. The estimated displacements in the north and east directions were within the range of accuracy of the initial survey data and hence could not be evaluated. This, in addition to the fact that the deduced out of plane displacements of the wall at several prisms were toward the retained soil which is not practically possible, leads to the conclusion that the wall face displacements are too small to be accurately evaluated with the survey equipment. The maximum measured vertical movement of all prisms for each wall is relatively small being equal to 0.22 inch for Wall 1 and 0.38 inch for Wall 3. The settlement occurring after wall

construction may be attributed to compression with time of the fine grained soil layers.

REFERENCES

1. *AASHTO Standard Specifications for Highway Bridges, 17th Edition*, American Association of State Highway and Transportation Officials (2002).
2. ASTM Standard D6637-10, “Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method,” ASTM International, West Conshohocken, PA. (2010).
3. *AASHTO LRFD Bridge Design Specifications, 5th Edition*, American Association of State Highway and Transportation Officials (2010).
4. FHWA Publication No. FHWA-NHI-10-024., “Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes”, Federal Highway Administration, US Department of Transportation (2009).

APPENDIX A – TENSAR GEOGRID LOAD-EXTENSION CURVES

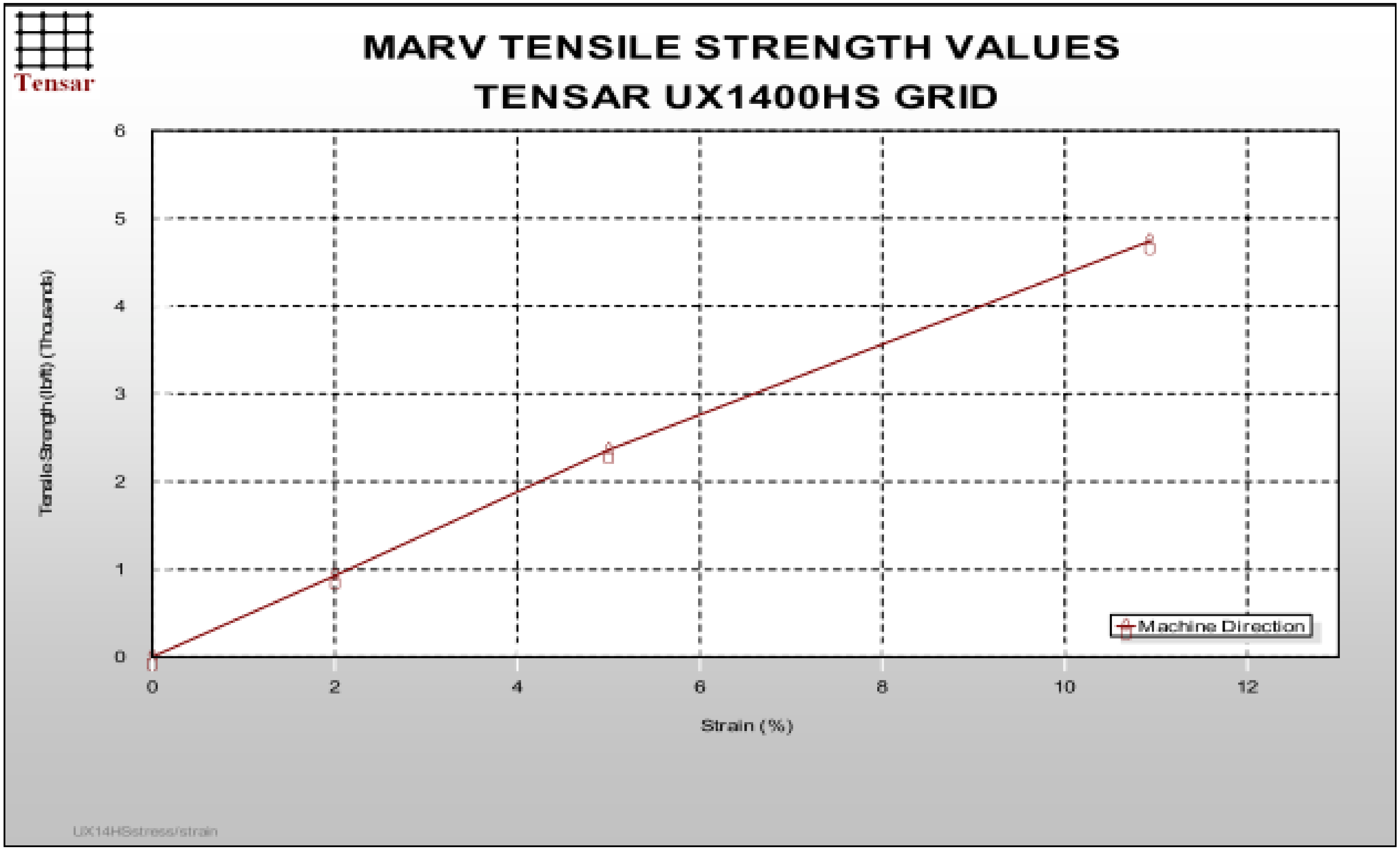


Figure 6. Marv Tensile Strength Values, Tensar UX1400HS Grid

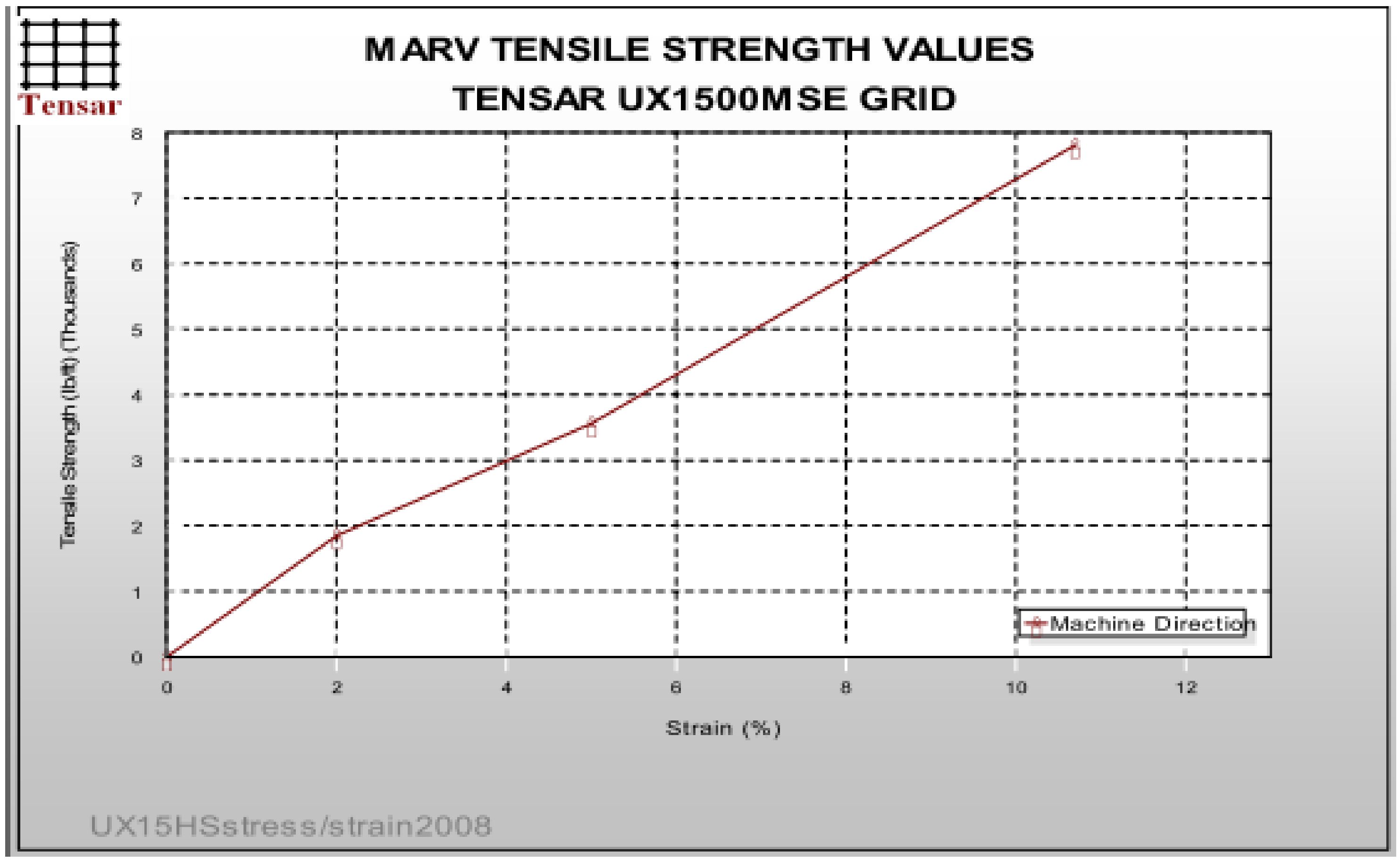


Figure 7. Marv Tensile Strength Values, Tensar UX1500M SE Grid

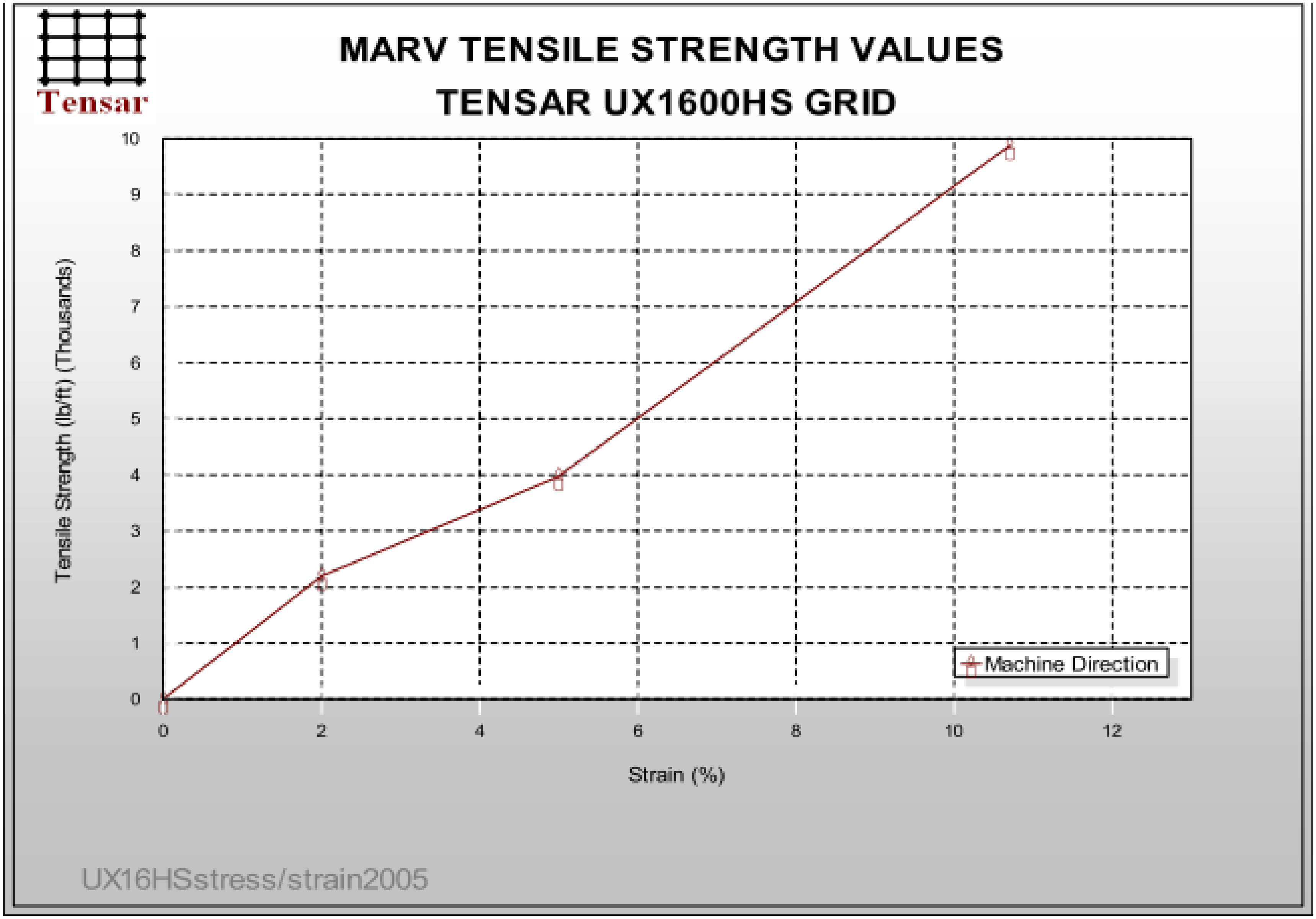


Figure 8. Marv Tensile Strength Values, Tensar UX1600HS Grid

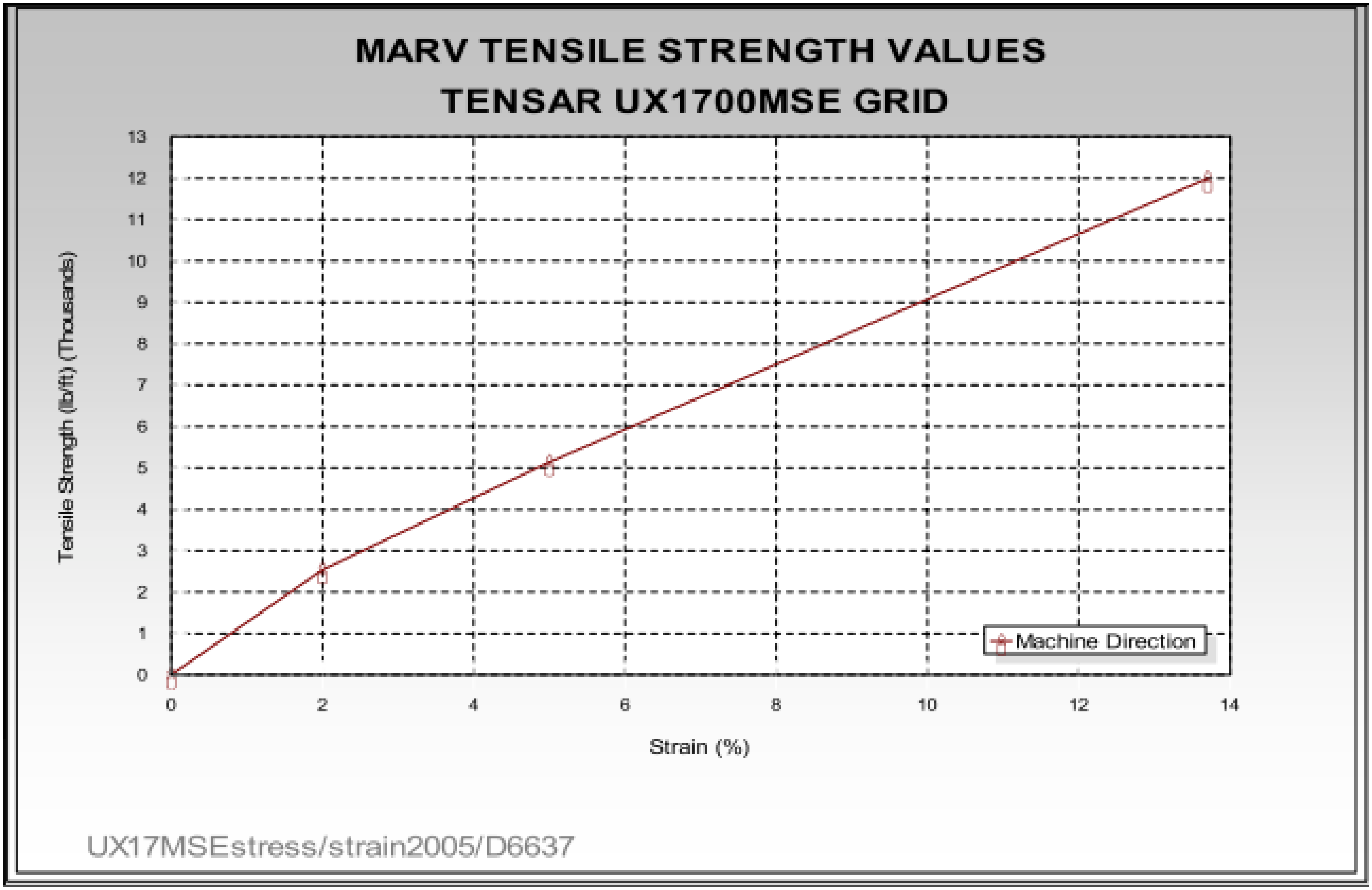


Figure 9. Marv Tensile Strength Values, Tensar UX1700MSE Grid

APPENDIX B – STRAIN GAGE, TILTMETER, AND OPTICAL PRISM SELECTED LOCATIONS

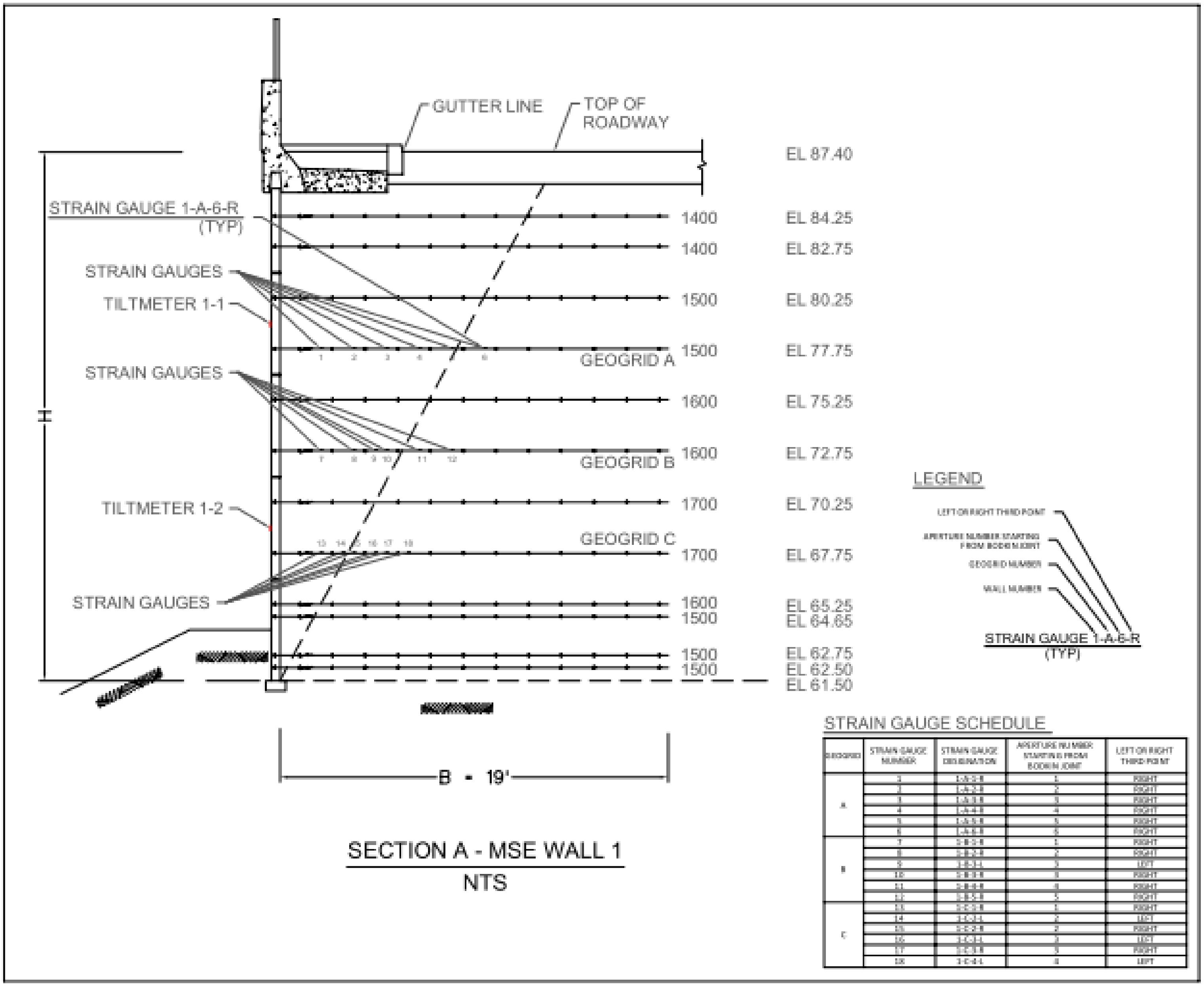


Figure 10. Section A – MSE Wall 1

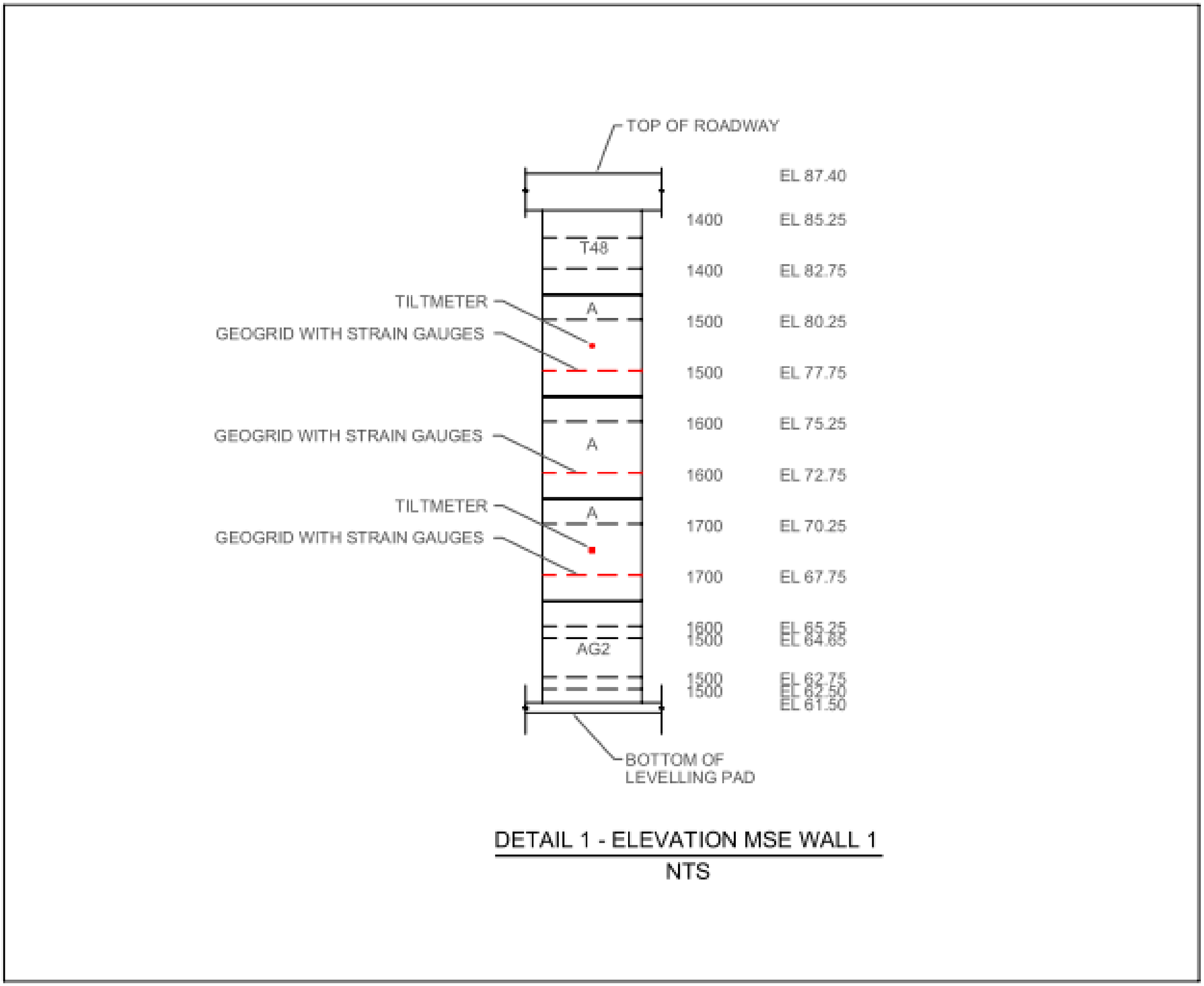


Figure 11. Detail 1 – Elevation MSE Wall 1

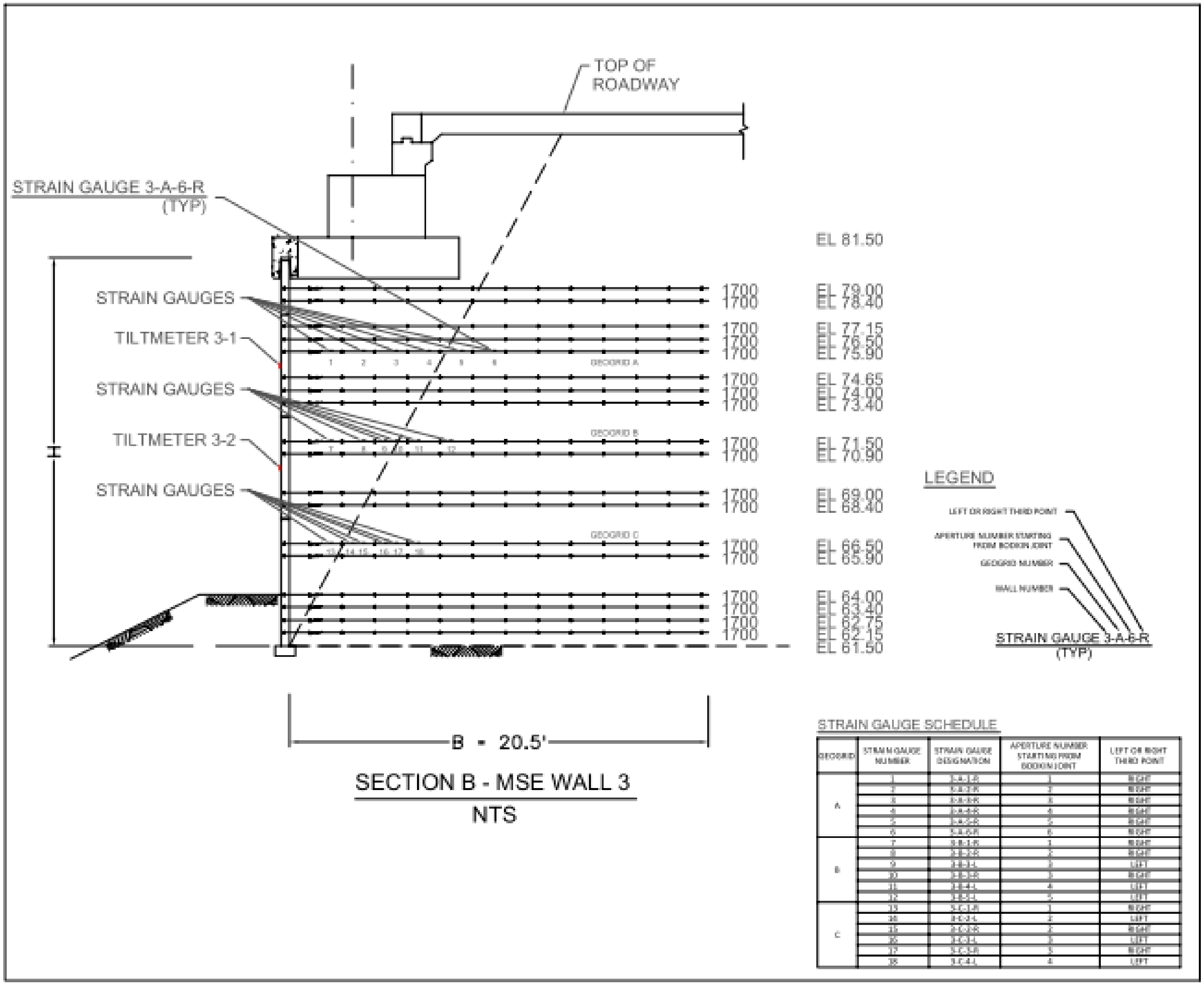


Figure 12. Section B – MSE Wall 3

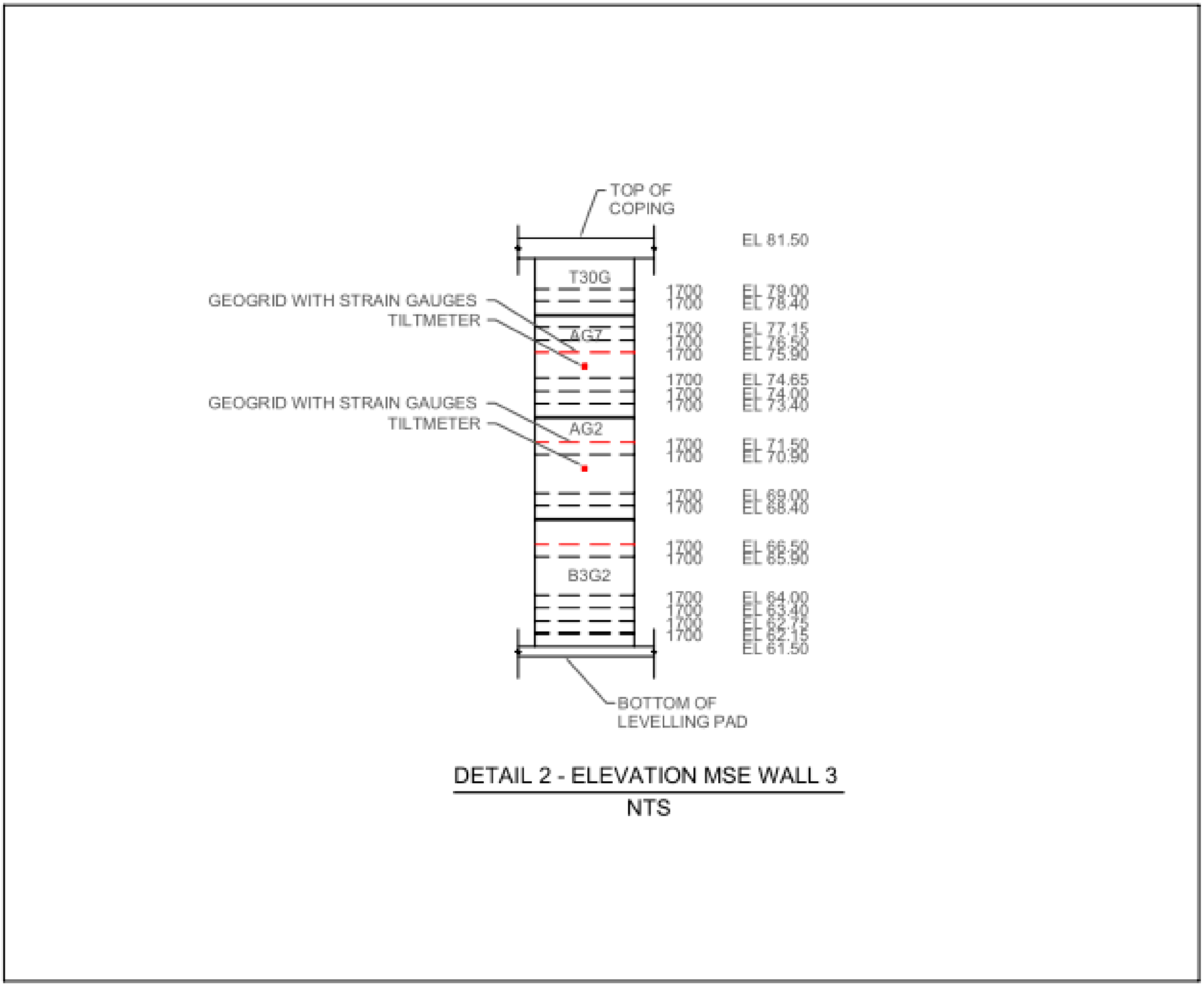


Figure 13. Detail 2 – Elevation MSE Wall 3

Figure 14. Optical Prism Locations at Wall 1

Figure 15. Optical Prism Locations at Wall 3

APPENDIX C – STRAIN GAGE INSTALLATION LOGS

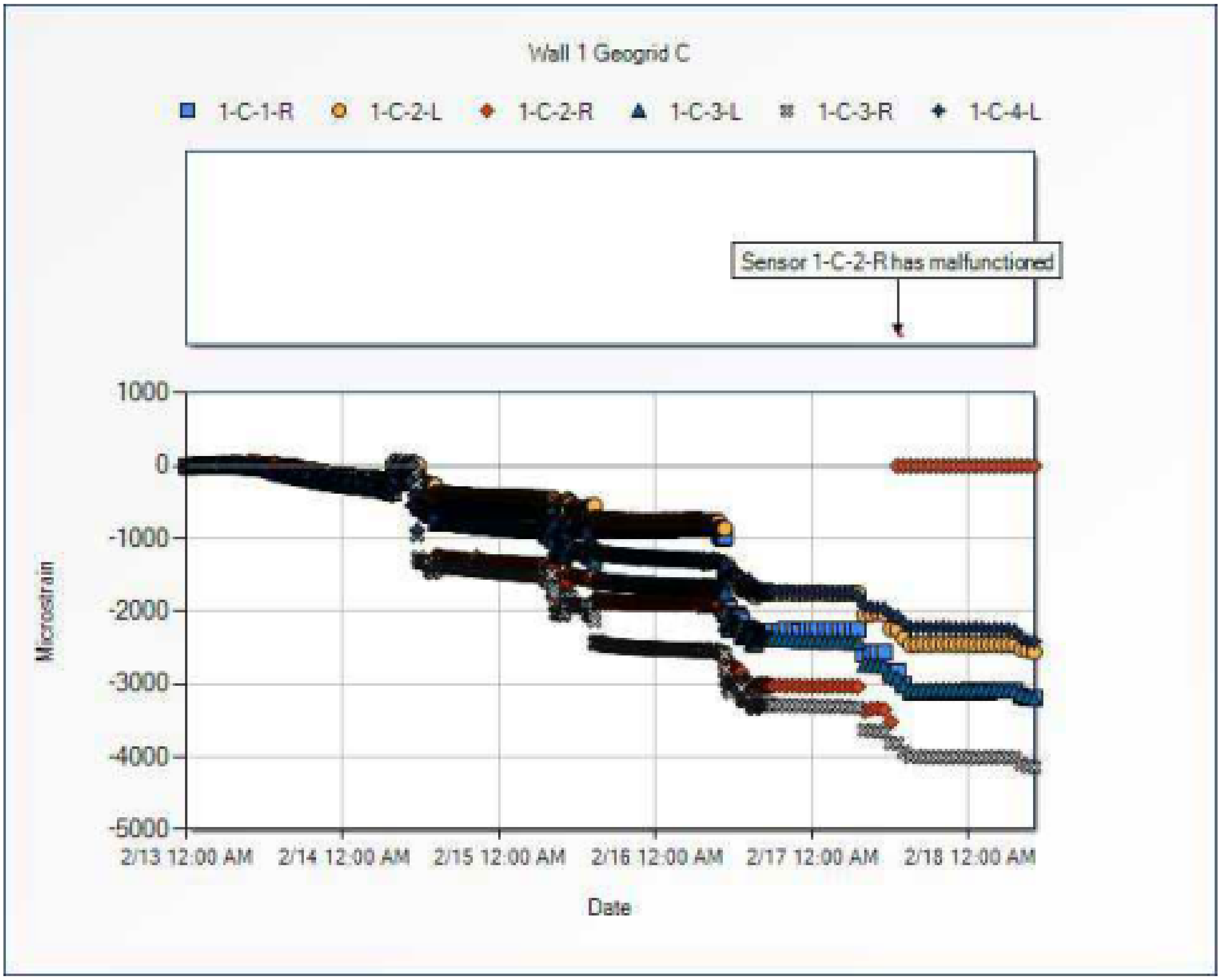


Figure 16. Microstrain over time for Wall 1 Geogrid C

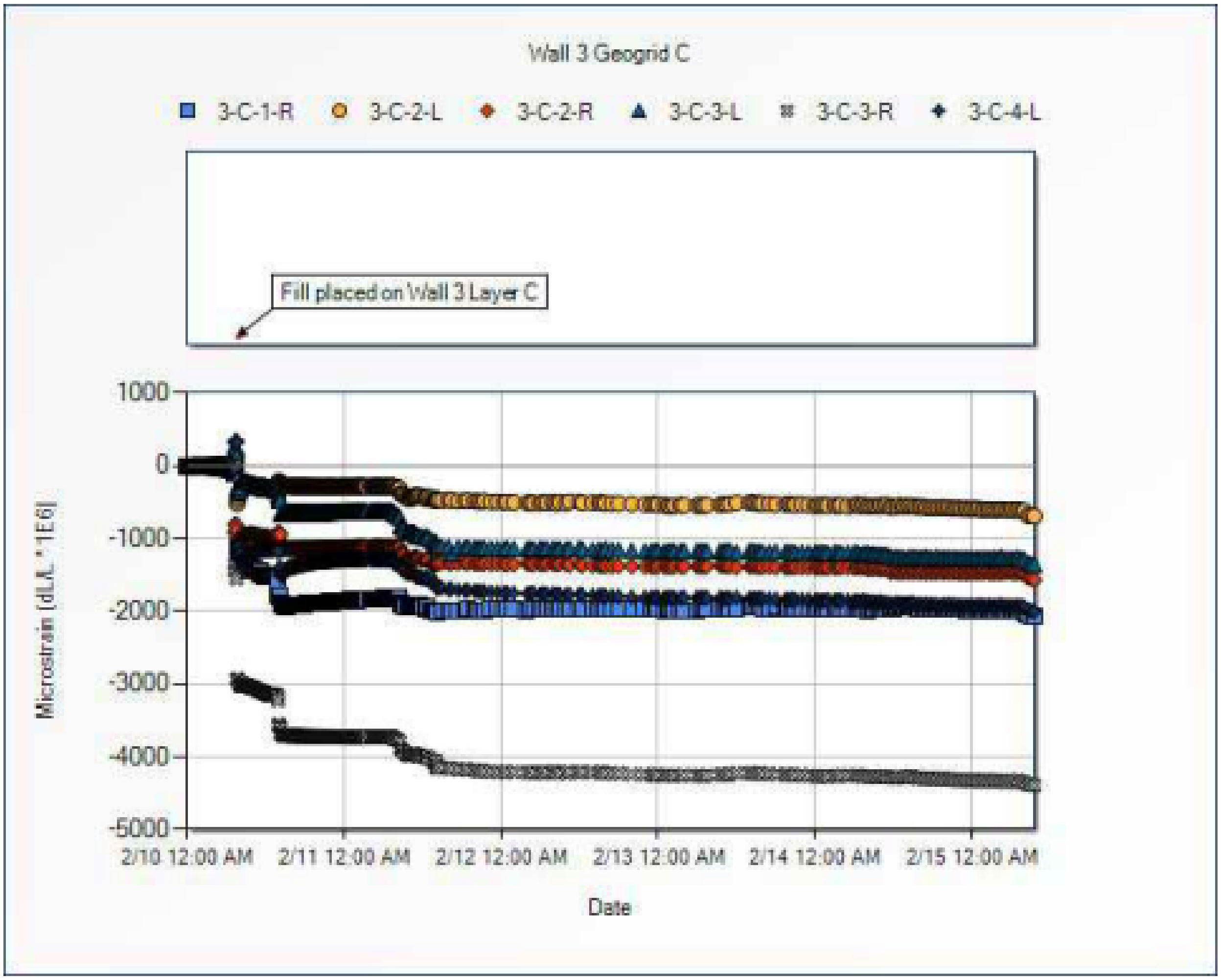


