Project: CARVER HIGH SCHOOL

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ABSTRACT

A two tier 50 ft tall geosynthetic reinforced MSE wall was built in early 2011 to support athletic fields at the New Carver High School in Columbus, GA. Contract documents required the general contractor, through their qualified sub-contractors to provide both the design and construction of this SRW block faced wall, roughly 50' tall over most of its 750-foot length. In September 2011 the top tier experienced some block cracking in radii, so the project team sought out a third-party review, before the project was completed. This paper will discuss the results of that review, along with the negotiations between the Owner, General Contractor, and Sub-Contractors that went into deciding to improve the global stability of the tiered wall system.

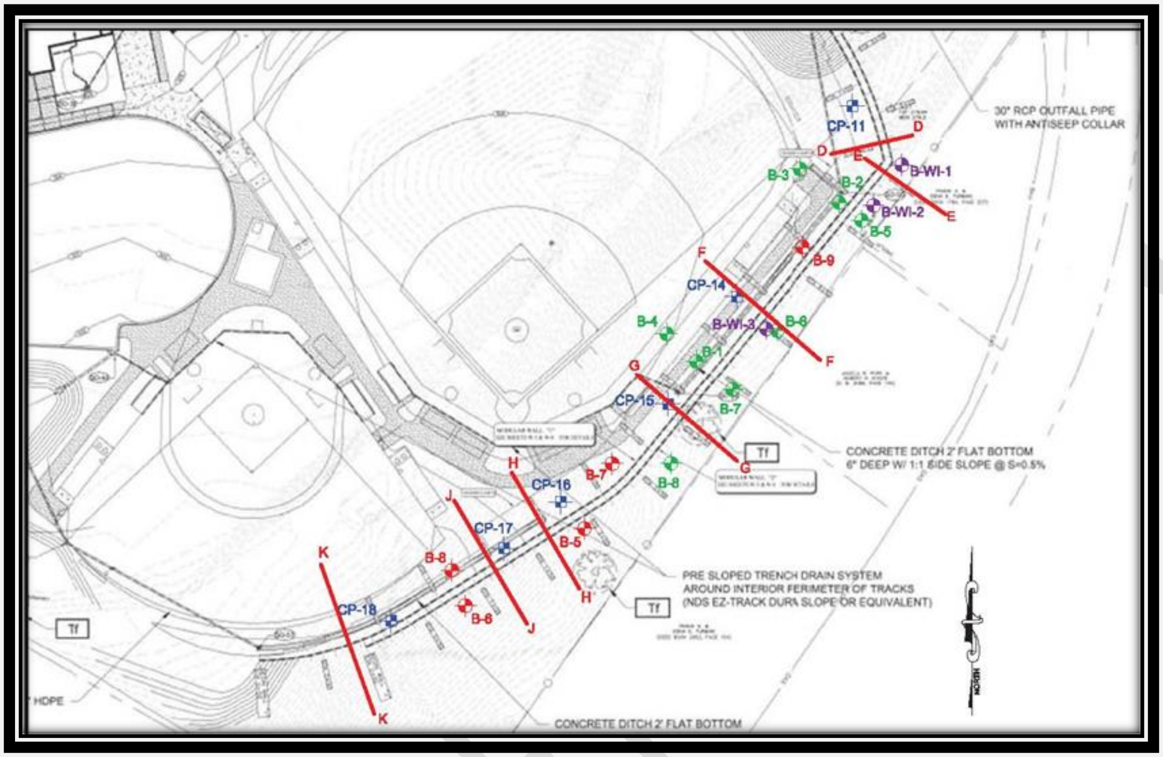
The paper presents the process used to select a buttress wall to improve global stability for a portion of the wall length after consideration of several options. The paper will also discuss several challenges encountered during construction relative to temporary global stability, drainage outlets, and materials handling at a limited access site that were addressed with some innovative solutions.

PROJECT DESCRIPTION and MSEW DETAILS

Muscogee County School District, decided to demolish the existing George Washington Carver high school in Columbus, GA and rebuild a new modernized high school on the same urban site. To expand the school footprint and provide updated athletic facilities, a two-tier geosynthetic reinforced MSEW was constructed of the east/southeast property boundary, see Figure 1. The top wall is 756 feet long and varies in height from 2 to 22 feet, but is at least 20 feet tall, over most of its length. A 6 feet wide bench separates the top wall, from the bottom wall which is 668 feet long and varies in height from 2 to 31.3 feet tall. At a nearly 50 feet change-in-grade these MSEWs were built in early 2011 by a specialty MSEW contractor that provided the engineering design and construction drawings per the contract documents. Figure 2 shows the typical original MSEW section using five unique strength polyester geogrids and concrete block facing.

Construction was monitored by a geotechnical engineer on a part-time basis. The foundation soils were mostly native residual and alluvial soils approved for the anticipated bearing pressure, with some areas requiring an undercut of 4 feet and backfilling with clean stone. When perched water was encountered near the bottom of the excavation, the clean stone base was expanded vertically to intercept it, also functioning as a heel drain in the northeast portion (above sta. 3+50) of the bottom wall.

Figure 1: Site Plan with Design Sections



A sandy fill with some silt and rock fragments was used to construct the geogrid reinforced zone, with a tested phi angle of 34.5 degrees, well above the specified strength of 30 degrees used in the design. The retained soils were the on-site clayey sands with a plasticity index of about 20 and a post-construction tested phi able of 33 degrees.

