SEGMENTAL RETAINING WALL BEST PRACTICES

SRW HISTORY ARTICLE SERIES

This is a new article in a series of technical articles on the history of segmental retaining walls developed under a grant from the NCMA Education and Research Foundation.

INTRODUCTION

Since segmental retaining walls (SRWs) where first introduced in the early 1980s the specifications, design, construction and inspection of the SRW system has changed considerably. New and improved practices have been developed that address the most common issues found on SRW projects.

This article presents the most up-to-date recommendations for the roles and responsibilities, specification, construction and inspection of SRW projects. These recommendations are not intended to override engineering judgment or commonsense as different projects have unique conditions. For the full recommendation, please consult the *Segmental Retaining Walls Best Practices Guide for the Specification, Design, Construction and Inspection of SRW Systems* (Ref. 9) and all the articles presented in this "SRW History Article" series.

ROLES AND RESPONSIBILITIES

Successfully installed SRW projects depend on clear roles and responsibilities for the owner, site civil engineer, SRW design engineer and SRW installer.

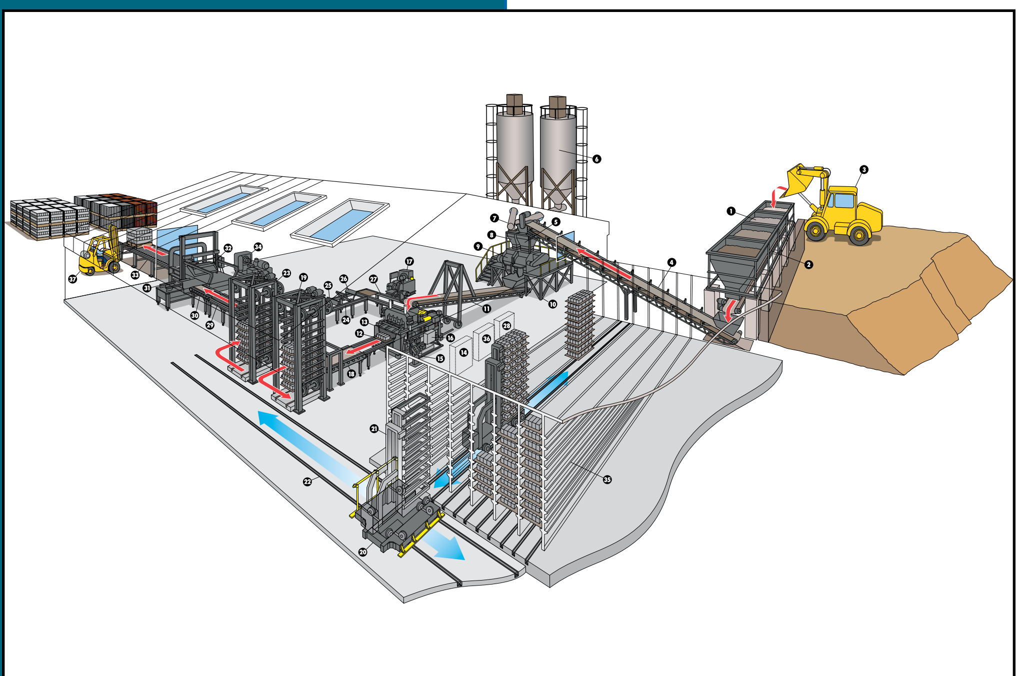

Figure 1. Modern Batch Plant (Courtesy of Columbia Machine)

Prior to the initiation of a project, the owner should work with the SRW design engineer to establish the scope of responsibilities and understand the limits of the SRW design engineer's responsibilities. Segmental retaining walls are a relatively new earth retention system in North America compared to other retaining wall systems, which has led to the frequent use of design-build relationships where the SRW design engineer works for the SRW installer. **This practice should be avoided to minimize potential conflicts of interest while ensuring that the SRW design engineer works for, and is accountable to, the project owner.** The recommended roles and responsibilities can be found in Chapter 1 of the *SRW Best Practices* (Ref. 9) and *TEK 15-3A, Roles and Responsibilities on Segmental Retaining Wall Projects* (Ref. 26).