Figure 17. Microstrain over time for Wall 3 Geogrid C

Table 4 – Route 22 Liberty Avenue & Conrail Bridge Instrumentation

GEOGRID	STRAIN GAUGE NUMBER	STRAIN GAUGE DESIGNATION	RIB NUMBER STARTING FROM BODKIN JOINT	LEFT OR RIGHT THIRD POINT	CABLE DISTANCE TO WALL FACE	CABLE DISTANCE TO LOGGER BOX	CABLE DISTANCE TO BOTTOM OF WALL	TOTAL DISTANCE (FT)	ELEVATION (FT)	READING BEFORE SPLICING	READING AFTER SPLICING	GAUGE READING AFTER ATTACHED TO GEOGRID	PICTURE OF INSTALLATION
A (WALL 3)	1	3-A-1-R	1	RIGHT	3	25	16.5	44.5	75.90	120 OHM	124 OHM		
A (WALL 3)	2	3-A-2-R	2	RIGHT	4.5	25	16.5	46	75.90	120 OHM	124 OHM		
A (WALL 3)	3	3-A-3-R	3	RIGHT	6	25	16.5	47.5	75.90	120 OHM	124 OHM		
A (WALL 3)	4	3-A-4-R	4	RIGHT	7.5	25	16.5	49	75.90	120 OHM	124 OHM		
A (WALL 3)	5	3-A-5-R	5	RIGHT	9	25	16.5	50.5	75.90	120 OHM	124 OHM		
A (WALL 3)	6	3-A-6-R	6	RIGHT	10.5	25	16.5	52	75.90	120 OHM	124 OHM		
B (WALL 3)	7	3-B-1-R	1	RIGHT	3	25	11.5	39.5	71.50	120 OHM	124 OHM		
B (WALL 3)	8	3-B-2-R	2	RIGHT	4.5	25	11.5	41	71.50	120 OHM	124 OHM		
B (WALL 3)	9	3-B-3-L	3	LEFT	6	25	11.5	42.5	71.50	120 OHM	124 OHM		
B (WALL 3)	10	3-B-3-R	3	RIGHT	6	25	11.5	42.5	71.50	120 OHM	124 OHM		
B (WALL 3)	11	3-B-4-L	4	LEFT	7.5	25	11.5	44	71.50	120 OHM	124 OHM		
B (WALL 3)	12	3-B-5-L	5	LEFT	9	25	11.5	45.5	71.50	120 OHM	124 OHM		
C (WALL 3)	13	3-C-1-R	1	RIGHT	3	25	6.5	34.5	66.50	120 OHM	124 OHM		
C (WALL 3)	14	3-C-2-L	2	LEFT	4.5	25	6.5	36	66.50	120 OHM	124 OHM		
C (WALL 3)	15	3-C-2-R	2	RIGHT	4.5	25	6.5	36	66.50	120 OHM	124 OHM		
C (WALL 3)	16	3-C-3-L	3	LEFT	6	25	6.5	37.5	66.50	120 OHM	124 OHM		
C (WALL 3)	17	3-C-3-R	3	RIGHT	6	25	6.5	37.5	66.50	120 OHM	124 OHM		
C (WALL 3)	18	3-C-4-L	4	LEFT	7.5	25	6.5	39	66.50	120 OHM	124 OHM		
A (WALL 1)	1	1-A-1-R	1	RIGHT	3	40	16.5	59.5	77.75	120 OHM	124 OHM		
A (WALL 1)	2	1-A-2-R	2	RIGHT	4.5	40	16.5	61	77.75	120 OHM	124 OHM		
A (WALL 1)	3	1-A-3-R	3	RIGHT	6	40	16.5	62.5	77.75	120 OHM	124 OHM		
A (WALL 1)	4	1-A-4-R	4	RIGHT	7.5	40	16.5	64	77.75	120 OHM	124 OHM		
A (WALL 1)	5	1-A-5-R	5	RIGHT	9	40	16.5	65.5	77.75	120 OHM	124 OHM		
A (WALL 1)	6	1-A-6-R	6	RIGHT	10.5	40	16.5	67	77.75	120 OHM	124 OHM		
B (WALL 1)	7	1-B-1-R	1	RIGHT	3	40	11.5	54.5	72.75	120 OHM	124 OHM		
B (WALL 1)	8	1-B-2-R	2	RIGHT	4.5	40	11.5	56	72.75	120 OHM	124 OHM		
B (WALL 1)	9	1-B-3-L	3	LEFT	6	40	11.5	57.5	72.75	120 OHM	124 OHM		
B (WALL 1)	10	1-B-3-R	3	RIGHT	6	40	11.5	57.5	72.75	120 OHM	124 OHM		
B (WALL 1)	11	1-B-4-R	4	RIGHT	7.5	40	11.5	59	72.75	120 OHM	124 OHM		
B (WALL 1)	12	1-B-5-R	5	RIGHT	9	40	11.5	60.5	72.75	120 OHM	124 OHM		