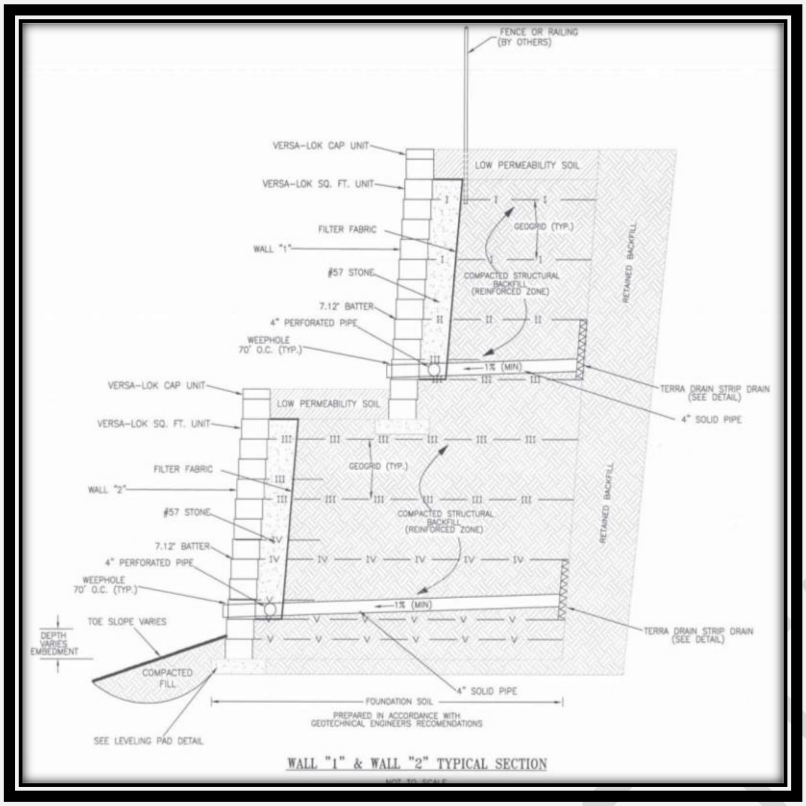


Figure 2: Typical Original Tiered MSEW Section

Movement in the tight radius corners started prior to completion of the top MSEW. This consisted mostly of minor block cracking and block joint separation, prompting the Owner to initiate monitoring of the top of wall face by conventional land surveying methods. Monitoring points every 10-feet along the top of wall were surveyed every 30 days to quantify rate and direction of movement. After measuring movement for another 90 days, the Owner and Architect became concerned about long-term stability.

Cooperation. The Owner desiring to identify if the measured movement was typical behavior or precursor of serious instability enlisted the cooperation of the stakeholders. The Owner, Architect, and General Contractor jointly selected a third -party reviewer to be retained by the Owner, to evaluate the design, construction, and performance. The parties also agreed to abide by the recommendations of the third-party reviewer, as the main contract for the high school building was still underway. The standard contract retention amount was significant, providing motivation to attain a cooperative effort amongst all these parties to resolve the situation.

THIRD PARTY REVIEW

The visual site inspection indicated the tiered wall system was reasonably well-built and appeared to be performing well, with the current (6 month) wall batter generally within acceptable limits of performance, $\pm$ 2 degrees of original stacked batter. The largest measured horizontal movement was 2.75-inches relating to maximum change in batter of 0.5-degrees. There was no evidence of gross structure movement, but the athletic field surfaces had been recently re-graded. The third-party review received verbal input, plus testing and installation data from all the stakeholders, including three post-construction foundation borings providing shear strength and consolidation testing data.

The MSEW contractor provided a “stamped” design that required the Owner to verify the assumed design soil properties and groundwater conditions. Neither the Owner, nor their quality assurance materials testing engineer realized the degree of reliance the MSEW contractor was placing on their testing program. This resulted in testing frequencies well below standard industry practice for reinforced fill gradation, compaction, and shear strength, lead to concerns about consistent quality of completed structure. In fact, all soil shear strength verification testing was done post-construction on grab samples and yielded the results in Table 1. The tested reinforced fill phi angle (ϕ’) of 34.5^o favorably exceeded the assumed design ϕ’ of 30.0^o

Table 1:	Reinforced	Fill Testing	Proctor and	Strength
Jun 2011	γd = 119.7 pcf	ωopt = 11.7 %	ϕ’ = 34.3 degs.	c = 86 psf
Aug 2011	γd = 116.0 pcf	ωopt = 14.0 %	ϕ’ = 35.9 degs.	c = 295 psf
Aug 2011	γd = 121.5 pcf	ωopt = 12.0 %	ϕ’ = 34.3 degs.	c = 288 psf
Average	γd = 119.1 pcf	ωopt = 12.6 %	ϕ’ = 34.8 degs.	c = 233 psf

Design Review yielded several concerns about the original two-tier MSEW design, among them; uniform (ϕ’ = 30.0^o) soil, independently designed tiers, and limited global stability analysis. Using MSEW3.0 by ADAMA Engineering a design check was performed combining the tiers into a single wall, revealing; insufficient bearing capacity, many short geogrid layers in the top tier, and several layers with tensile over-stress and/or deficient pullout safety factors in sections “D”, “E”, “F” and “G” (see Figure 1) for both the “as-built” and “as-designed” (□’ = 30.0^o) soil strengths. The combined tiered wall system was also analyzed in global stability for both soil strength conditions, with the minimum safety factors calculated well below acceptable design standards ($FS \geq 1.3$) for the various sections, see Table 2, with typical results shown in Figure 3.