The following are some of the roles recommended for SRW projects:

<u>**Site Civil Engineer:**</u> The civil engineer is in charge of the project site and coordinates all other disciplines and contractors. All the surface and subsurface evaluations are coordinated by this professional. The site civil engineer will also coordinate all pavement, utilities, grading and traffic control structures around the SRW project.

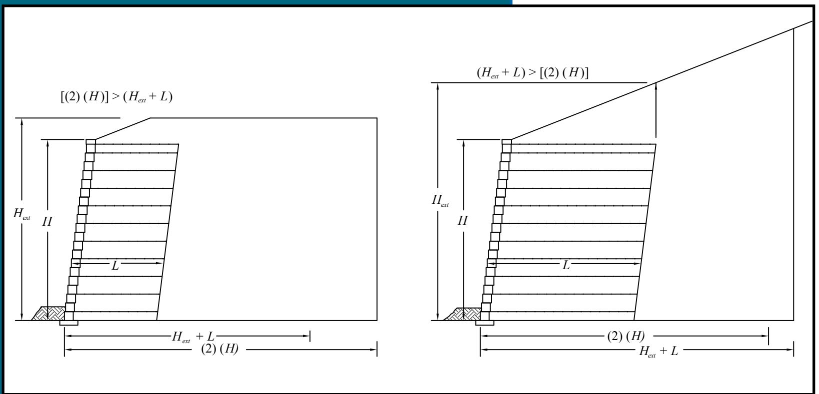

Figure 2. SRW Design Envelope

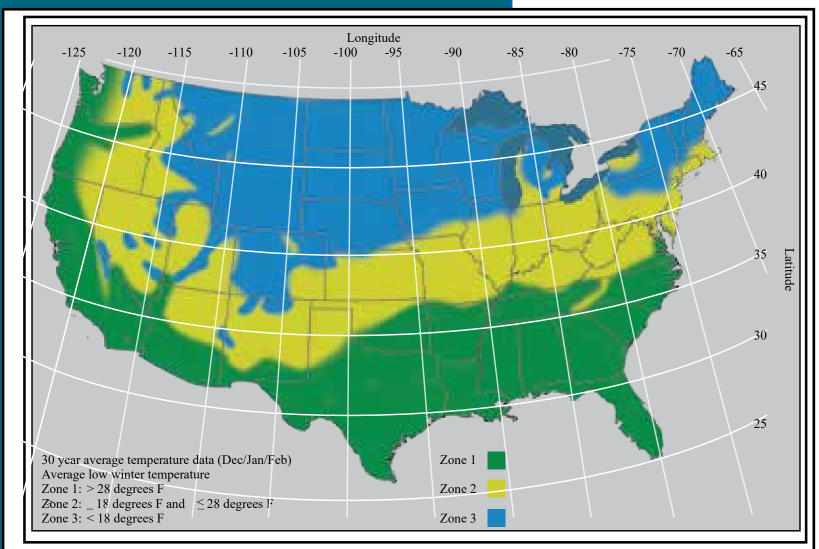

Figure 3. Climate Exposure Zones for Roadway Applications

<u>SRW Design Engineer:</u> The design engineer's services include the design of the SRW (external, internal and facial stability), the layout of geosynthetic reinforcement, minimum embedment and, if global stability may be a concern, coordinates with the project's geotechnical engineer to adjust the design if necessary. It is recommended that this professional work for the owner or owner's representative. Also, the retaining wall limits are now defined as twice the height of the wall (2*H*) or the height of the projection from the tail of the reinforcement to the finished grade above the wall (H_{ext}) plus the distance equal to the length of the reinforcement (See Figure 2).

SPECIFICATIONS BEST PRACTICES

Specifications are necessary to establish the materials selected on an SRW project. The recommendations within this article are consistent with the recommendations in the *Design Manual for Segmental Retaining Walls* (Ref. 4), *SRW Best Practices Guide* and the "SRW Specifications" article (Ref. 14).

Segmental Retaining Wall (SRW) Units

These material recommendations present the requirements for the SRW facing unit based on the climate zone and exposure of the project (See Figure 3 and Table 1) on commercial and transportation projects.