C (WALL 1)	13	1-C-1-R	1	RIGHT	3	40	6.5	49.5	67.75	120 OHM	124 OHM		
C (WALL 1)	14	1-C-2-L	2	LEFT	4.5	40	6.5	51	67.75	120 OHM	124 OHM		
C (WALL 1)	15	1-C-2-R	2	RIGHT	4.5	40	6.5	51	67.75	120 OHM	124 OHM		
C (WALL 1)	16	1-C-3-L	3	LEFT	6	40	6.5	52.5	67.75	120 OHM	124 OHM		
C (WALL 1)	17	1-C-3-R	3	RIGHT	6	40	6.5	52.5	67.75	120 OHM	124 OHM		
C (WALL 1)	18	1-C-4-L	4	LEFT	7.5	40	6.5	54	67.75	120 OHM	124 OHM		

Table 5 – Installation Log for Wall 3, Layer A, Gage Readings

Geocomp CORPORATION

Installation Log

INSTALLATION LOG FOR WALL 3, LAYER A

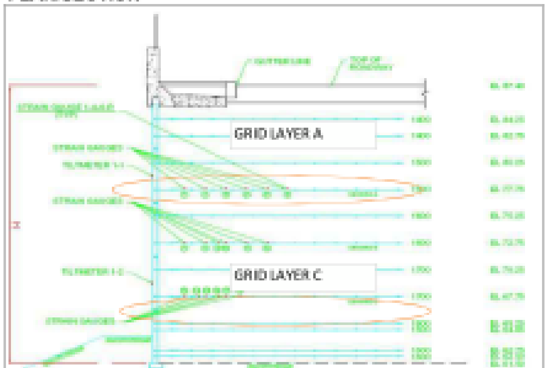
Client: PB AMERICAS
Project: RT22
Location: HILLSIDE, NJ

Instrument Type: 120 Ohm Strain Gages
Manufacturer:

GAGE ATTACHMENT DATE: 10/30/2010
FIELD INSTALLATION DATE:
FIRST FILL DATE:

				GAGE READINGS (OHMS)			
STRAIN GAUGE DESIGNATION	RIB # STARTING FROM BODKIN JOINT	LEFT OR RIGHT THIRD POINT	TOTAL CABLE DISTANCE (FT)	AFTER ATTACHMENT TO GEOGRID	AFTER TRANSPORT TO SITE	AFTER FIELD INSTALLATION	AFTER FIRST FILL PLACEMENT
3-A-1-R	1	RIGHT	44.5	122.0	122		
3-A-2-R	2	RIGHT	46	122.2	121		
3-A-3-R	3	RIGHT	47.5	122.3	122		
3-A-4-R	4	RIGHT	49	122.3	121		
3-A-5-R	5	RIGHT	50.5	122.5	122		
3-A-6-R	6	RIGHT	52	122.2	122		

PLAN/SECTION



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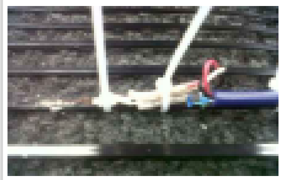
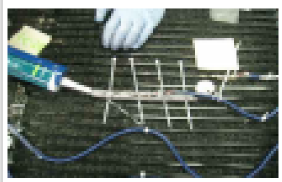
PHOTOS





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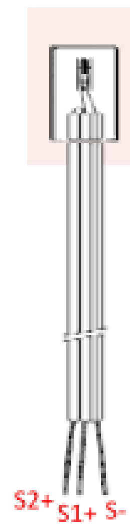


Table 6 – Installation Log for Wall 3, Layer B, Gage Readings

Geocomp CORPORATION

Installation Log

INSTALLATION LOG FOR WALL 3, LAYER B

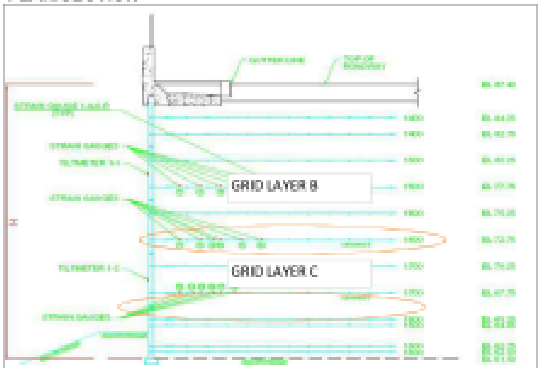
Client: PB AMERICAS
Project: RT22
Location: HILLSIDE, NJ

Instrument Type: 120 Ohm Strain Gages
Manufacturer:

GAGE ATTACHMENT DATE: 10/30/2010
FIELD INSTALLATION DATE:
FIRST FILL DATE:

STRAIN GAUGE DESIGNATION	RIB # STARTING FROM BODKIN JOINT	LEFT OR RIGHT THIRD POINT	TOTAL CABLE DISTANCE (FT)	GAGE READINGS (OHMS) AFTER ATTACHMENT TO GEOGRID	AFTER TRANSPORT TO SITE	AFTER FIELD INSTALLATION	AFTER FIRST FILL PLACEMENT
3-B-1-R	1	RIGHT	39.5	122.0	121	121	
3-B-2-R	2	RIGHT	41	122.0	121	121	
3-B-3-L	3	LEFT	42.5	122.3	121	121	
3-B-3-R	3	RIGHT	42.5	122.2	121	121	
3-B-4-L	4	LEFT	44	122.6	122	121	
3-B-5-L	5	LEFT	45.5	122.3	122	121	

PLAN/SECTION



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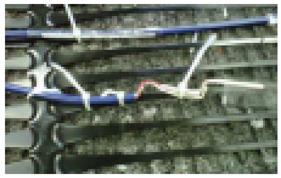
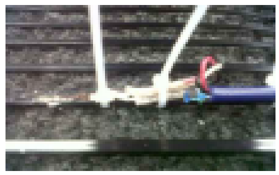
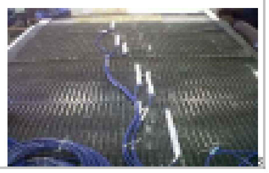
PHOTOS







