Eight ways to achieve improved retaining-wall performance

A refresher course for SRW success

By Michael R. Simac

Photos courtesy of Earth Improvement Technologies

Photo 1 | No site-specific design.

Photo 2 | Structural excavation protection during work.

Segmental Retaining Wall (SRW) performance can be improved greatly by implementing good construction techniques. Since SRW construction started some 20 years ago, a number of good guidelines have proven to be at the core of a properly executed project. This article highlights those techniques and describes their importance to ensuring a successful installation and good long-term performance.

The eight sections outlined below are not new. In fact, in many ways they are timeless. So this may be a refresher course for many readers. However, it is important to revisit their justification, as time and the quest for better, cheaper, and faster ways to deliver SRW projects, has eroded the compulsory nature of these critical techniques in the minds of some SRW designers, unknowing property owners/developers, and primarily SRW installation contractors.

Since the predominant SRW project delivery system is: "contractor supplied design," SRW installation contractors assume significant contractual responsibility for the entire process, sometimes unknowingly, including even some design-related issues. Therefore, it is incumbent upon the SRW installers to understand the entire interrelated SRW design and construction process to better evaluate the benefits of "taking your time to do it right the first time." This article will illustrate the value of eight core construction techniques by examining the consequences of short-changing them, often resulting in poor performance.

1. Project and site-specific design

A quality SRW project always starts with a good design. The design should be presented in construction drawings consisting of: a plan view, elevation (profile) view, typical cross-sections, details as required, and material/installation specifications. A design professional should prepare the SRW construction drawings to project specific geometry, for exclusive use with the soils available or planned for use at that location. The design should be optimized based on installed costs, not minimum wall face area or geosynthetic reinforcement costs.

Installers should not construct SRWs from construction drawings marked "preliminary" or "not for construction" or fail to have the official "seal" of a design professional registered in the state of the project location. Professionally "sealed" SRW construction drawings are often a project specification and/or building code requirement, and usually are required to obtain a building permit.

The SRW installer should not mistake material/supplier provided assistance, in the form of design charts/tables, typical SRW sections/details, quantity estimates, or even preliminary design drawings, as the construction drawings sufficient to build a quality SRW. Although material/supplier assistance is usually accurate, it is rarely tailored to project specific geometry or to site-specific soil strengths. Using a "typical" or "preliminary" design, based on "assumed" higher soil strengths not present in the completed structure, has resulted in many poorly performing, often significantly distorted, SRWs, with some progressing to failure **(Photo 1)**.

The SRW construction drawings should include most of the construction techniques outlined below.

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Photo 3 | Inadequate surface-water control during work.

2. Survey SRW plan location

The SRW plan location should be physically located on site by a registered land surveyor or the general contractor's construction staking personnel. A SRW alignment survey on site assists the installer in identifying potential conflicts in the SRW drawings, or with property lines, right-of-way limits, easements, existing or proposed utilities, buildings, excavation support, and wall plan geometry layout. The SRW construction drawings **(see section 1.)** should prescribe the plan location at the bottom of wall to start construction that accounts for the preset batter of the specific SRW system to attain the desired horizontal location at the top of wall (normally the location shown on the site/civil engineer's grading plan).

The SRW alignment stakes, typically offset 4 to 10 ft. in front of the wall, may also provide information as to the grades for top and bottom SRW elevation, and possibly geogrid type, length, and vertical spacing. Due to the difficulties in changing SRW plan location once construction begins, the extra time and effort to survey the exact location is a cost-effective quality control technique. The frustration level can get quite high when the installer builds it right, but in the wrong place!

3. Protect excavation during construction

The SRW installer must maintain a stable excavation during construction. Stability during excavation is generally excluded in most SRW design professional's construction drawings because the type and extent of excavation is directly related to the SRW installer's equipment, means, and methods of excavation.

Therefore, the SRW installer must independently determine excavation backslopes and benching schemes that remain stable during construction, providing the necessary temporary excavation support to ensure worker safety and to meet OSHA requirements; and also to protect existing structures or utilities, accounting for any imposed construction equipment loadings. The project geotechnical report sometimes provides useful information on soil cut slopes. When conventional cut slopes and benching schemes are inadequate, temporary structural excavation support becomes necessary. Most SRW installers specifically exclude structural excavation support from their quotations and contracts since it is typically designed and installed by specialty geotechnical contractors. Temporary excavation support may consist of: steel or plastic sheet piling, cantilevered or tied-back "H" pile and lagging walls, tangent pile walls, jet grouting, or structural diaphragm slurry walls **(Photo 2)**.

The SRW installer must also prevent surface stormwater from entering the excavation or work area, an essential to maintain stability and to minimize construction delays. This is usually accomplished with a series of diversion berms and/or drainage swales. Since these features are considered incidental to the work, and generally not shown on the site grading plan, it will be the SRW installer's responsibility to protect the work area by installing the drainage features needed for the protection desired. This can be difficult because the site grading, and water-flow pattern, sometimes change daily. Therefore, most SRW contractors opt to "safe up" at the end of each day or as a storm approaches. When those measures are inadequate, a portion of the completed work can be destroyed **(Photo 3)**.