Table 1: Freeze/Thaw Durability Recommendations for Roadway and Non-Roadway Applications

Exposure Zone	SRW Properties[3]	Freeze/Thaw Testing (C1262 (Ref. 21))
Zone 1 and Non-Roadway applications	ASTM C1372 (Ref. 22)	None
Zone 2 –No/negligible de-icing salt exposure[1]	ASTM C1372	Proven field performance or test in water: • ≤1% wt. loss in 5 of 5 samples after 100 cycles; or • ≤1.5% wt. loss in 4 of 5 samples after 150 cycles.
Zone 2 – De-icing salt exposure[2]	ASTM C1372, plus • Targeted compressive strength: 4000 psi; • Targeted absorption: 7 pcf (112 kg/m³)	Test in 3% saline solution: • ≤1% wt. loss in 5 of 5 samples after 20 cycles; or • ≤1.5% wt. loss in 4 of 5 samples after 30 cycles.
Zone 3 – No/negligible de-icing salt exposure[1]	ASTM C1372, plus • Targeted compressive strength: 4000 psi (27.6 MPa); • Targeted absorption: 7 pcf (112 kg/m³)	Test in water: • ≤1% wt. loss in 5 of 5 samples after 100 cycles; • ≤1.5% wt. loss in 4 of 5 samples after 150 cycles.
Zone 3 – De-icing salt exposure[2]	ASTM C1372, plus • Targeted compressive strength: 5500 psi (37.9 MPa); • Targeted absorption: 7 pcf (112 kg/m³)	Test in 3% saline solution: • ≤1% wt. loss in 5 of 5 samples after 40 cycles; or • ≤1.5% wt. loss in 4 of 5 samples after 50 cycles.

1. Exposure is unlikely or unplanned, but may include occasional exposure.
2. Exposure to de-icing salts is likely or expected.
3. The minimum compressive strength and maximum absorption values listed are targets rather than absolute values. Unit durability assessment is quantified through ASTM C1262 testing. If freeze/thaw testing meets the requirements, other higher or lower strength or absorption values than shown here are acceptable.

Table 2: Soil Gradation, Geogrid Length, Reinforcement Spacing and Gravel Fill Based on Wall Height

Wall Height ft (m)	Reinforced Zone Material			Design and Layout Criteria		
		Gradation	Plasticity**	Reinf. Spacing, Max.	L/H, min.	Gravel Fill Thickness in. (mm)
H ≤10 (H ≤ 3)	Recommended	Table 3	Moderate	24 in. (610 mm)	0.6	24 in. (610 mm) from face 12 in. (305 mm) behind unit
	Alternate	Table 3 #200 waived	Moderate	16 in. (406 mm)	0.7	30 in. (762 mm) from face 18 in. (457 mm) behind unit
10 < H ≤ 20 (3 < H ≤ 6)	Recommended	Table 3	Low	24 in. (610 mm)	0.6	Top 10 ft (3 m) same as above, remainder 36 in. (914 mm) from the face, 24 in. (610 mm) behind unit
H > 20 (H > 6)	Recommended	Table 3	Low	24 in. (610 mm)	0.6	Top 10 ft (3 m) and lower 10 ft (3 m) to 20 ft (6 m) same as above, remainder 48 in. (1219 mm) from the face, 36 in. (914 mm) behind unit
**Moderate plasticity is defined as PI<20 and LL<40 and low plasticity is PI<6						

Table 3: Reinforced Soil Gradation Dependant on Wall Height

Sieve Size	Percent Passing for Walls ≤ 20 ft (6m)	Percent Passing for Walls >20 ft (6m)
1 in. (25 mm)	100	100
No. 4	100–20	100–20
No. 40	0-60	0-60
No. 200	0-35	0-15

Geosynthetic Reinforcement

The recommendations presented in the article on geosynthetic reinforcement (Ref. 18) should also be considered when specifying polyester geogrid, since the quality of the fiber used on the geogrid affects the durability of the reinforcement. When specifying polyester geogrid, the engineer is recommended to use the materials that have been submitted to the National Transportation Product Evaluation Program (NTPEP) for Geosynthetic Reinforcement (REGEO). The NTPEP REGEO program provides an independent, third-party evaluation and on-site audit of geosynthetic reinforcement. These reports include design reduction factors for creep and installation damage, which may or may not be applicable for all projects, but should be reviewed by the SRW design engineer for applicability. Current NTPEP reports are available online in the Datamine section of the NTPEP website, www.ntpep.org.