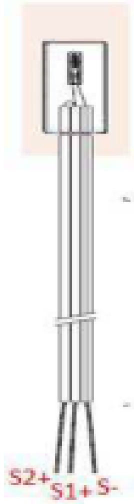


Table 7 – Installation Log for Wall 3, Layer C, Gage Readings

Geocomp CORPORATION

Installation Log
INSTALLATION LOG FOR WALL 3, LAYER C

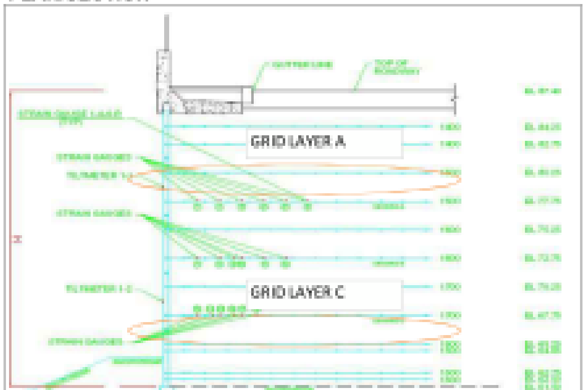
Client: PB AMERICAS
Project: RT22
Location: HILLSIDE, NJ

Instrument Type: 120 Ohm Strain Gages
Manufacturer:

GAGE ATTACHMENT DATE: 10/30/2010
FIELD INSTALLATION DATE:
FIRST FILL DATE:

				GAGE READINGS (OHMS)			
STRAIN GAUGE DESIGNATION	RIB # STARTING FROM BOOKIN JOINT	LEFT OR RIGHT THIRD POINT	TOTAL CABLE DISTANCE (FT)	AFTER ATTACHMENT TO GEOGRID	AFTER TRANSPORT TO SITE	AFTER FIELD INSTALLATION	AFTER FIRST FILL PLACEMENT
3-C-1-R	1	RIGHT	34.5	121.9	121	121	
3-C-2-L	2	LEFT	36	122.0	120	121	
3-C-2-R	2	RIGHT	36	122.3	120	121	
3-C-3-L	3	LEFT	37.5	122.4	121	122	
3-C-3-R	3	RIGHT	37.5	122.5	121	121	
3-C-4-L	4	LEFT	39	122.3	121	121	

PLAN/SECTION



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PHOTOS

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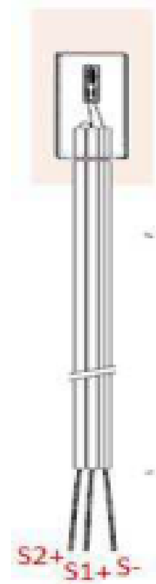


Table 8 – Installation Log for Wall 1, Layer A, Gage Readings

Installation Log

INSTALLATION LOG FOR WALL 1, LAYER A

Client: PB AMERICAS
Project: RT22
Location: HILLSIDE, NJ

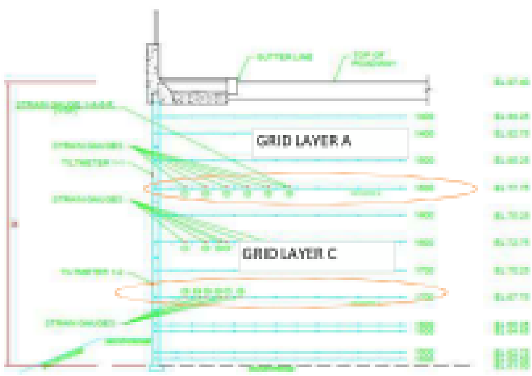
Instrument Type: 120 Ohm Strain Gages
Manufacturer:

GAGE ATTACHMENT DATE:
FIELD INSTALLATION DATE:
FIRST FILL DATE:

GAGE READINGS (OHMS)

STRAIN GAUGE DESIGNATION	RIB # STARTING FROM BODKIN JOINT	LEFT OR RIGHT THIRD POINT	TOTAL CABLE DISTANCE (FT)	AFTER ATTACHMENT TO GEOGRID	AFTER TRANSPORT TO SITE	AFTER FIELD INSTALLATION	AFTER FIRST FILL PLACEMENT
1-A-1-R	1	RIGHT	59.5	122.7	122		
1-A-2-R	2	RIGHT	61	123	122		
1-A-3-R	3	RIGHT	62.5	123.2	122		
1-A-4-R	4	RIGHT	64	122.8	122		
1-A-5-R	5	RIGHT	65.5	122.8	122		
1-A-6-R	6	RIGHT	67	123.1	122		

PLAN/SECTION



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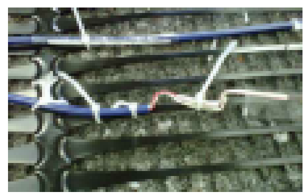
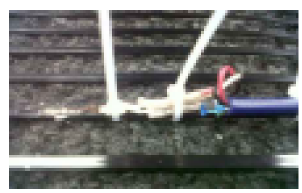
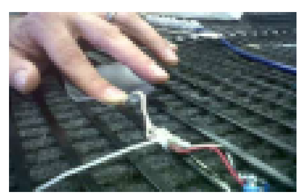
PHOTOS







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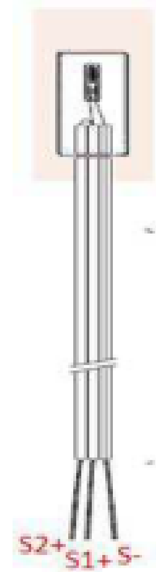


Table 9 – Installation Log for Wall 1, Layer B, Gage Readings

Installation Log
INSTALLATION LOG FOR WALL 1, LAYER B

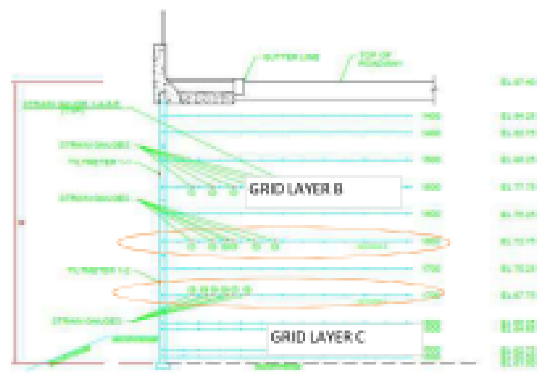
Client: PB AMERICAS
Project: RT22
Location: HILLSIDE, NJ

Instrument Type: 120 Ohm Strain Gages
Manufacturer:

GAGE ATTACHMENT DATE: 11/3/2010
FIELD INSTALLATION DATE:
FIRST FILL DATE:

				GAGE READINGS (OHMS)			
STRAIN GAUGE DESIGNATION	RIB # STARTING FROM BODKIN JOINT	LEFT OR RIGHT THIRD POINT	TOTAL CABLE DISTANCE (FT)	AFTER ATTACHMENT TO GEOGRID	AFTER TRANSPORT TO SITE	AFTER FIELD INSTALLATION	AFTER FIRST FILL PLACEMENT
1-B-1-R	1	RIGHT	54.5	122.3	121	121	
1-B-2-R	2	RIGHT	56	123.1	122	121	
1-B-3-L	3	LEFT	57.5	122.6	121	121	
1-B-3-R	3	RIGHT	57.5	122.2	122	121	
1-B-4-R	4	RIGHT	59	122.3	121	121	
1-B-5-R	5	RIGHT	60.5	122.9	122	121	

PLAN/SECTION



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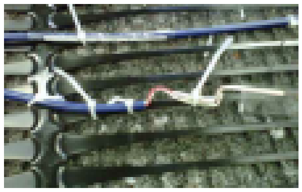

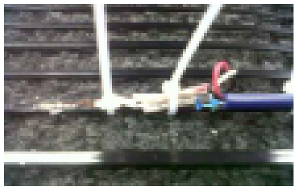

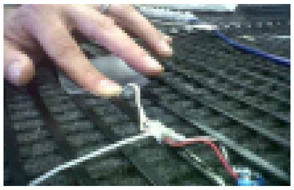

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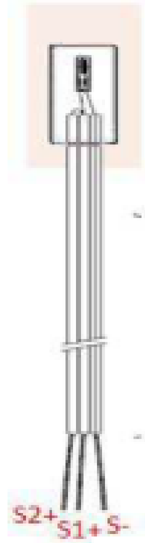


Table 10 – Installation Log for Wall 1, Layer C, Gage Readings

Geocomp
CORPORATION

Installation Log
INSTALLATION LOG FOR WALL 1, LAYER C

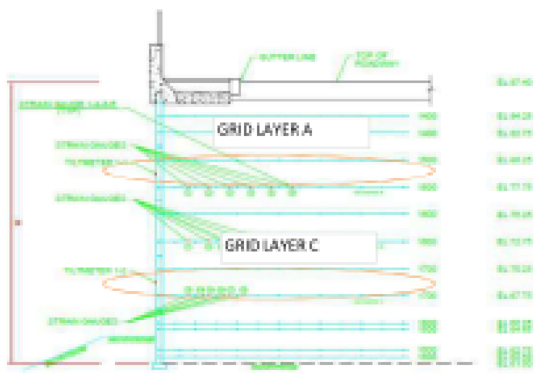
Client: PB AMERICAS
Project: RT22
Location: HILLSIDE, NJ

Instrument Type: 120 Ohm Strain Gages
Manufacturer:

GAGE ATTACHMENT DATE: 11/2/2010
FIELD INSTALLATION DATE:
FIRST FILL DATE:

STRAIN GAUGE DESIGNATION	RIB # STARTING FROM BODKIN JOINT	LEFT OR RIGHT THIRD POINT	TOTAL CABLE DISTANCE (FT)	GAGE READINGS (OHMS) AFTER ATTACHMENT TO GEOGRID	AFTER TRANSPORT TO SITE	AFTER FIELD INSTALLATION	AFTER FIRST FILL PLACEMENT
1-C-1-R	1	RIGHT	49.5	122.4	122		
1-C-2-L	2	LEFT	51	122.2	121		
1-C-2-R	2	RIGHT	51	122.6	121		
1-C-3-L	3	LEFT	52.5	122.7	122		
1-C-3-R	3	RIGHT	52.5	122.4	121		
1-C-4-L	4	LEFT	54	122.3	122		

PLAN/SECTION



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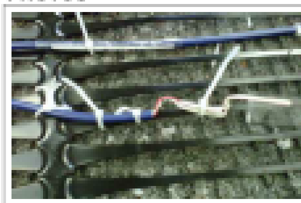
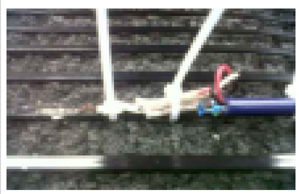
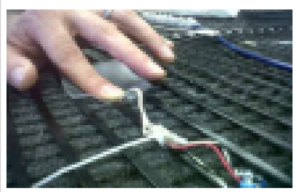
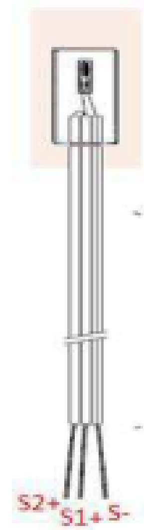
PHOTOS









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APPENDIX D – TILTMETER INSTALLATION LOGS

INSTALLATION LOG FOR TILTMETERS 1-1 AND 1-2

Client: PB AMERICAS
Project: RT22
Location: HILLSIDE, NJ

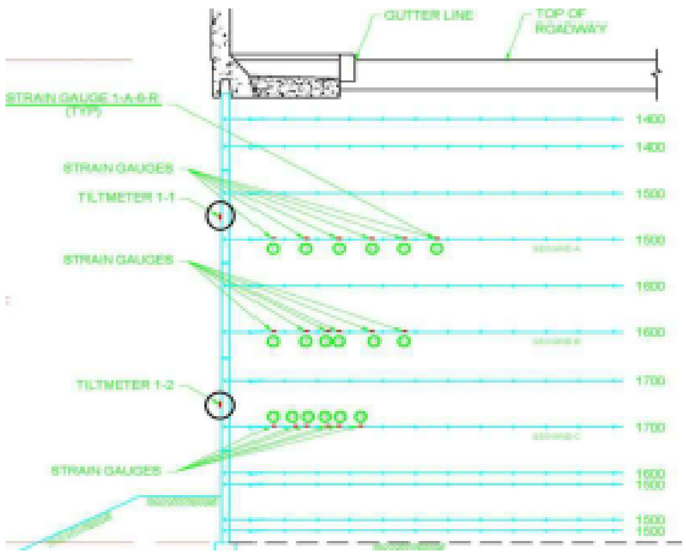
TILTMETER INSTALLATION DATE: 3/4/2011
TILTMETER INITIAL WIRING DATE 3/4/2011
TILTMETER CONFIGURATION FINALIZED DATE: 3/10/2011

Instrument Type: MEMS Tiltmeter Model 6160
Manufacturer: Geokon

TABLE 1

TILTMETER LOCATION	SERIAL #	INITIAL TEMPERATURE READING (OHMS)
1-1	1026276	7003
1-2	1026275	7100

TILTMETER LOCATION PLAN: WALL 1



WALL 1 TILTMETER PLOT

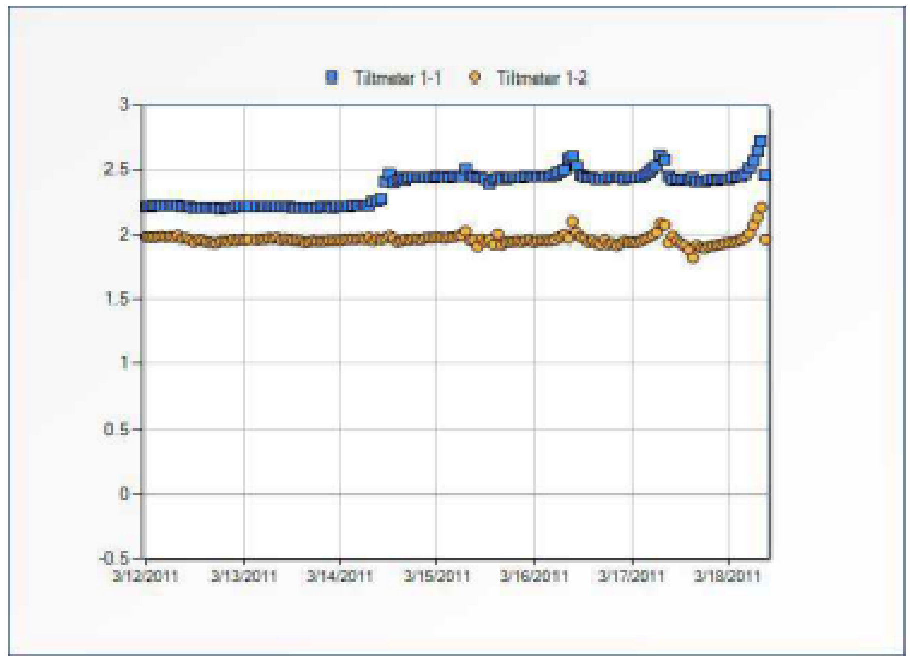


Figure 18. Installation Log for Tiltmeter 1-1 and 1-2

Geocomp Corporation

INSTALLATION LOG FOR TILTMETERS 3-1 AND 3-2

Client: PB AMERICAS
Project: RT22
Location: HILLSIDE, NJ

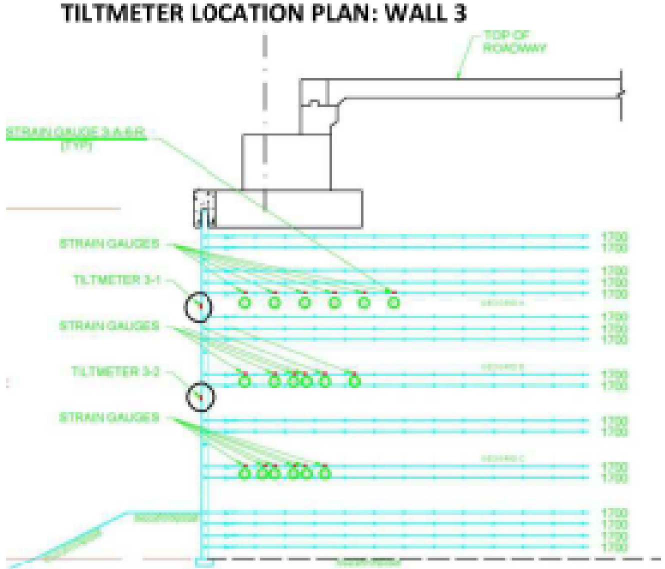
TILTMETER INSTALLATION DATE: 3/4/2011
TILTMETER INITIAL WIRING DATE 3/4/2011
TILTMETER CONFIGURATION FINALIZED DATE: 3/10/2011