Table 2:	GLOBAL	STABILITY	Safety Factor	Results
Section	As-Built Soils Circular	As-Built Soils 3-part Wedger	ϕ’ = 30.0^o Soils Circular	ϕ’ = 30.0^o Soils 3-part Wedge
D	1.06	1.11	1.12	1.06
E	1.14	1.14	1.16	1.14
F	1.14	1.08	1.21	1.14
G	1.21	1.09	1.19	1.21
H	1.18	1.25	1.34	1.18
J	1.10	1.09	1.24	1.10
K	1.49	1.43	1.45	1.42

Figure 3a: Original Two-Tier MSEW – Section “E” - As Designed Soils

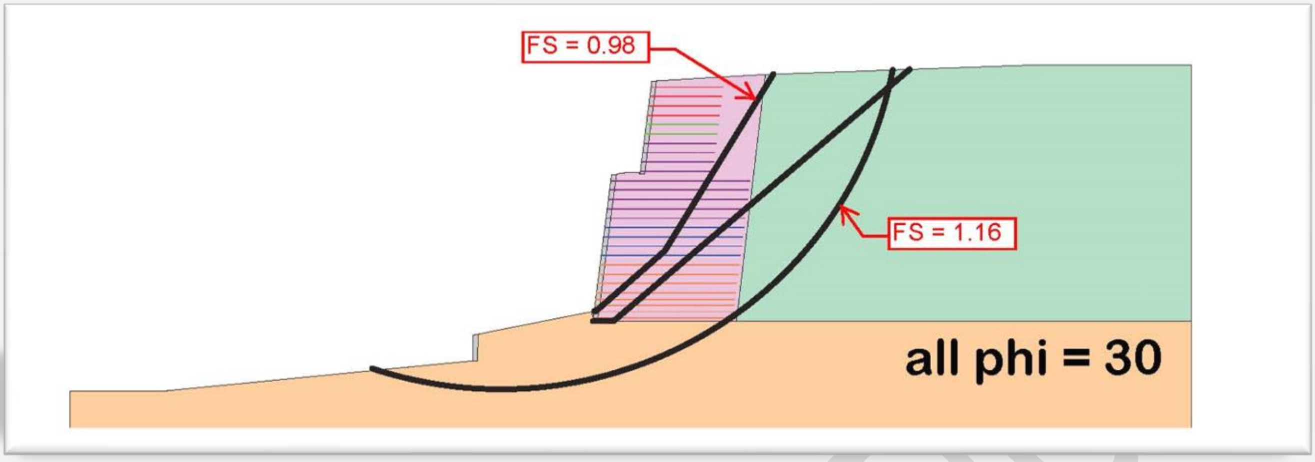
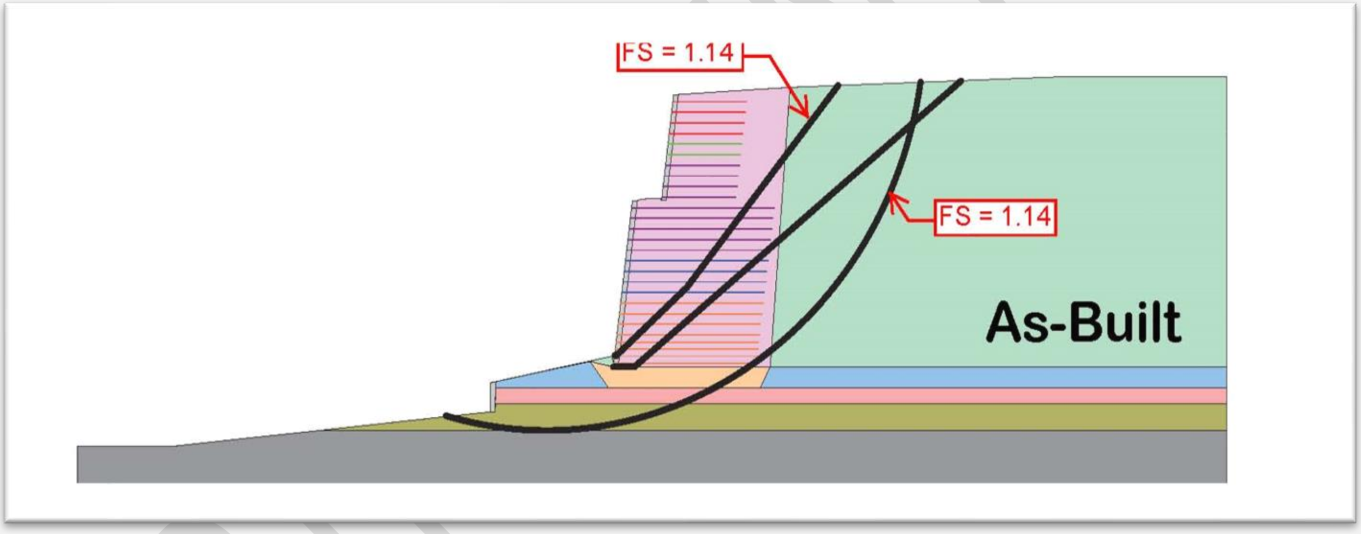


Figure 3b: Original Two-Tier MSEW – Section “E” - As-Built Soils



Stabilization was required by the third-party reviewer, recommending that the original MSEW designer determine the appropriate repair procedures. The third-party review also recommended additional geotechnical testing to better define the as-built soil conditions along the alignment to minimize the stabilization’s scope.