Soils

Understanding the on-site soils (the retained and foundation soils, and depending on suitability, the reinforced soils) as well as the imported soils (the gravel fill, leveling pad, and where the on-site soils are not suitable, the reinforced soils) is essential to understanding how the retaining wall will function. Soils in a reinforced SRW represent about 90% of the system. Without an adequate understanding of these soils, it is impossible to design a reinforced soil retaining wall that will perform successfully.

The designer must select the appropriate materials and properties when specifying soil for SRW construction. These are some expanded guidelines to adjust the soil requirement depending on the height of the wall (see Tables 2 and 3).

DESIGN BEST PRACTICES

The *NCMA SRW Design Manual* and the *SRW Best Practices Guide* are excellent references for designing segmental retaining walls. All the newer recommendations for the design of retaining walls apply to reinforced SRWs with different site constraints such as high groundwater and surface water or tiers. To address these concerns, refer to Sections 8-13 in the *SRW Best Practices Guide.*

Table 4: Minimum SRW Design Criteria

Minimum Safety Factor	Static	Dynamic (Seismic)*
Sliding (Base/Internal)	1.5	75% of Static
Overturning	2.0	75% of Static
Geogrid Overstress	1.5	75% of Static
Pullout from Soil/Block	1.5	75% of Static
Internal Compound Stability	1.3	1.1
Global Stability	1.3	1.1
Bearing Capacity	2.0	75% of Static
Additional Detailing		
Criteria Reinforced Zone Width	60% of Wall Height (*H*)	60% of Wall Height (*H*) fro Bottom and Middle Layers; 90% of Wall Height (*H*) for Upper Layers.
Minimum Wall Embedment	6 inches (152 mm)	6 inches (152 mm)
Minimum Anchorage Length	12 inches (305 mm)	12 inches (305 mm)
Maximum Wall Batter	20 degrees	20 degrees
Maximum Geogrid Spacing	See Table 2	16 inches (406 mm)

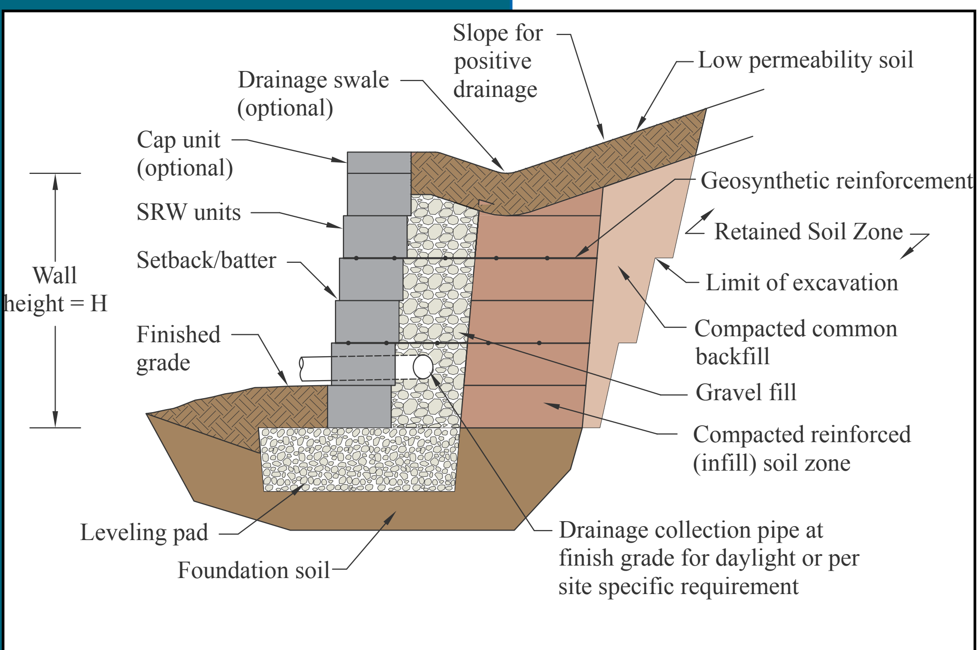

Figure 4. Geogrid Length on reinforced SRW

The minimum factor of safety requirements are shown on Table 4 and are expanded in the *SRW Design Manual*. The article on "SRW Design" (Ref. 13) discusses all the available design methods in more detail.