Instrument Type: MEMS Tiltmeter Model 6160
Manufacturer: Geokon

TABLE 1

TILTMETER LOCATION	SERIAL #	INITIAL TEMPERATURE READING (OHMS)
3-1	1026278	6950
3-2	1026277	6760

TILTMETER LOCATION PLAN: WALL 3



WALL 3 TILTMETER PLOT

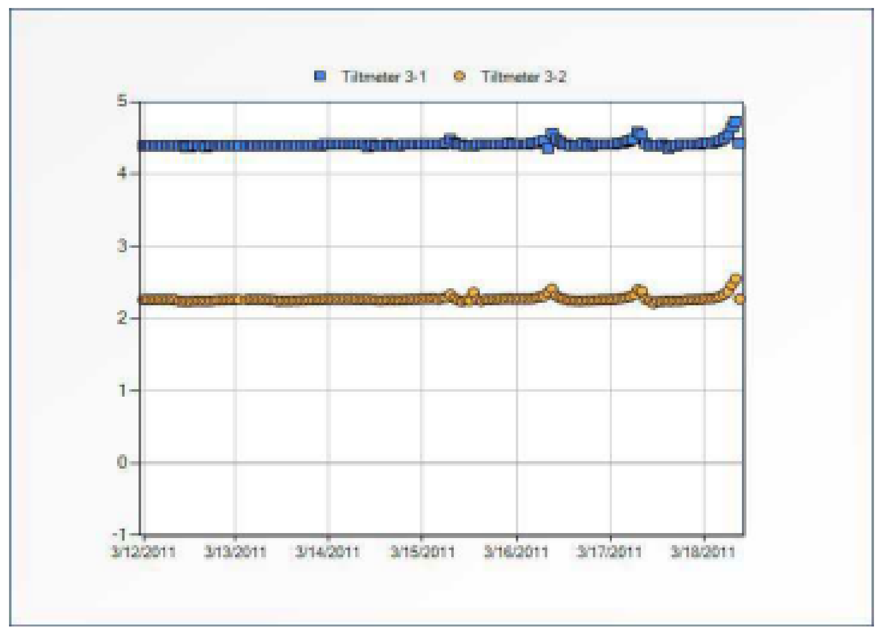


Figure 19. Installation Log for Tiltmeter 1-1 and 1-2

APPENDIX E – CONSTRUCTION PHOTOS

Figure 20. Bodkin Joint

Figure 21. Instrumented Geogrid with Strain Gages

Figure 22. Place Select Fill on Top of Geogrid

Figure 23. Wall 1 and Wall 3 at End of Construction

APPENDIX F – INSTRUMENTATION MONITORING DATA SUBMITTED BY GEOCOMP

Geocomp
CONSULTING, INC.
Technologies to manage risk for infrastructure

Boston
Atlanta
New York
San Francisco
www.geocomp.com

November 4, 2011

Mr. Andrew Foden
PB Americas, Inc.
506 Carnegie Center Blvd
Princeton, NJ 08540

Project No: 52091A
Project: Long-term Bridge Performance Monitoring
Route 22, Liberty Ave and Conrail Bridge
Instrumentation Installation and Monitoring Services

Andrew;

Geocomp performed manual surveys on June 30, 2011 and October 28, 2011 on eight survey targets to supplement the automated monitoring of strain gages on the geogrid and tilt meters on the abutment walls of the Route 22, Liberty Ave and Conrail Bridge project.

Attached to this letter the following has been provided:

- Summary report containing charts of all strain gage and tilt meter data from installation to present
- Pictures illustrating the installed locations on both walls of the survey prisms utilized in the manual surveying
- Tables containing the data for each point from the two manual surveys on June 30, 2011 and October 28, 2011
- Summary tables containing measured displacements of all survey points from June 30, 2011 to October 28, 2011 manual surveys

Geocomp has provided all pertinent information believed to be necessary for PB America's evaluation of the performance of the constructed bridge abutment. Please don't hesitate to request any further information that will aid PB America with this evaluation.

Best Regards,

Dan Scott
Staff Engineer
Geocomp Consulting, Inc.