STABILIZATION DESIGN

The Contractor performed some additional post-construction geotechnical investigation and strength testing to better define the retained and reinforced zone soils, offering a 3H:1V toe slope initiating 5-feet up the face of the lower wall for the initial stabilization design. While more testing with higher soil shear strengths and the 3H:1V toe berm improved global stability, there were still sections “G” and “E” with unacceptable global and compound safety factors (<1.3). Additionally, applied bearing stresses (8,300 psf) were well above the previously approved allowable bearing pressure (5,800 psf) and several geogrid layers were still overstressed. A 3H:1V stabilization toe berm was deemed an insufficient stabilization method.

Partial excavation and replacement of the upper tier was deemed disruptive to the construction schedule and too costly with the athletic field improvements already installed. Likewise, structural stabilization with tiebacks or soil nails were deemed too costly. Therefore, the focus returned to finding a way to make a toe buttress work.

Auxiliary Geotechnical Investigation was undertaken and funded by the Owner to define the foundation conditions and appropriate soil strengths for each design section shown in Figure 1. These properties are presented in Table 3 and were based on the auxiliary geotechnical testing combined with the other post-construction geotechnical investigation and testing done to date. This allowed all parties designing and/or evaluating toe buttress designs to be using agreed upon soil strengths.

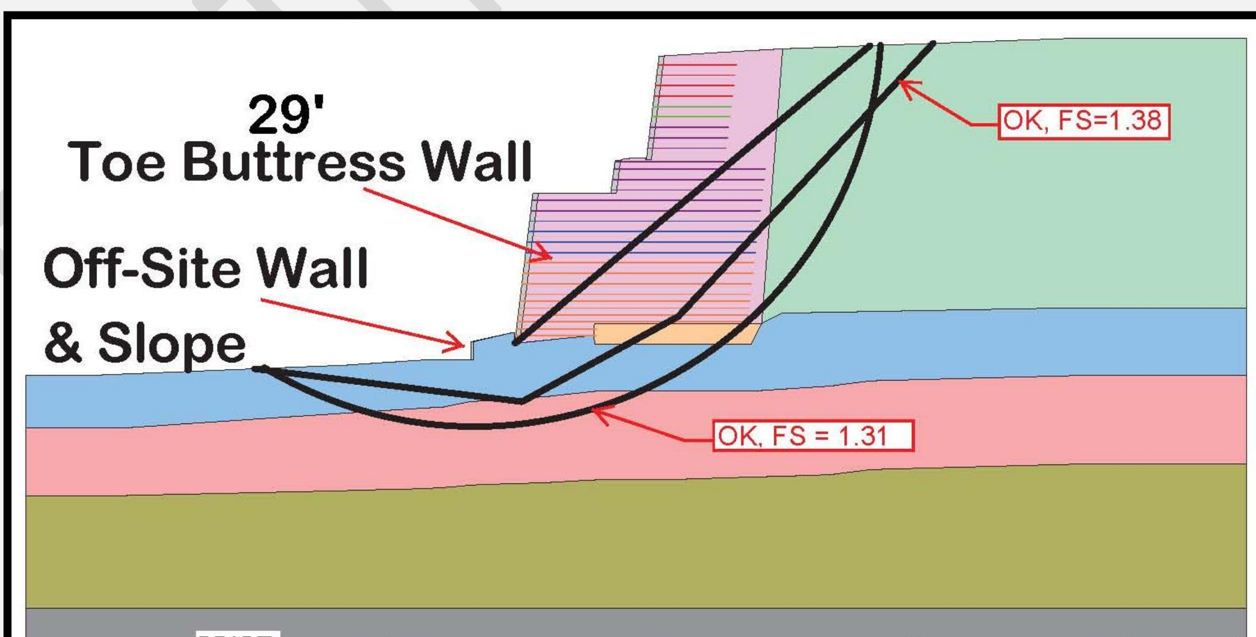
Small Toe Buttress Wall: A small, 10-feet tall, MSEW toe buttress constructed 12 feet in front of the lower tier was proposed by the Contractor. The small MSEW toe buttress was shown to improve the global and compound stability to acceptable safety factors (~1.3). However, the Owner rejected the proposal because it failed to address the internal stability issues relative to overstressed geogrid layers, and pullout of the shorter upper tier geogrid reinforcement layers.

Tall Toe Buttress Wall: After more rigorous design a taller, 10-to-29-feet, MSEW toe buttress constructed 15 feet in front of the lower tier was proposed by the Contractor. Raising the toe buttress wall height, eliminated all internal stability issues with the lower tier, and increased the toe weight providing further global and compound stability improvements (FS>1.3), see Figure 4. The length of the toe buttress MSEW ultimately ran almost the entire length of the lower tier wall, to ensure global stability. The applied bearing pressures were reduced by adding 15 feet to the width of the reinforced soil mass, keeping them below the higher assigned allowable soil bearing pressures, see Table 3. Figure 5 shows typical tall toe-buttress MSEW section.