Reinforcement Length

All geogrid length recommendations are only minimum guidelines. However, the guideline gives the designer an idea of the area required to install the SRW, which will make installation simpler and will be supported by the design calculations. The longer reinforcement provides greater reinforcement depth and increases the 'stiffness' of the structure. This typically results in less lateral deformations. SRW walls with structures or slopes on top of the wall require longer reinforcement.

The minimum geogrid lengths and recommended spacing are available depending on the wall height (See Table 2). The principle is that the taller the structure, the longer and closer the reinforcement should be placed.

Water and Drainage

It is important to know the site topography and recognize the potential for water to infiltrate the SRW system. Underdrains and chimney drains for cut walls are alternatives for these site conditions and they can be accompanied with swales (see Figure 5).

Site drainage should be considered in SRW design. Evacuating roof drains or parking lots behind the SRW will lead to problems and should be avoided. Underground drain pipes and water lines are also another potential area for concern. A best practice for surface water should be:

> Surface water and drain water from structures shall not be discharged behind the SRW structure. Water shall be collected and discharged to the drain discharging away from the SRW structure.

These underdrains can be a geosynthetic composite drain or a stone chimney drain. In walls designed using a poorly draining soil (fines greater than 15 percent), a gravel under-drain (blanket) should be installed below the reinforced soil mass to provide a drainage path for water from behind the reinforced soil mass to exit the wall system. Thus reducing the potential for disruptive hydrostatic pressures. The