4. Outlets for internal drainage

The construction drawings **(see section 1.)** should provide a drainage design that indicates the type and location of drainage outlets along the entire length of the wall. Internal SRW drainage consists of the wall face drain, a blanket drain at the base of the reinforced soil mass, and a back (chimney) drain behind the reinforced soil mass. The drainage outlet should be

Photo 4 | No outlet provided; collection pipe above flow line.

physically connected to the collection pipe (slotted and running parallel to wall face) and consist of solid pipe that gravity flows water collected by the drainage system to the outside and beyond the SRW.

Although significant experience has shown that drainage outlets below a free-draining aggregate leveling pad perform better, some SRW designers and project constraints necessitate outlet through the front face at grade. Front face outlets require low permeability soil, such as well-graded aggregate base course, be used up to the outlet elevation, with free-draining aggregate above. Since water always finds the "path of least resistance" it is important that the outlet connection is coincident with a "low point" of the collection system **(Photo 4)**.

In either case, the outlet should be constructed immediately so that the drainage system is effective throughout wall construction, as well as permanently. It is quite surprising how many walls have been constructed (even according to plan!) with drainage collection pipes but no outlet. Failure to properly outlet the internal drainage system is the third most-common critical error made during SRW construction.

5. Monitoring activities

The SRW installation contractor should implement quality control procedures to ensure that all work is examined by the contractor's personnel prior to covering up with soil. This may include checking placement elevations; geosynthetic type, strength, and length; facing connections; soils being used for construction; compaction procedures, etc. Some contractors highlight portions of the SRW plan as installation is accomplished and have a second person check the work and sign the plan. Additionally, it is recommended, whether required by project specifications or not, that the SRW installer retain an independent qualified geotechnical engineer to:

a) Approve foundation soils beneath SRW as capable of supporting the SRW based upon the applied bearing pressure shown on the plans **(see section 1.)** The foundation soils within the entire geosynthetic reinforcement length should be observed by a geotechnical engineer and approved, prior to starting the leveling pad. This is to ensure that soil materials provoking vertical settlement or mass instability are removed prior to SRW construction **(Photo 5)**.

b) Approve fill source for reinforced soil volume per project or SRW installation specifications by shear testing, index testing, or visual description. The soil used in the reinforced soil volume (in contact with geosynthetic reinforcement) is critical to its structural stability. This documentation is essential to proving that appropriate soil materials are used in the reinforced soil volume, and knowing prior to use, a soil is acceptable.

c) Test compaction to document that the reinforced soil volume is constructed according to plan. Compaction testing provides the best quantitative measure of constructed fill quality and an indirect

Photo 5 | Soft foundation soils left in place.

correlation to the soil strength. Simply put, poor compaction will lead to poor performance. Test all fill soils except for drainage aggregate.

d) Observe and document installation of SRW system components to establish a complete construction record. These observations would include: material certifications, SRW facing unit placement, geosynthetic reinforcement type, length, and placement elevation, wall face alignment, etc.

Owner-sponsored construction quality assurance testing (CQAT) is generally insufficient in scope to address the work itemized above, and also to meet the detailed documentation requirements for building officials or civil litigation, particularly when the SRW installation contractor provided the design. And in many instances an owner's CQAT representative is unfamiliar with all the SRW installation requirements and may not have the SRW construction drawings. The SRW installation contractor is in a better position to establish and prove the work provided met or exceeded the specification requirements by including third party quality control testing and observation in work quotations and project delivery procedures, particularly if a dispute arises.

6. Filling, compacting the hand-compaction zone

The most common critical error made in SRW construction is poor compaction in the "hand compaction zone." The "hand compaction zone" are those soils placed within and just behind the SRW facing units, i.e., from the front face back 3 to 5 ft. horizontally. Recommended equipment for "hand compaction zone" compaction are hand operated, walk-behind compaction equipment such as a vibrating plate tamp, jumping jack tamper, and/or small (12-18 in.-diameter) drum rollers.

SRW manufacturers have designated the "hand compaction zone" to assist in maintaining wall alignment during construction by minimizing construction loads near the wall face. This has led to significant confusion among SRW installers who have interpreted these instructions (or cautions) to mean little or no compaction is required in the "hand compaction zone," and equipment should be kept away from the SRW wall facing. Failure to compact soil in the "hand compaction zone" has dire consequences **(Photo 6)**. Note that the machine-compacted portion of the MSE fill is still performing well.

The deleterious effects of these equipment cautions are exacerbated by the rampant SRW installer technique of pre-stacking multiple courses of SRW units **(Photo 7)**. This leads to extremely thick, 12-24 in., (and poorly) compaction lifts of the main soil fill. However, the largest effect of this technique is on the filling and compaction of the wall face drainage aggregate and the "hand compaction zone" soils. Drainage aggregate placed into the top of 2-4 multi-stacked SRW units, has little opportunity to completely fill the voids within, between, and behind the SRW units. This leads to inadequately filled SRW units, particularly at the bottom of the stacking interval, usually a geosynthetic reinforcement connection layer/level. Therefore, multi-stacked

Photo 6 | No compaction within 3-5 feet of wall face.