Table 3: Recommended Soil Parameters

Analysis Section*	Location*	Depth (ft)	Effective Phi Angle** (degrees)	Est. Allowable Bearing Capacity*** (psf)	Moist Density** (pcf)
D	Foundation	0-13	33	6,000	115
		13-30	25		
		30-60	33		
	Reinforced	0-44	33	N/A	125
	Retained	0-44	33	N/A	115
E	Foundation	0-13	33	6,000	115
		13-30	25		
		30-60	33		
	Reinforced	0-52	33	N/A	125
	Retained	0-52	35	N/A	115
F	Foundation	0-20	33	8,500	125
	Reinforced	0-53	33	N/A	125
	Retained	0-53	33	N/A	115
G	Foundation	0-3	33	11,500	125
		3-8	25		
		8-20	33		
	Reinforced	0-53	33	N/A	125
	Retained	0-53	33	N/A	115
H	Foundation	0-17	33	10,000	130
		17-40	25		125
	Reinforced	0-35	30	N/A	130
	Retained	0-35	30	N/A	130
J	Foundation	0-17	33	8,500	130
		17-40	25		125
	Reinforced	0-28	30	N/A	125
	Retained	0-28	30	N/A	125
K	Foundation	0-17	33	8,500	130
		17-40	25		125
	Reinforced	0-18	30	N/A	125
	Retained	0-18	30	N/A	125

Figure 4: Global Stability with 29' Toe-Buttress MSEW – Section "E" – As-Built Soils