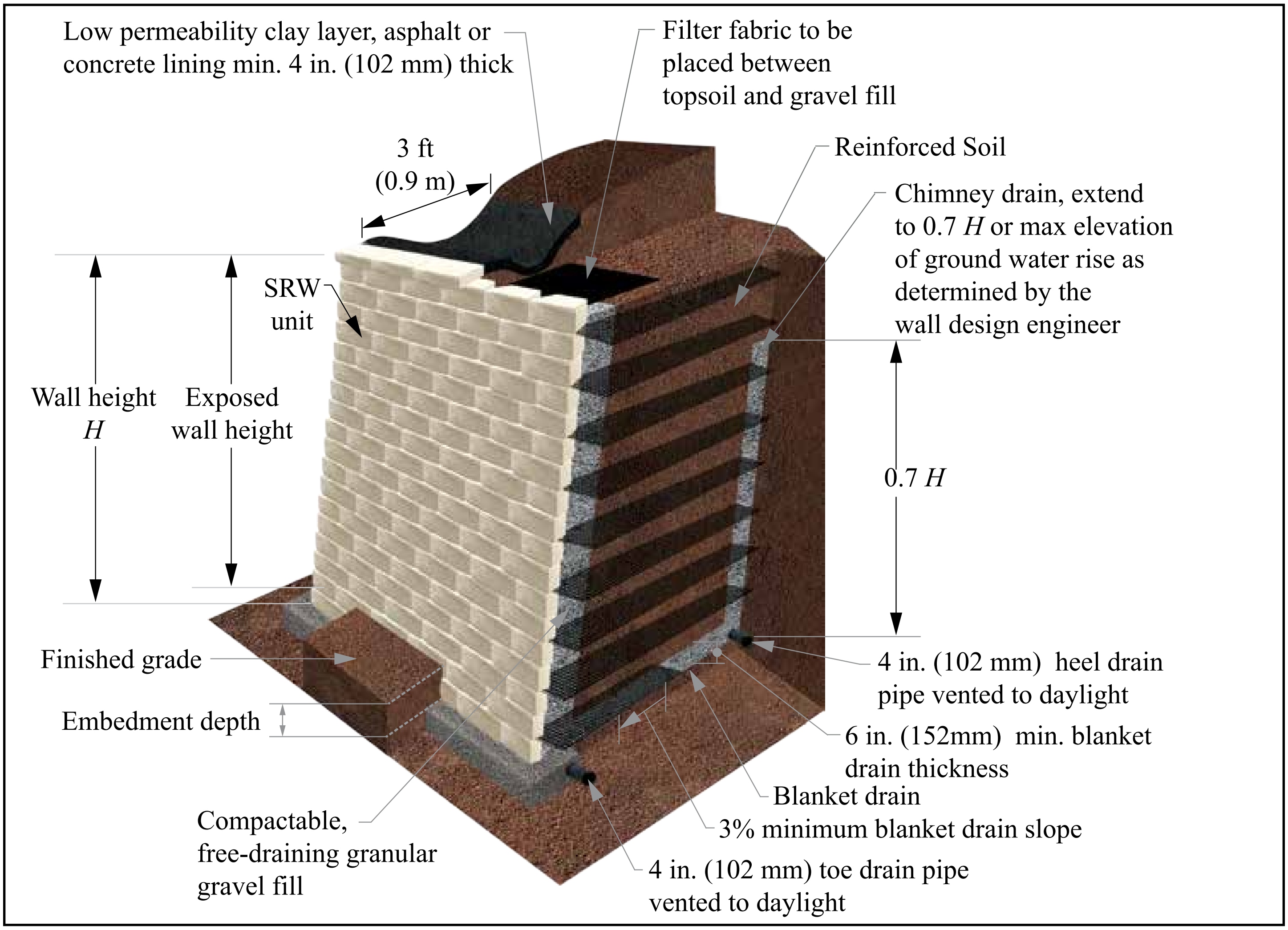

Figure 5. SRW Design for High Ground Water Table (Ref. 9)

chimney drain would intercept with the blanket layer on a secondary drain pipe for a complete drainage path that will evacuate all the water out of the system (See Figure 5) and away from the wall.

INSPECTION BEST PRACTICES

The article "SRW Inspection" (Ref. 17) and the *SRW Best Practices Guide* address walls that require special inspections by the local building departments (generally walls over 4 ft (1.2 m) in height). It also addresses testing for bearing capacity, good foundation conditions, and compaction density. Testing should also be defined in the specifications to be done on a part-time or full-time basis. Usually the inspector will be observing the wall once or twice during construction or inspection for compaction testing only or remaining on site during the whole construction process. What happens between inspection visits is the responsibility of the contractor and may or may not be documented. In the "SRW Construction" article (Ref. 16), examples of good and poor construction are presented that underscore the importance of adequate inspection.