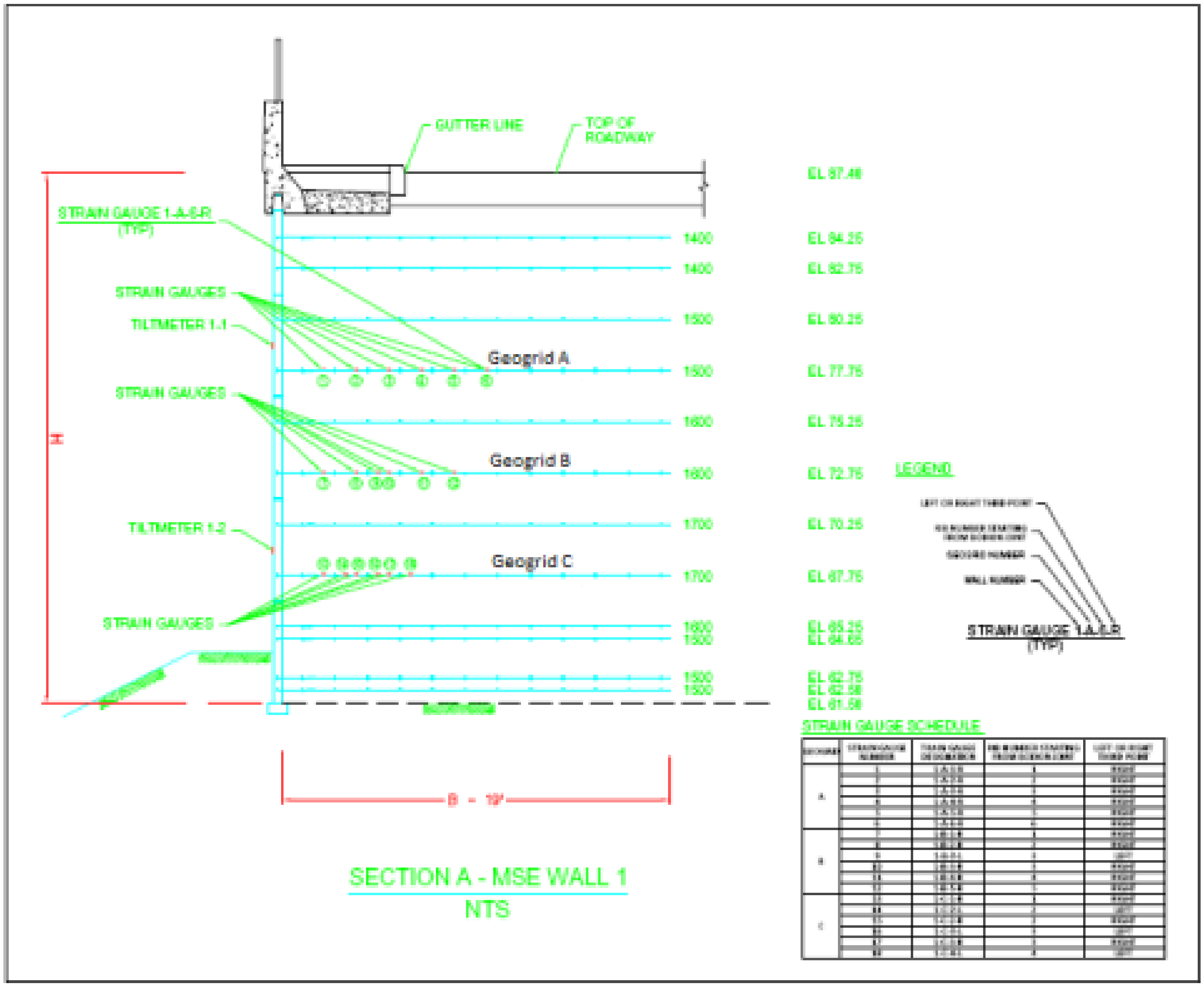


Figure 24. Profile View of Wall 1

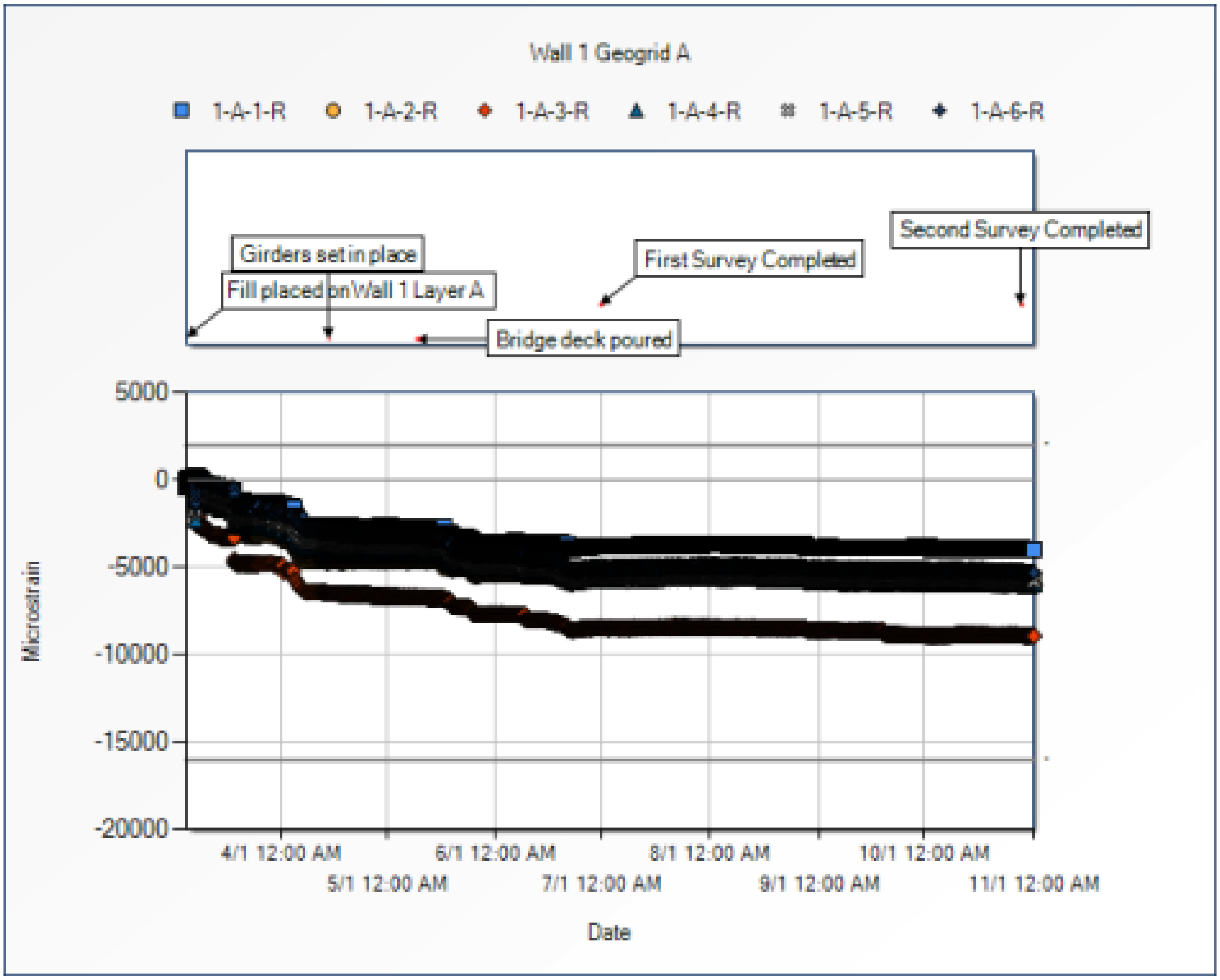


Figure 25. Microstrain over time for Wall 1 Geogrid A

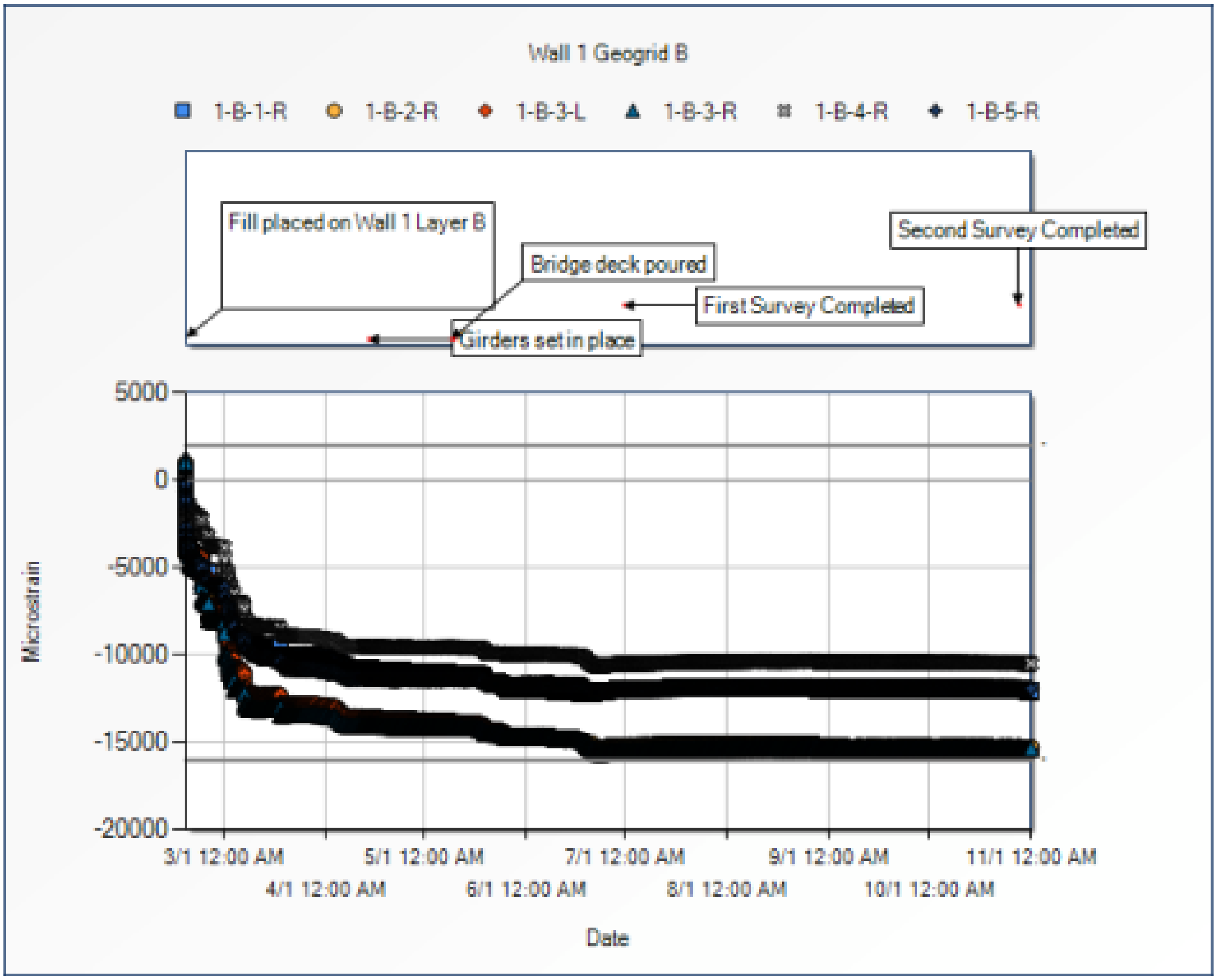


Figure 26. Microstrain over time for Wall 1 Geogrid B

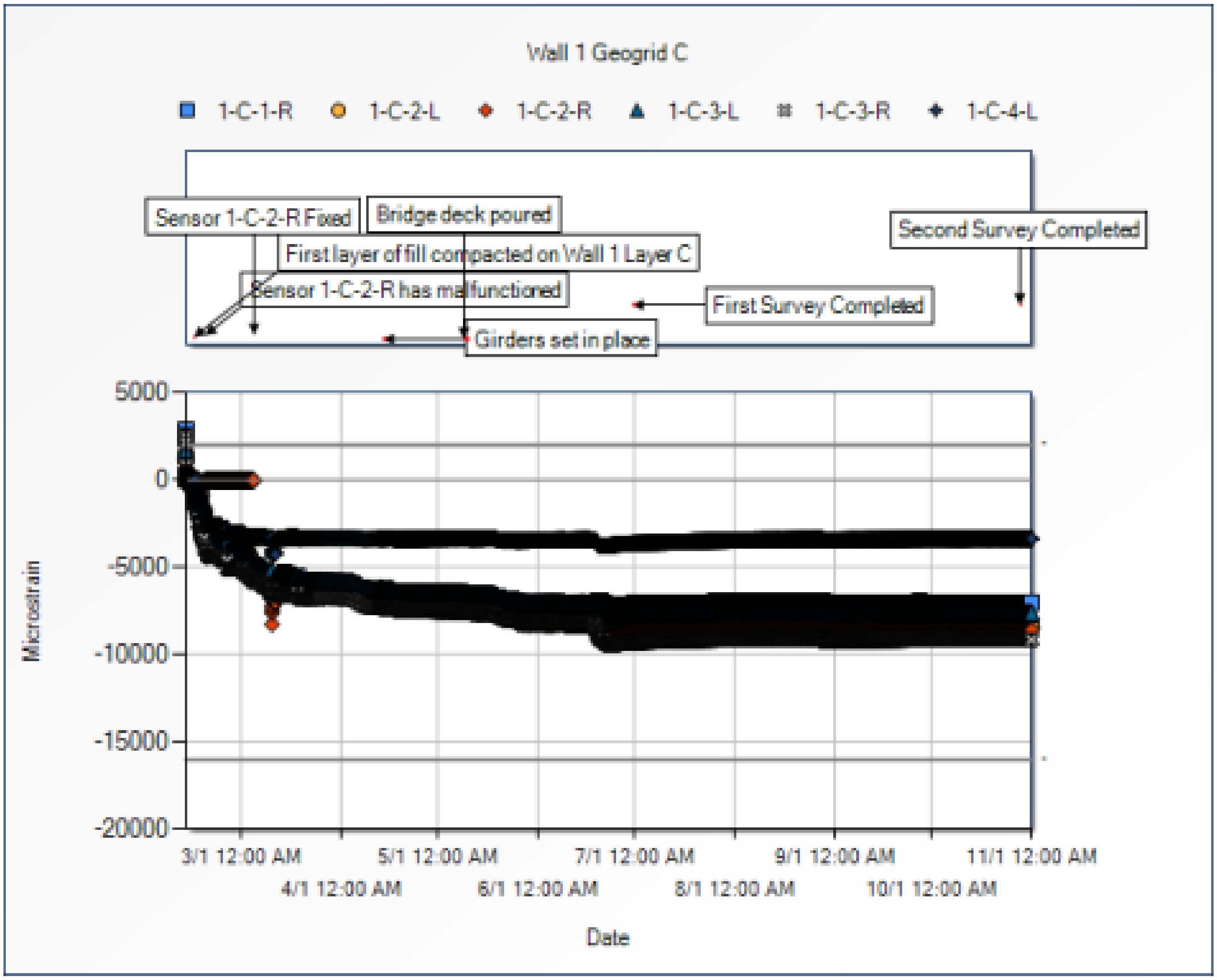


Figure 27. Microstrain over time for Wall 1Geogrid C

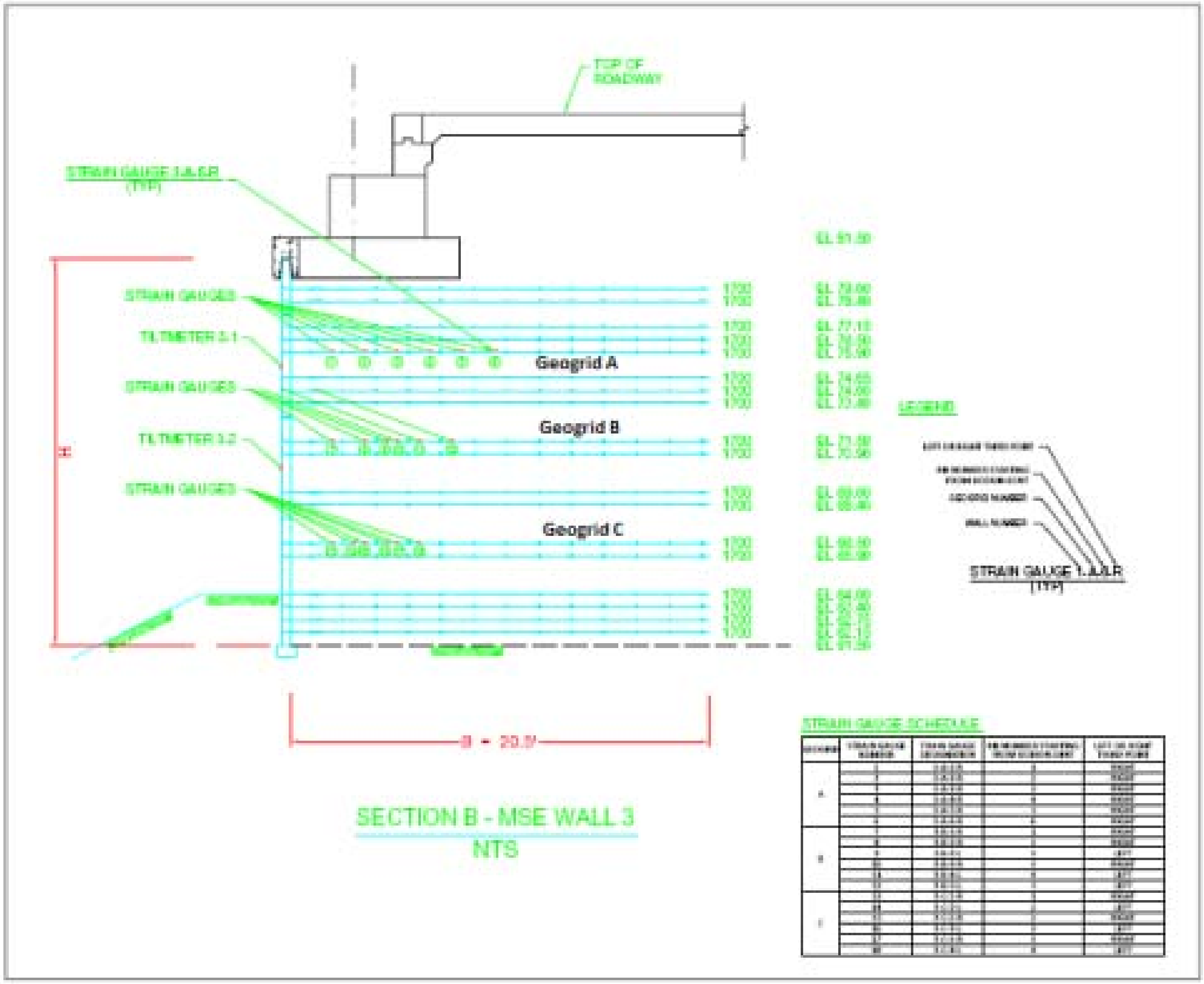


Figure 28. Profile view of Wall 3

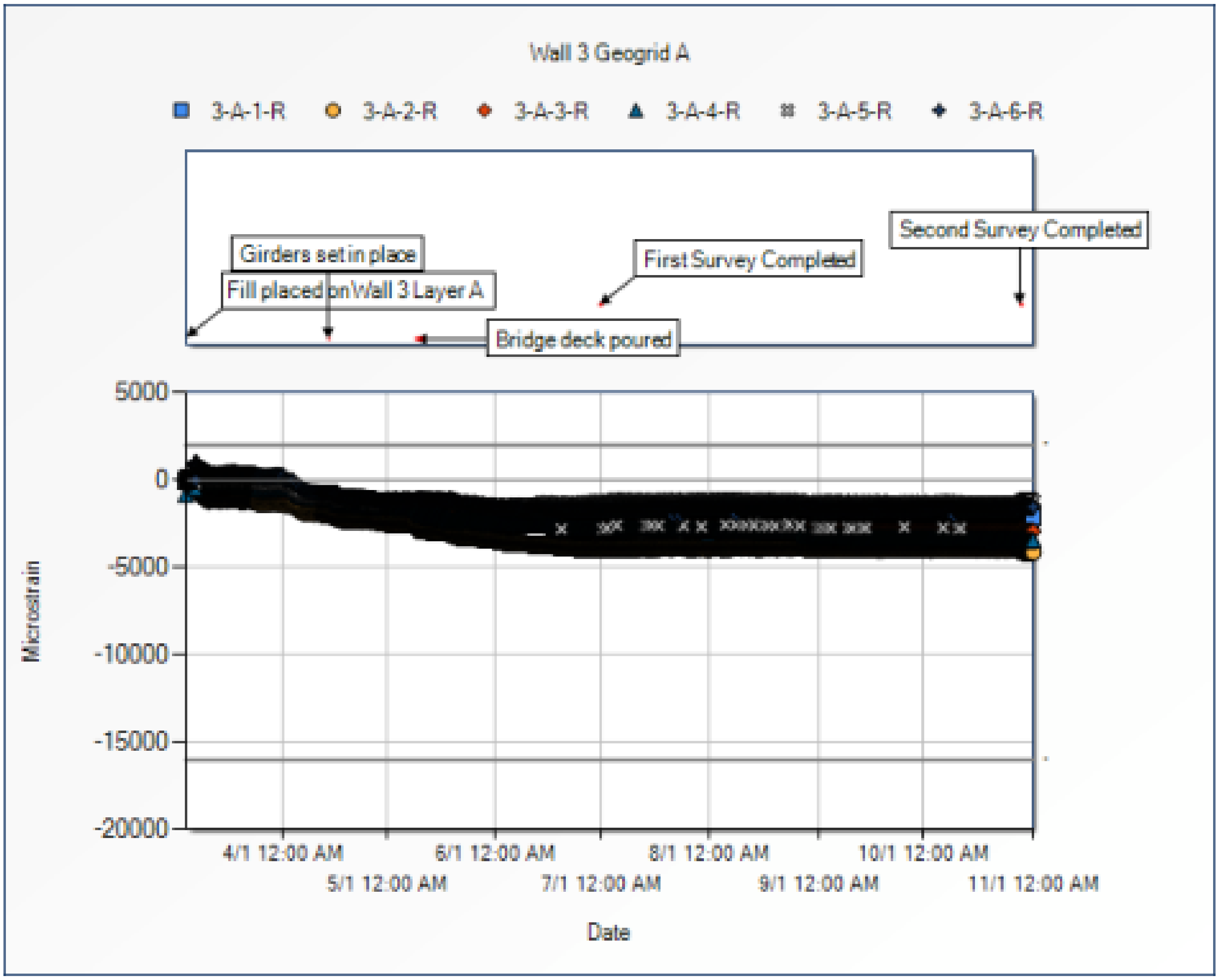


Figure 29. Microstrain over time for Wall 3 Geogrid A

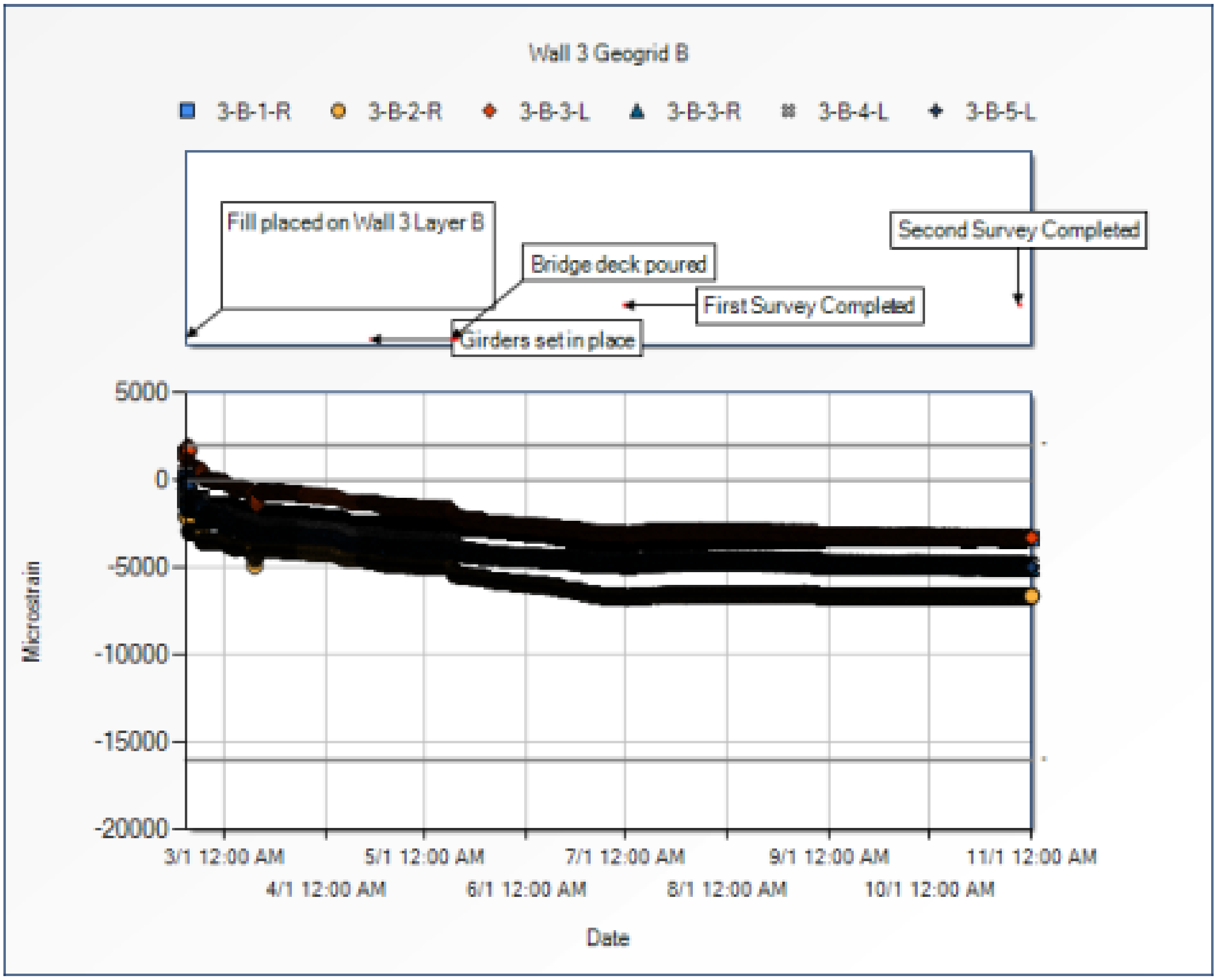


Figure 30. Microstrain over time for Wall 3 Geogrid B

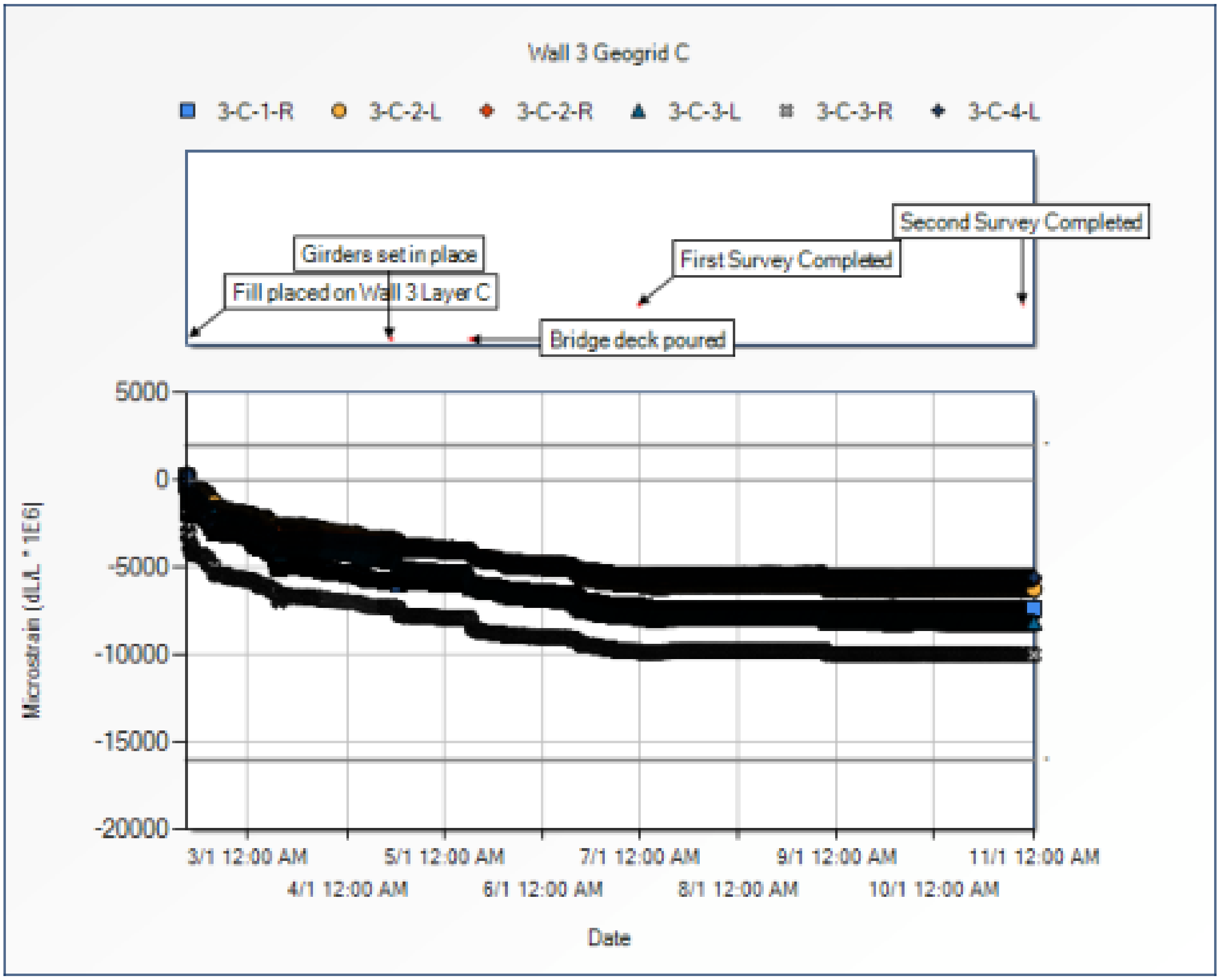


Figure 31. Microstrain over time for Wall 3 Geogrid B

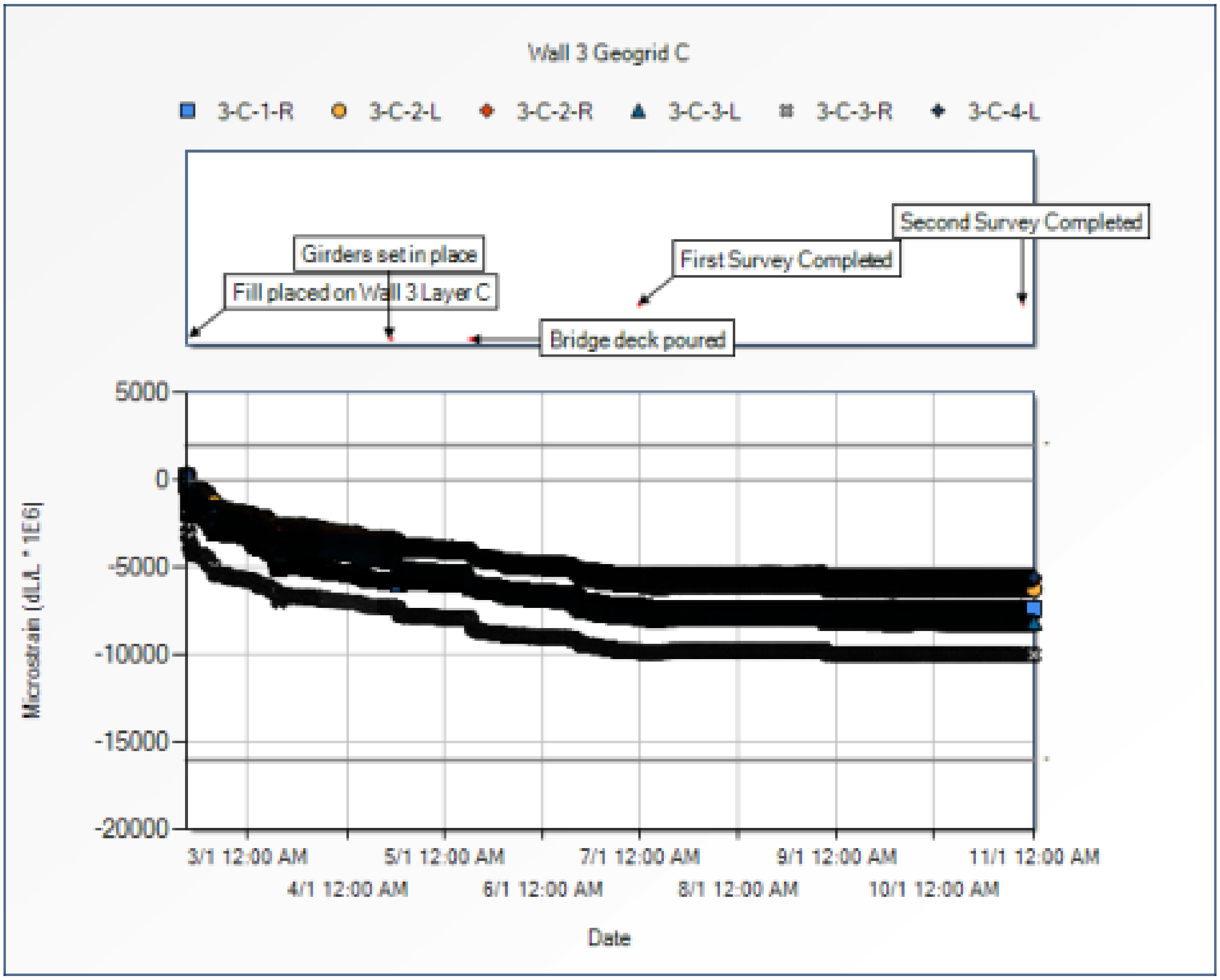


Figure 32. Microstrain over time for Wall 3 Geogrid C

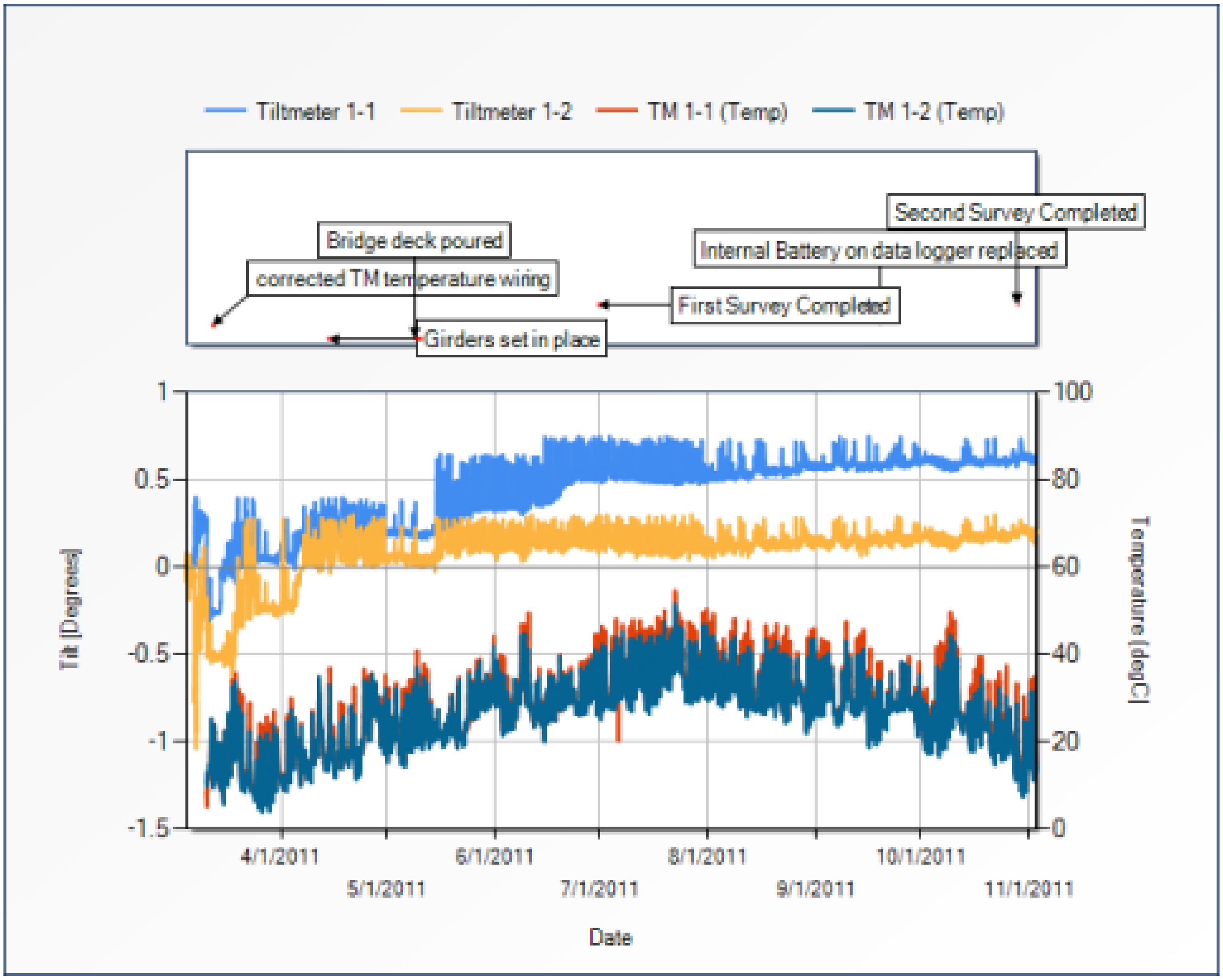


Figure 33. Tilt over time for Wall 1

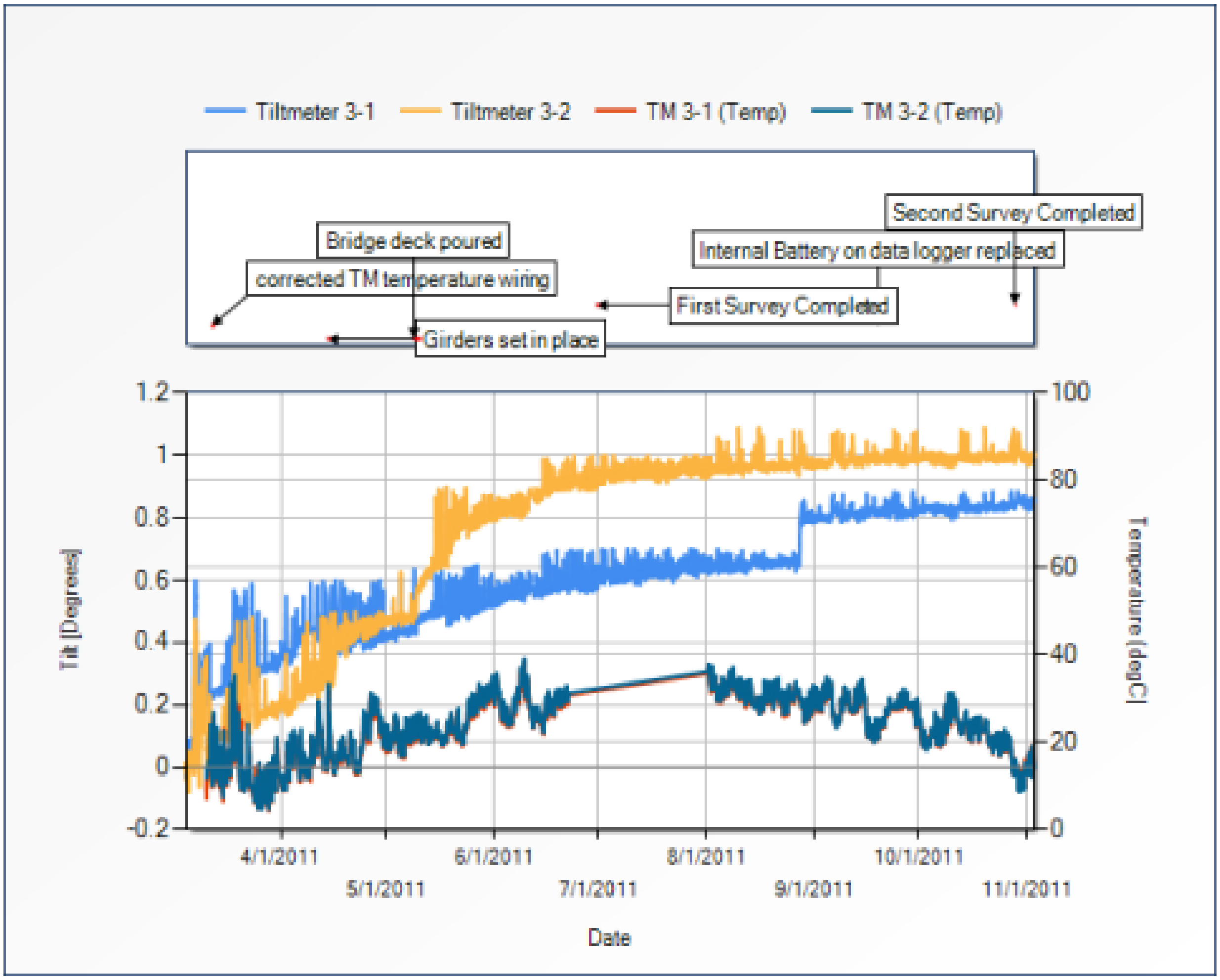


Figure 34. Tilt over time for Wall 3

Figure 35. Wall 1 Survey Point Locations

Figure 36. Wall 3 Survey Point Locations

Table 11 – Data from manual survey performed June 30, 2011 and October 28, 2011

Manual Survey Data for : Rt-22 Liberty Ave & Conrail

1st Survey performed: 06/30/2011, 8:00 AM
2nd Survey performed: 10/28/2011, 8:30 AM
Survey Performed by: Krunal Patel & Ray Patel
1st Survey Weather: 82°F, Sunny
2nd Survey Weather: 29°F, Sunny

NOTE: ALL READING ARE IN FEET

Reference Prisms

Ref-1 (On Popeyes)

Sets		Readings of 1st Manual Survey (06/30/11)			Readings of 2nd Manual Survey (10/28/11)			
		Face I	Face II	Avg	Face I	Face II	Avg	
Set #1	Northing	298.434	298.434	298.4340	298.43	298.431	298.4305	
	Easting	100.027	100.033	100.0300	100.035	100.033	100.0340	
	Height	12.804	12.804	12.8040	12.801	12.799	12.8000	
Set #2	Northing	298.435	298.435	298.4350	298.431	298.429	298.4300	
	Easting	100.025	100.028	100.0265	100.035	100.034	100.0345	
	Height	12.804	12.8	12.8020	12.802	12.799	12.8005	
Set #3	Northing	298.436	298.434	298.4350	298.429	298.43	298.4295	
	Easting	100.05	100.054		100.035	100.034	100.0345	
	Height	12.803	12.804	12.8035	12.801	12.8	12.8005	
Set #4	Northing	298.434	298.434	298.4340	298.43	298.43	298.4300	
	Easting	100.013	100.018	100.0155	100.035	100.034	100.0345	