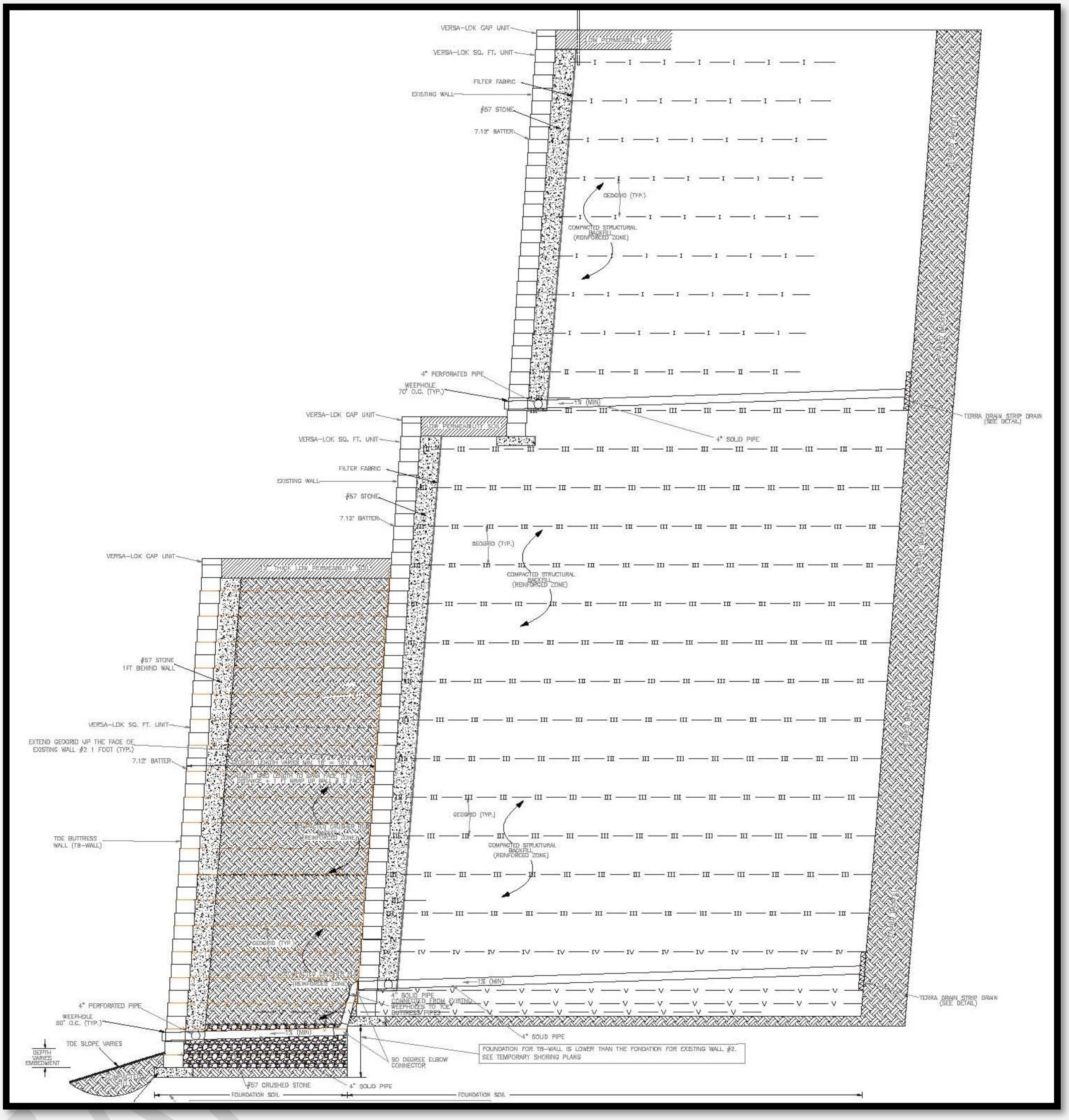


Figure 5: Typical Toe-Buttress MSEW

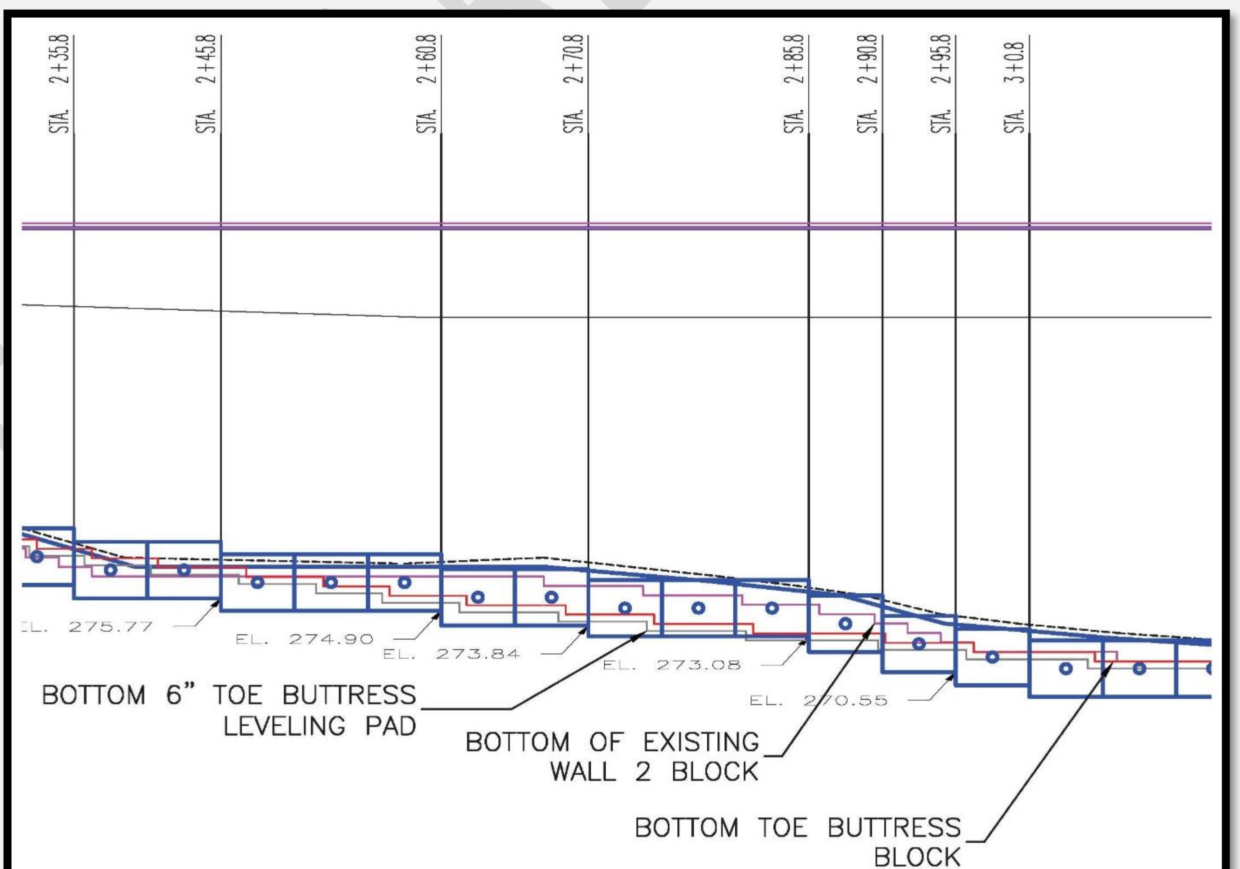
In January 2013, approximately a year after the initial third-party review the Owner agreed the tall toe buttress wall was sufficient stabilization for the tiered MSEW system and approved its use with two stipulations. The Owner required the Contractor continue monitoring both MSEWSs for movement throughout construction. The Owner also required the Contractor to ensure there was adequate stability during construction, as apartments were occupied on the adjacent property. The Owner emphasized this, by providing analyses indicating low global stability safety factors (~1.0) during excavation of the foundation for the toe buttress MSEW.

CONSTRUCTION

The Contractor mobilized and began construction of the toe buttress wall in the northeast corner approximately 3 months later. The Contractor opted to excavate the foundation for the toe-buttress MSEW in 50-feet increments as a technique to minimize disturbance of the existing two-tier MSEW. The excavation of the first 50-feet section was completed and placement of the first course of facing blocks begun when, survey monitoring of the existing MSEWs in the northeast corner registered significant movement. Work stopped immediately, and the excavation was backfilled to maintain stability of the existing two-tier MSEW.

The Contractor worked with the authors to develop a cost-effective excavation support system to permit safe construction of the toe-buttress MSEW. The unsupported excavation height varied from 2 to 3.3 feet depending on the location along the alignment, as shown in Figures 5 and 6. The soil nail supporting the excavation facing panel was placed beneath the original MSEW construction to avoid damaging the gravel pad that was placed for foundation stabilization beneath the entire reinforced zone of the lower tier MSEW, see Figure 7. This also allowed placement of the soil nail grout without contaminating the gravel foundation pad, that was part of the original foundation drainage system. Stability was maintained during installation of the excavation support by using a leap-frogging slot cut approach as illustrated in Figure 8.