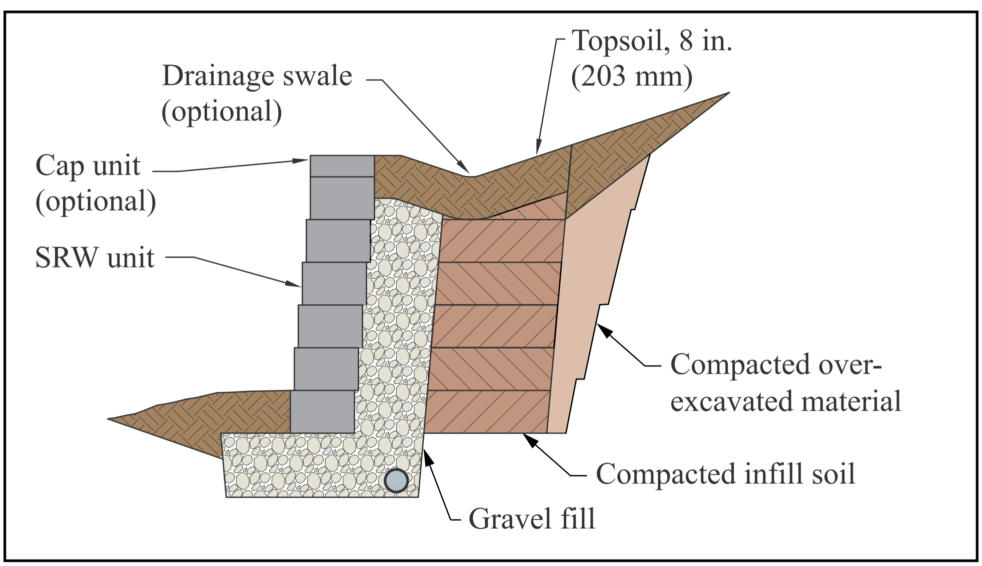

Figure 6. Completed Gravity Segmental Retaining Wall

The specifications should establish the inspection and testing requirements in advance of providing the wall design. While quality control is the responsibility of the wall contractor, quality assurance is the responsibility of the owner. The owner should retain the services of an independent testing and inspection firm to provide quality assurance for the project, which may also be the project geotechnical engineer.

Inspection of SRW wall construction shall include the review of plans for conformance to building code standards, on-site inspection for approval of the subgrade soils when the leveling pad is installed, on-site compaction testing during construction, and certification of the completed wall by the engineer of record, confirming the construction followed the design specifications.

SRW Unit

The inspector must verify that the SRW units and all the accessories delivered meet the required specifications and that the placement is monitored and documented. Placement recommendations are product specific and must follow the manufacturer recommendations.

Backfill Placement

The inspector will also have to review the materials used to verify they meet the specification and monitor the placement following the specified frequency. The maximum lift thickness for infill soil placement is 8 in. (200 mm) and never higher than the height of SRW unit. Compaction should be accomplished in a predetermined number of passes of compaction equipment and should be verified by on-site compaction testing. Only hand-operated compaction equipment should be allowed within 3 ft (914 mm) of the back of wall face, preferably a vibrating plate compactor with a minimum weight of 250 lb (113 kg). If smaller equipment is used, lift heights may need to be smaller to reach the specified densities. The specifications call regularly for a minimum density of 95% of the standard Proctor (Ref. 23) design at a moisture content of - 1% to +3% of the optimum water content. The inspector should note the method of compaction and the compaction equipment. Test reports should be kept to confirm the soils tested met the design requirements.