	Height	12.802	12.802	12.8020	12.801	12.799	12.8000	
Set #5	Northing	298.434	298.434	298.4340	298.429	298.429	298.4290	
	Easting	100.015	100.018	100.0165	100.034	100.034	100.0340	
	Height	12.801	12.802	12.8015	12.802	12.799	12.8005	

Ref-2 (On existing Rt-22 overpass)

Sets		Readings of 1st Manual Survey (06/30/11)			Readings of 2nd Manual Survey (10/28/11)			
		Face I	Face II	Avg	Face I	Face II	Avg	
Set #1	Northing	91.286	91.214	91.2500	91.269	91.273	91.2710	
	Easting	226.263	226.262	226.2625	226.258	226.262	226.2600	
	Height	20.714	20.714	20.7140	20.718	20.713	20.7155	
Set #2	Northing	91.288	91.285	91.2865	91.269	91.274	91.2715	
	Easting	226.267	226.263	226.2650	226.259	226.263	226.2610	
	Height	20.714	20.711	20.7125	20.718	20.714	20.7160	
Set #3	Northing	91.254	91.249	91.2515	91.268	91.274	91.2710	
	Easting	226.236	226.23		226.257	226.263	226.2600	
	Height	20.713	20.714	20.7135	20.717	20.714	20.7155	
Set #4	Northing	91.302	91.3	91.3010	91.269	91.274	91.2715	
	Easting	226.278	226.274	226.2760	226.258	226.262	226.2600	
	Height	20.713	20.713	20.7130	20.717	20.714	20.7155	
Set #5	Northing	91.303	91.298	91.3005	91.268	91.273	91.2705	
	Easting	226.278	226.274	226.2760	226.258	226.263	226.2605	
	Height	20.715	20.712	20.7135	20.717	20.713	20.7150	

Ref-3 (On column, under Rt-22 overpass)

Sets		Readings of 1st Manual Survey (06/30/11)			Readings of 2nd Manual Survey (10/28/11)			
		Face I	Face II	Avg	Face I	Face II	Avg	
Set #1	Northing	69.171	69.173	69.1720	69.16	69.162	69.1610	
	Easting	164.922	164.92	164.9210	164.92	164.923	164.9215	
	Height	12.477	12.477	12.4770	12.477	12.474	12.4755	
Set #2	Northing	69.173	69.172	69.1725	69.16	69.161	69.1605	
	Easting	164.925	164.922	164.9235	164.918	164.924	164.921	
	Height	12.476	12.475	12.4755	12.477	12.474	12.4755	
Set #3	Northing	69.155	69.153	69.1540	69.161	69.163	69.1620	
	Easting	164.888	164.883		164.919	164.923	164.921	
	Height	12.476	12.474	12.4750	12.477	12.474	12.4755	
Set #4	Northing	69.181	69.179	69.1800	69.16	69.162	69.1610	
	Easting	164.939	164.935	164.9370	164.92	164.924	164.9220	
	Height	12.475	12.472	12.4735	12.478	12.474	12.476	
Set #5	Northing	69.18	69.178	69.1790	69.161	69.162	69.1615	
	Easting	164.938	164.933	164.9355	164.919	164.923	164.921	
	Height	12.475	12.473	12.4740	12.477	12.474	12.4755	