Figure 6: Profile View of Excavation Support Panels



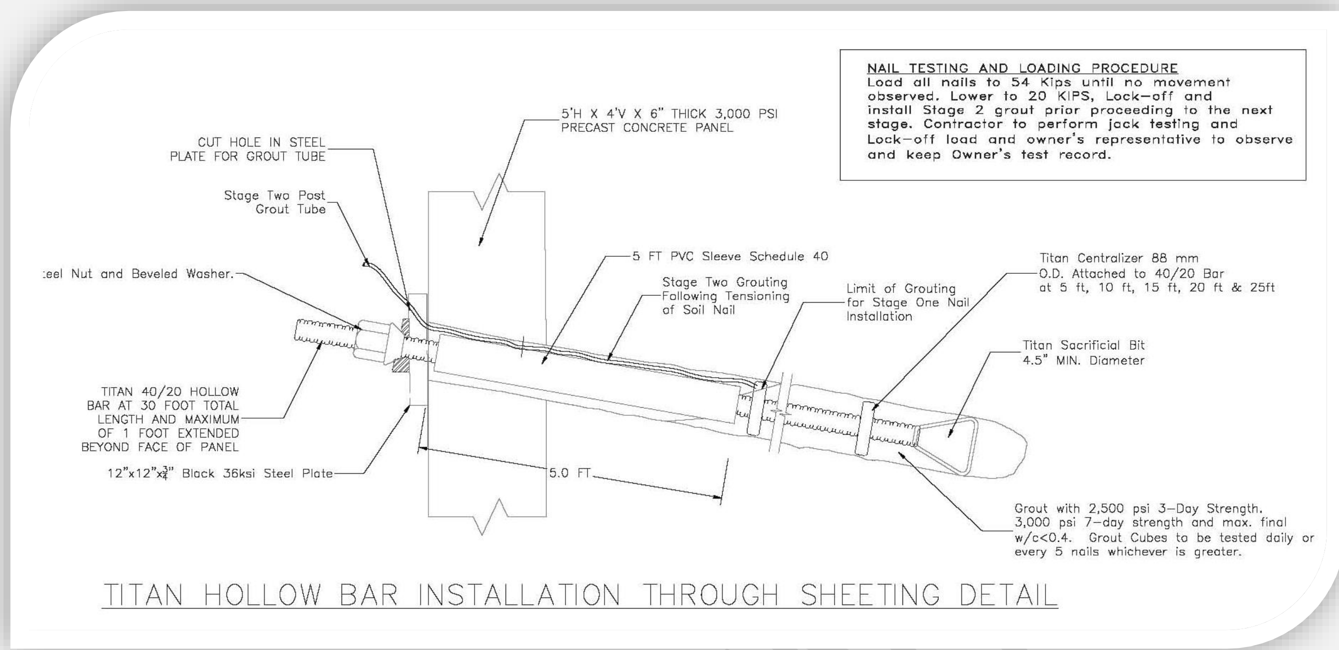


Figure 7: Typical Section of Excavation Support Panels

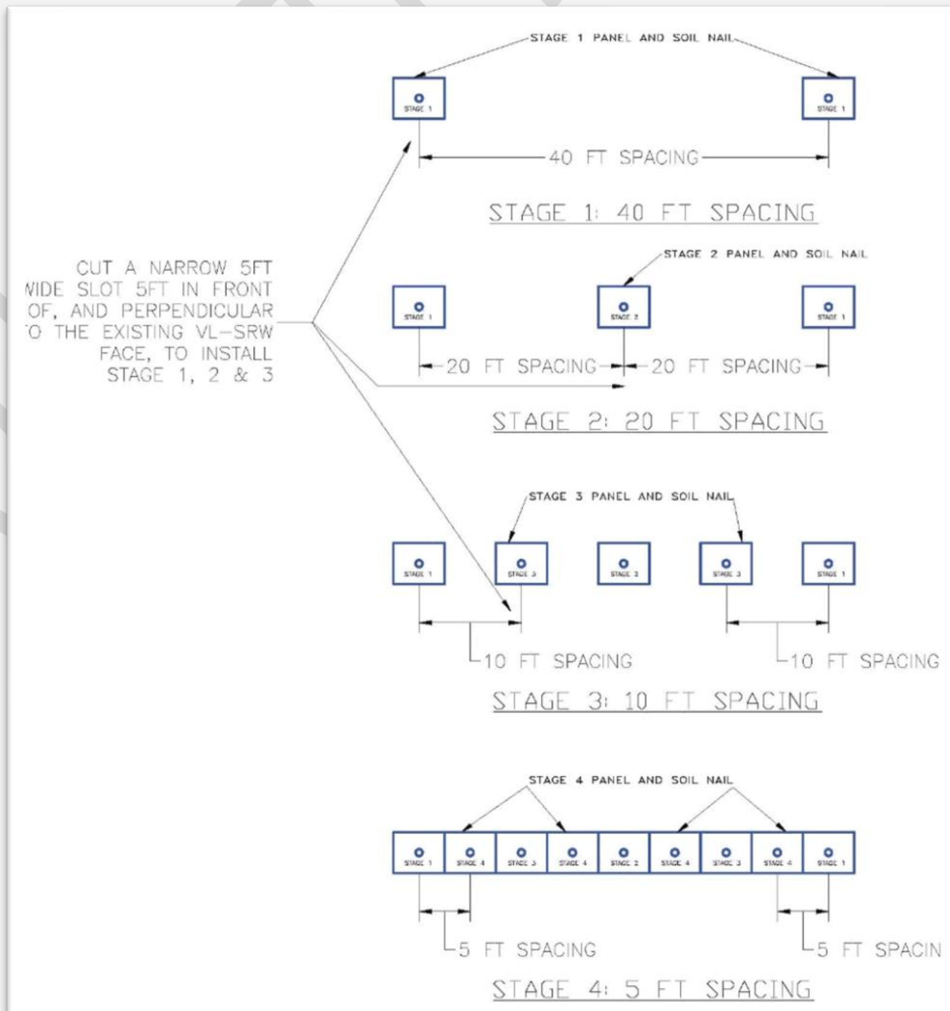


Figure 8: Installation Sequence Excavation Support Panels

The toe-buttress repair including the excavation support system was approved by the Owner in July 2013. Additional reviews and commentary of the design came from the Contractors and their insurance companies as cost and responsibility was becoming clearer to all parties involved. The authors answered all questions and made small improvements / modifications to design based on same. The Owner worked the Contractors on retention and other payment issues to facilitate the stabilization finally moving forward in September 2013, about two years after the third-party reviewer's initial site visit.

Construction access posed several logistic problems. The site could only be entered from the northeast, with only a 5-feet property width beyond the face of the toe-buttress wall all materials had to travel over the toe-buttress fill being placed, see Figure 9. All existing soil needed to remain in place as the excavation support was placed. Therefore, the slot cuts were excavated and then partially backfilled to facilitate access. Each of the soil nails were tested to a 54-kip capacity, see Figure 10, and then locked off at 20 kips, see Figure 7.

A high priority for the original two-tier MSEW was maintaining continuity of the drainage outlet system by extending it through the toe-buttress wall face, see Figure 5, and Figure 11 black pipe through face. At the lowest elevations of the toe-buttress wall there was insufficient property and slope fall to outlet leveling pad drain, so riser pipes were installed to monitor whether water is accumulating in the leveling pad. The risers are large enough to allow hand pumping, or if the problem is persistent, electric sump pumps to remove the water. A clean gravel fill was used to fill the entire reinforced soil volume of the toe-buttress MSEW, see Figure 12.