Photo 7 | Multi-stacking of SRW units.

blocks reduce facing connection strength by compromised (non-compacted) interaction with aggregate, and lower filled SRW unit weights than anticipated, all requirements of the connection testing upon which the design is based.

Additionally, multi-stacking of SRW units decreases lateral stability between geosynthetic layers by reducing the overall weight, (inadequate filling), and thick lifts reducing the ability to compact the aggregate into the densest, stiffest configuration. Without a stiff, stable facing system, created by densifying aggregate within, between, and behind the SRW units, compaction of the soils within the "hand compaction zone" becomes more difficult. That is why even solid SRW units require drainage aggregate, easily compacted by vibration, behind and between the units, to create a stiff facing system. Multi-stacking of SRW units tends to leave thick (12-24 in.), loose soil layers to be compacted by light walk-behind compaction equipment in the "hand compaction zone," especially if the soil is windrowed at the facing to reduce the aggregate volume of the wall face drain **(Photo 8)**.

The SRW installer can eliminate these SRW facing issues by following the manufacturer's suggested installation procedures of placing and filling one SRW block course at a time. Compaction in the "hand compaction zone" can be greatly improved by filling the SRW units with drainage aggregate and tensioning the geosynthetic reinforcement prior to placing the main reinforced soil fill. Initiate compaction of each block course soil lift (6-8 in.) by compacting the wall face drainage aggregate with vibration. Normally two passes just behind the facing units is sufficient. Next, use the appropriate (vibratory or kneading) walk-behind equipment to compact the soil fill within 4 to 5 ft. of the SRW unit.

Lastly, use mechanized equipment to compact the remaining soil fill layer all the way back to the excavation face or to meet the mass grading fill placement. Use care to make sure the compaction efforts of the wall installer are overlapped by the mass grading contractor at the back of the reinforced soil zone. Sufficient compaction testing early on in the project should establish the most efficient procedure (passes and direction) for specific equipment and soil types placed behind the drainage aggregate.

7. Placement and tensioning of the reinforcement

The correct geosynthetic reinforcement type (strength) and length should be placed at the locations shown on the plans: i.e., wall station and elevation. Tensioning of the geosynthetic reinforcement assists in controlling SRW facing alignment movement and improves the lateral stability of facing during construction for compaction. Consistency in the SRW installer's tensioning procedures will lead to more uniform completed SRW facing alignment. Most SRW installers have found taut, pulled tight with no wrinkles, is the most repeatable geosynthetic tension to use. Uniform tension may be maintained by pins, stakes, piles of fill, or by hand until soil can be placed over the geosynthetic. The geosynthetic should not be tensioned until connection with the SRW facing is complete, including filling in, between, and behind with drainage aggregate.

8. Protecting the SRW from water immediately after construction, and permanently

Surface stormwater intrusion into the completed SRW structure is the second most-common cause of poor performance. After completing the SRW, most installers seem to think their project is done. However, protecting the SRW facing and reinforced soil volume from the ravages of surface erosion until the permanent drainage, pavement, and/or erosion control structures are in place is a critical but difficult task, with changing site conditions controlled by others **(Photo 9)**. It is critical because final payment is usually not issued until the SRW is accepted by the owner.

Therefore, the SRW installer should push to construct all completed permanent drainage systems as soon as practical, particularly those associated with the

Photo 8 | Loose soil left near drainage aggregate.

Photo 9 | Surface water erosion of completed structure.

Photo 10 | Poor surface drainage infiltrates reinforced soil.

SRW, such as impermeable cover soils, drainage swales, etc. Meet with the site grader to go over the importance of diverting water around the completed SRW, and into the appropriate drainage collection structures, as construction continues toward completion **(Photo 10)**.

Periodically check the project site grading to identify problems and changes in surface drainage patterns. In extreme situations, the SRW installer may want to construct a secondary diversion system to protect the work.

Summary

The construction procedures discussed above are offered as a way for SRW installers to improve the performance of geosynthetic reinforced soil retaining walls faced with SRW units. The construction procedures are universal in that they apply to all reinforced soil structures and soil types. These procedures are even more advantageous when using high percentages of low-plastic, fine-grain silt and clay soils in the reinforced soil volume, an important component to the cost-effectiveness of using geosynthetic reinforcement in SRWs.

These construction techniques have been honed by both positive and negative experiences in building these structures. All the photos we've seen in this article have illuminated the negative consequences of poor construction procedures, and were chosen only to illustrate the issue being addressed. This is not an indictment of SRWs in general, well-established as a cost-effective change in grade construction method, for which many articles in this publication and others have highlighted the advantages. SRWs will continue to be used in great numbers, and with much success, and these construction procedures can be used to improve both the success rate and overall performance of SRWs. G

References

Collin, J., et. al. (1997) "Design Manual for Segmental Retaining Walls," National Concrete Masonry Association, 2nd edition. Herndon, Va.