Survey Prisms on Wall #1

Survey Prism 1-1

Sets		Readings of 1st Manual Survey (06/30/11)			Readings of 2nd Manual Survey (10/28/11)			
		Face I	Face II	Avg	Face I	Face II	Avg	
Set #1	Northing	196.78	196.773	196.7765	196.781	196.785	196.783	
	Easting	196.028	196.029	196.0285	196.028	196.029	196.0285	
	Height	19.141	19.137	19.1390	19.121	19.119	19.1200	
Set #2	Northing	196.783	196.778	196.7805	196.782	196.785	196.7835	
	Easting	196.029	196.028	196.0285	196.029	196.029	196.029	
	Height	19.139	19.139	19.1390	19.122	19.119	19.1205	
Set #3	Northing	196.788	196.789	196.7885	196.783	196.785	196.784	
	Easting	196.028	196.027	196.0275	196.027	196.029	196.028	
	Height	19.138	19.137	19.1375	19.122	19.119	19.1205	
Set #4	Northing	196.791	196.788	196.7895	196.782	196.785	196.7835	
	Easting	196.029	196.029	196.0290	196.028	196.028	196.0280	
	Height	19.139	19.139	19.1390	19.122	19.119	19.1205	
Set #5	Northing	196.792	196.786	196.7890	196.781	196.785	196.7830	
	Easting	196.029	196.027	196.0280	196.028	196.029	196.0285	
	Height	19.14	19.138	19.1390	19.122	19.119	19.1205	

Survey Prism 1-2

Sets		Readings of 1st Manual Survey (06/30/11)			Readings of 2nd Manual Survey (10/28/11)			
		Face I	Face II	Avg	Face I	Face II	Avg	
Set #1	Northing	196.647	196.642	196.6445	196.647	196.65	196.6485	
	Easting	195.656	195.657	195.6565	195.655	195.657	195.656	
	Height	14.687	14.686	14.6865	14.671	14.67	14.6705	
Set #2	Northing	196.65	196.647	196.6485	196.648	196.65	196.649	
	Easting	195.657	195.657	195.6570	195.656	195.658	195.6570	
	Height	14.687	14.686	14.6865	14.672	14.67	14.671	
Set #3	Northing	196.623	196.619		196.648	196.65	196.6490	
	Easting	195.656	195.656		195.657	195.655	195.6560	
	Height	14.686	14.686	14.686	14.672	14.67	14.6710	
Set #4	Northing	196.661	196.656	196.6585	196.648	196.65	196.649	
	Easting	195.658	195.656	195.6570	195.657	195.657	195.6570	
	Height	14.685	14.685	14.6850	14.673	14.67	14.6715	
Set #5	Northing	196.659	196.655	196.6570	196.648	196.65	196.6490	
	Easting	195.657	195.657	195.6570	195.655	195.657	195.6560	
	Height	14.687	14.685	14.6860	14.673	14.67	14.6715	

Survey Prism 1-3

Sets		Readings of 1st Manual Survey (06/30/11)			Readings of 2nd Manual Survey (10/28/11)			
		Face I	Face II	Avg	Face I	Face II	Avg	Difference
Set #1	Northing	196.756	196.75	196.7530	196.753	196.755	196.7540	
	Easting	195.98	195.979	195.9795	195.98	195.982	195.981	
	Height	10.05	10.048	10.0490	10.036	10.035	10.0355	
Set #2	Northing	196.76	196.755	196.7575	196.753	196.755	196.754	
	Easting	195.98	195.98	195.9800	195.981	195.98	195.9805	
	Height	10.05	10.048	10.0490	10.037	10.035	10.0360	
Set #3	Northing	196.731	196.727		196.753	196.755	196.7540	
	Easting	195.979	195.979		195.98	195.98	195.9800	
	Height	10.048	10.048	10.0480	10.038	10.035	10.0365	
Set #4	Northing	196.768	196.764	196.7660	196.754	196.756	196.7550	
	Easting	195.981	195.98	195.9805	195.98	195.979	195.9795	
	Height	10.049	10.048	10.0485	10.038	10.035	10.0365	
Set #5	Northing	196.768	196.764	196.7660	196.754	196.756	196.7550	
	Easting	195.98	195.98	195.9800	195.98	195.979	195.9795	
	Height	10.048	10.046	10.0470	10.038	10.035	10.0365	

Survey Prism 1-4

Sets		Readings of 1st Manual Survey (06/30/11)			Readings of 2nd Manual Survey (10/28/11)			
		Face I	Face II	Avg	Face I	Face II	Avg	Difference
Set #1	Northing	196.634	196.629	196.6315	196.626	196.628	196.627	0.0045
	Easting	195.983	195.983	195.9830	195.983	195.984	195.9835	-0.0005
	Height	5.471	5.469	5.4700	5.461	5.459	5.4600	0.0100
Set #2	Northing	196.638	196.634	196.6360	196.626	196.628	196.6270	0.0090
	Easting	195.983	195.982	195.9825	195.985	195.986	195.9855	-0.0030
	Height	5.471	5.47	5.4705	5.461	5.459	5.46	0.0105
Set #3	Northing	196.61	196.607		196.626	196.628	196.627	-196.6270
	Easting	195.982	195.981		195.985	195.985	195.985	-195.9850
	Height	5.471	5.47	5.4705	5.462	5.46	5.461	0.0095
Set #4	Northing	196.647	196.644	196.6455	196.627	196.629	196.628	0.0175
	Easting	195.983	195.983	195.9830	195.985	195.986	195.9855	-0.0025
	Height	5.471	5.47	5.4705	5.462	5.459	5.4605	0.0100
Set #5	Northing	196.646	196.642	196.6440	196.627	196.629	196.6280	0.0160
	Easting	195.983	195.983	195.9830	195.985	195.986	195.9855	-0.0025
	Height	5.47	5.468	5.4690	5.462	5.459	5.4605	0.0085

Survey Prisms on Wall #3

Survey Prism 3-1

Sets		Readings of 1st Manual Survey (06/30/11)			Readings of 2nd Manual Survey (10/28/11)			
		Face I	Face II	Avg	Face I	Face II	Avg	
Set #1	Northing	176.026	176.021	176.0235	176.018	176.02	176.019	
	Easting	169.515	169.514	169.5145	169.506	169.507	169.5065	
	Height	20.621	20.618	20.6195	20.588	20.586	20.587	
Set #2	Northing	176.029	176.027	176.0280	176.018	176.02	176.0190	
	Easting	169.517	169.516	169.5165	169.506	169.508	169.507	
	Height	20.619	20.617	20.6180	20.588	20.586	20.5870	
Set #3	Northing	176.009	176.007		176.018	176.02	176.0190	
	Easting	169.51	169.509		169.506	169.508	169.507	
	Height	20.619	20.617	20.6180	20.588	20.586	20.5870	
Set #4	Northing	176.037	176.033	176.0350	176.02	176.021	176.0205	
	Easting	169.519	169.518	169.5185	169.507	169.507	169.507	
	Height	20.62	20.618	20.6190	20.588	20.586	20.5870	
Set #5	Northing	176.035	176.033	176.0340	176.019	176.021	176.0200	
	Easting	169.518	169.517	169.5175	169.506	169.507	169.5065	
	Height	20.619	20.618	20.6185	20.588	20.586	20.587	

Survey Prism 3-2

Sets		Readings of 1st Manual Survey (06/30/11)			Readings of 2nd Manual Survey (10/28/11)			
		Face I	Face II	Avg	Face I	Face II	Avg	
Set #1	Northing	158.528	158.526	158.5270	158.522	158.526	158.5240	
	Easting	176.354	176.351	176.3525	176.343	176.345	176.344	
	Height	20.856	20.856	20.8560	20.828	20.826	20.8270	
Set #2	Northing	158.533	158.529	158.5310	158.522	158.524	158.5230	
	Easting	176.356	176.354	176.3550	176.344	176.346	176.3450	
	Height	20.855	20.854	20.8545	20.829	20.826	20.8275	
Set #3	Northing	158.511	158.507		158.522	158.525	158.5235	
	Easting	176.344	176.342		176.344	176.346	176.3450	
	Height	20.855	20.854	20.8545	20.828	20.826	20.827	
Set #4	Northing	158.541	158.536	158.5385	158.523	158.525	158.524	
	Easting	176.361	176.358	176.3595	176.344	176.346	176.345	
	Height	20.855	20.854	20.8545	20.828	20.826	20.827	
Set #5	Northing	158.54	158.536	158.5380	158.523	158.524	158.5235	
	Easting	176.359	176.357	176.3580	176.344	176.345	176.3445	
	Height	20.855	20.853	20.8540	20.828	20.826	20.8270	

Survey Prism 3-3

Sets		Readings of 1st Manual Survey (06/30/11)			Readings of 2nd Manual Survey (10/28/11)			
		Face I	Face II	Avg	Face I	Face II	Avg	Difference
Set #1	Northing	158.029	158.026	158.0275	158.02	158.021	158.0205	
	Easting	174.169	174.165	174.1670	174.162	174.163	174.1625	
	Height	12.039	12.027	12.0330	12.016	12.015	12.0155	
Set #2	Northing	158.032	158.03	158.0310	158.02	158.022	158.0210	
	Easting	174.171	174.169	174.1700	174.163	174.163	174.1630	
	Height	12.028	12.026	12.0270	12.017	12.014	12.0155	
Set #3	Northing	158.012	158.01		158.02	158.022	158.0210	
	Easting	174.159	174.158		174.162	174.163	174.1625	
	Height	12.027	12.027	12.0270	12.017	12.014	12.0155	
Set #4	Northing	158.042	158.038	158.0400	158.02	158.022	158.0210	
	Easting	174.175	174.173	174.1740	174.162	174.164	174.1630	
	Height	12.028	12.028	12.0280	12.017	12.015	12.0160	
Set #5	Northing	158.041	158.037	158.0390	158.02	158.021	158.0205	
	Easting	174.176	174.173	174.1745	174.162	174.164	174.163	
	Height	12.028	12.025	12.0265	12.017	12.015	12.016	

Survey Prism 3-4

Sets		Readings of 1st Manual Survey (06/30/11)			Readings of 2nd Manual Survey (10/28/11)			
		Face I	Face II	Avg	Face I	Face II	Avg	Difference
Set #1	Northing	157.731	157.728	157.7295	157.724	157.725	157.7245	0.0050
	Easting	174.223	174.22	174.2215	174.228	174.228	174.228	-0.0065
	Height	6.248	6.246	6.2470	6.239	6.237	6.2380	0.0090
Set #2	Northing	157.732	157.733	157.7325	157.724	157.726	157.725	0.0075
	Easting	174.235	174.224	174.2295	174.228	174.23	174.229	0.0005
	Height	6.247	6.248	6.2475	6.239	6.237	6.238	0.0095
Set #3	Northing	157.714	157.713		157.725	157.726	157.7255	
	Easting	174.214	174.212		174.229	174.23	174.2295	
	Height	6.249	6.247	6.2480	6.238	6.237	6.2375	
Set #4	Northing	157.742	157.74	157.7410	157.724	157.726	157.7250	0.0160
	Easting	174.23	174.228	174.2290	174.229	174.229	174.2290	0.0000
	Height	6.248	6.248	6.2480	6.239	6.237	6.2380	0.0100
Set #5	Northing	157.744	157.74	157.7420	157.724	157.726	157.7250	0.0170
	Easting	174.229	174.227	174.2280	174.229	174.23	174.2295	-0.0015
	Height	6.249	6.247	6.2480	6.239	6.237	6.2380	0.0100

Table 12 – Summary tables with measured displacements of all survey points from June 30, 2011 to October 28, 2011 manual surveys

Measured Displacements: 6/30/11-10/28/2011

Manual Survey Data for : Rt-22 Liberty Ave & Conrail

1st Survey performed: 06/30/2011, 8:00 AM
2nd Survey performed: 10/28/2011, 8:30 AM
Survey Performed by: Krunal Patel & Ray Patel
1st Survey Weather: 82°F, Sunny
2nd Survey Weather: 29°F, Sunny

NOTE: ALL READING ARE IN FEET

Reference Prisms

Summary	Initial Coordinates (ft)		Final Coordinates (ft)		Diff
Ref-1 (On Popeyes)	avg	stdev	avg	stdev	(ft)
Northing	298.4344	0.0005	298.4298	0.0006	-0.0046
Easting	100.0221	0.0072	100.0343	0.0003	0.0122
Height	12.8026	0.0011	12.8003	0.0003	-0.0023

Summary	Initial Coordinates (ft)		Final Coordinates (ft)		Diff
Ref-2 (On existing Rt-22 overpass)	avg	stdev	avg	stdev	(ft)
Northing	91.2779	0.0255	91.2711	0.0004	-0.0068
Easting	226.2699	0.0071	226.2603	0.0004	-0.0096
Height	20.7133	0.0006	20.7155	0.0004	0.0022

Summary	Initial Coordinates (ft)		Final Coordinates (ft)		Diff
Ref-3 (On column, under Rt-22 overpass)	avg	stdev	avg	stdev	(ft)
Northing	69.1715	0.0104	69.1612	0.0006	-0.0103
Easting	164.9293	0.0082	164.9213	0.0004	-0.0080
Height	12.4750	0.0014	12.4756	0.0002	0.0006

Prisms on Wall #1

Summary	Initial Coordinates (ft)		Final Coordinates (ft)		Diff
vey Prism 1-1	avg	stdev	avg	stdev	(ft)
Northing	196.7848	0.0059	196.7834	0.0004	-0.0014
Easting	196.0283	0.0006	196.0284	0.0004	0.0001
Height	19.1387	0.0007	19.1204	0.0002	-0.0183

Summary	Initial Coordinates (ft)		Final Coordinates (ft)		Diff
Survey Prism 1-2	avg	stdev	avg	stdev	(ft)
Northing	196.6521	0.0067	196.6489	0.0002	-0.0032
Easting	195.6569	0.0003	195.6564	0.0005	-0.0005
Height	14.6860	0.0006	14.6711	0.0004	-0.0149

Summary	Initial Coordinates (ft)		Final Coordinates (ft)		Diff
Survey Prism 1-3	avg	stdev	avg	stdev	(ft)
Northing	196.7606	0.0065	196.7544	0.0005	-0.0062
Easting	195.9800	0.0004	195.9801	0.0007	0.0001
Height	10.0483	0.0008	10.0362	0.0004	-0.0121

Summary	Initial Coordinates (ft)		Final Coordinates (ft)		Diff
Survey Prism 1-4	avg	stdev	avg	stdev	(ft)
Northing	196.6393	0.0066	196.6274	0.0005	-0.0119
Easting	195.9829	0.0002	195.9850	0.0009	0.0021
Height	5.4701	0.0007	5.4604	0.0004	-0.0097

Prisms on Wall #3

Summary	Initial Coordinates (ft)		Final Coordinates (ft)		Diff
Survey Prism 3-1	avg	stdev	avg	stdev	(ft)
Northing	176.0301	0.0054	176.0195	0.0007	-0.0106
Easting	169.5168	0.0017	169.5068	0.0003	-0.0099
Height	20.6186	0.0007	20.5870	0.0000	-0.0316

Summary	Initial Coordinates (ft)		Final Coordinates (ft)		Diff
Survey Prism 3-2	avg	stdev	avg	stdev	(ft)
Northing	158.5336	0.0056	158.5236	0.0004	-0.0100
Easting	176.3563	0.0031	176.3447	0.0004	-0.0115
Height	20.8547	0.0008	20.8271	0.0002	-0.0276

Summary	Initial Coordinates (ft)		Final Coordinates (ft)		Diff
Survey Prism 3-3	avg	stdev	avg	stdev	(ft)
Northing	158.0344	0.0061	158.0208	0.0003	-0.0136
Easting	174.1714	0.0035	174.1628	0.0003	-0.0086
Height	12.0283	0.0027	12.0157	0.0003	-0.0126

Summary	Initial Coordinates (ft)		Final Coordinates (ft)		Diff
Survey Prism 3-4	avg	stdev	avg	stdev	(ft)
Northing	157.7363	0.0062	157.7250	0.0004	-0.0112
Easting	174.2270	0.0037	174.2290	0.0006	0.0020
Height	6.2477	0.0004	6.2379	0.0002	-0.0098