Figure 11: Drainage Outlets Through & from Beneath Toe-Buttress MSEW

The stabilization was completed in mid-October 2013, see Figure 13. Survey monitoring of the original MSEWs during installation of the temporary shoring and throughout construction of the toe-buttress indicated very small lateral and vertical movements (< 0.02 ft.) in only a few isolated locations. Monitoring was continued through a one-year warranty period without any discernible movement.

SUMMARY and CONCLUSIONS

Global and compound stability deficiencies in a 50-feet tall two-tier geosynthetic reinforced MSEW can be remediated using a toe-buttress wall at a confined access site. Construction of the 10-to-29-feet tall toe-buttress wall was required to improve the internal stability of the original lower tire MSEW. Site geometry and soil conditions required that small height excavation support consisting of 4'-by5' concrete panels stabilized by a single 54-kip capacity soil nail be used beneath the existing original MSEW construction to ensure safe working conditions for construction of the toe-buttress wall. While it took almost two-years to resolve all the design, responsibility, and funding issues relative to the stabilization work, it was successfully executed in about 60 days, and performed well since that time.

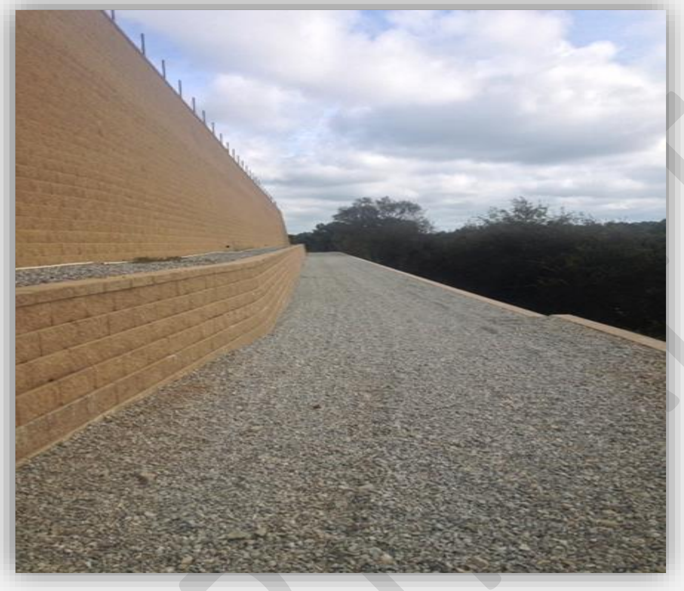


Figure 12: Completed Top Toe-Buttress MSEW

Figure 13: Completed NE Corner MSEW

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Acknowledgements: The authors appreciate of the cooperation of Robert Hecht, Construction Manager for the Owner – Muscogee County School District.