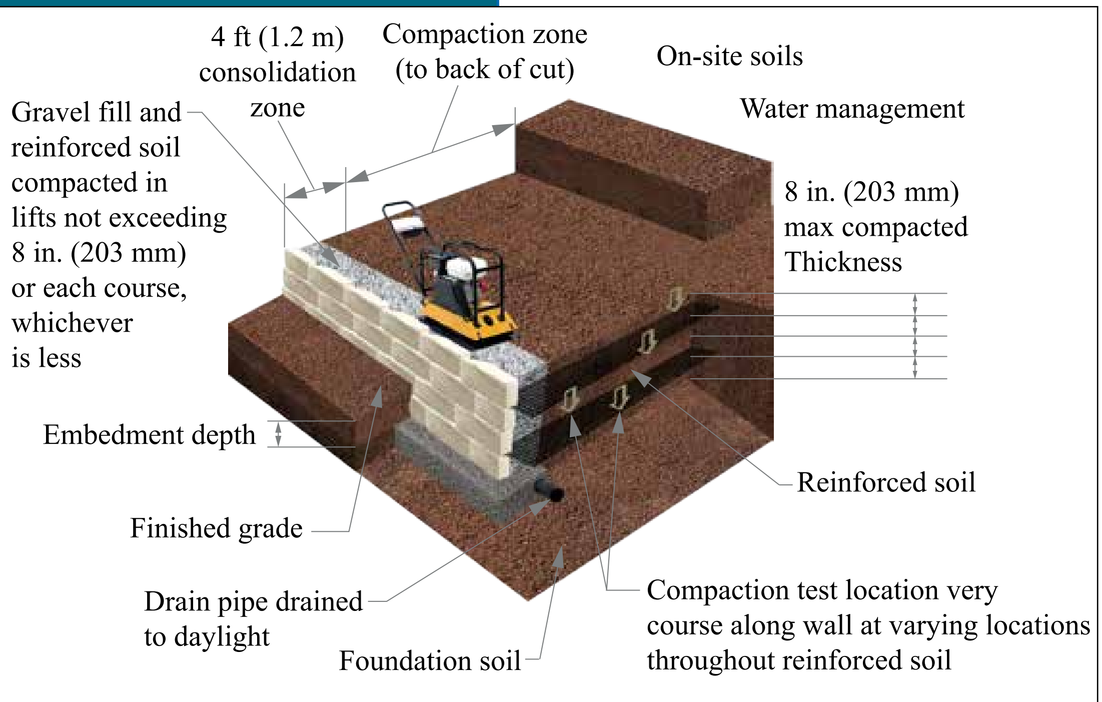

Figure 7. Backfill Placement

Soil Reinforcement Placement

Geogrid reinforcement is an important element in reinforced SRW design and construction. The inspector should verify that the quality and placement of the geogrid has been closely monitored to guarantee the long-term

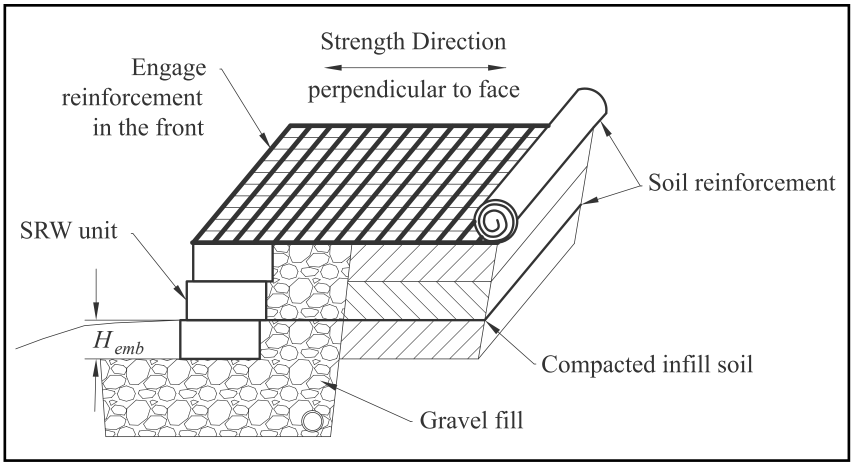

Figure 8. Geogrid Placement

performance of the wall. During construction, the geosynthetic design strength, reinforcement orientation and placement, connection to the block and vertical spacing have to be monitored more closely.

SUMMARY

The use of geosynthetics for construction and the quality reputation of SRWs has revolutionized the civil engineering industry. SRWs provide a structurally stable solution to earth retaining wall problems and offer a valued-added feature to site developments. This article delivers the most up-to-date recommendations to assist designers, owner and specifiers with specifying, designing and building well-performing walls.

This article in the SRW History Market learning series intends to provide designers and contractors with industry 'best practices.' Extensive research on durability, production and design, as well as improved installation and inspection practices, have resulted in reliable SRW construction in various applications.

As addressed in this article, the industry emphasizes the practices that have proven to give the best results on different project conditions. What was learned is summarized here:

- Encourage project, owners to directly contract the services of the SRW Design engineer and the inspection company.
- Materials should meet the requirement for the area and exposure where the project will be located.
- Soils are a key element, and the use of poor quality soils may save the project money initially but, are not a long-term solution (drainage and construction).
- Drainage, drainage, drainage: put effort into controlling groundwater and surface water away from the wall.
- Provide good specifications for the project, communicate what is desired and what is expected.
- Provide a good quality control program and testing to confirm everything meets the project requirements. (Construction QA)
- Contract with a reputable SRW manufacturer to get the product desired. (Production QA)
- Contract with a reputable designer that understands the site, the requirements of design, and has the experience to design for the potential unknowns.(The best design may not be the cheapest, but reflects good judgment on key design items.)
- Contract with an NCMA certified SRW installer that has experience with similar projects. This installer will be able to provide the quality work needed for the project. (Construction QC)

SRWs provide a cost-effective alternative for grade changes on site and are a value-added option to the site. Careful design and construction can ensure that the project gives the owner the high quality, long-term performance expected.

SRWs are one of the best alternatives for retaining walls from both cost and aesthetics and with good practice they will only get better.

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