SEGMENTAL RETAINING WALL CONSTRUCTION

SRW HISTORY ARTICLE SERIES

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

INTRODUCTION

Segmental Retaining Walls (SRWs) have progressed from simple landscaping wall solutions used to replace boulder and timber tie retaining walls in the 1980s to one of the major types of mechanically stabilized earth (MSE) walls used in residential, commercial and transportation construction around the world. In the mid-2000s it was estimated that SRW construction exceeded 300,000,000 million ft^2 (28 M m^2) per year.

Figure 1. Geosynthetically Reinforced Soil–Integrated Bridge System (GRS-IBS) Walll

Many walls have been built successfully to heights exceeding 70 ft (21 m) with techniques developed since the 1980s. In addition, the outstanding performance of SRWs under seismic conditions has been proven through research (Research Article Ref. 17) and actual case studies. Recent research (Ref. 11, 14, 15) continues to show that designs using current established design methodology are very conservative (Allen and Bathurst, Ref. 2). In AASHTO LRFD Bridge Design Specifications, 6th edition, 2012 (Ref. 1), seismic design is not mandatory for walls with simple geometry with seismic accelerations less than 0.4 g. All these referenced documents confirmed the strong performance of SRWs and show how well MSE walls can perform with good quality design, materials, and construction.

Figure 2: Poor Installation Example

(The reinforcement has been installed in the wrong direction, the geogrid is not horizontal or taut, the geogrid was not installed all the way to the front of the unit, and the soil and gravel have not been compacted)

Previous NCMA articles have discussed the development of SRWs, the different types of walls available, the changes in the design, and specifications (Ref. 17, 19, 20, 21, and 22). Recently, the Federal Highway Administration (FHWA) introduced the Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS) system which incorporates SRW units and geosynthetic reinforcement to build bridge abutment retaining walls. This new application, with well-known materials, is gaining momentum with DOTs across the country.

Construction is considered the most critical element as the performance of SRWs is highly depended on the quality of construction. Thus, the National Concrete Masonry Association (NCMA) continuously develops resources for contractors and educates them in understanding the SRW design considerations and the importance of the recommended SRW construction practices (Ref. 17).

This article is intended to discuss all the important elements and provide best practices of SRW construction from the responsibility of parties in a project, site conditions per design, materials to construction itself. (A poor construction example can be seen on Figure 2)

GENERAL

Site Conditions

Site conditions by definitions are:
A contract clause that typically requires the contractor to, at a minimum, inspect and understand the grade level and above-ground job site conditions prior to the start of any construction activities. The clause may also obligate the contractor to take full responsibility for the site's subsurface conditions. (Dictionary of Construction.com, 2015).

Before starting the construction process, a site review is recommended to verify that existing and proposed finish grades shown on the drawings are in agreement with the topographic information from the project grading plan, structures or utilities in the project agree with the information used for the design and are incorporated as they will affect the retaining wall. If the site conditions vary from the construction documents, then it is recommended to always notify the designer to evaluate a solution and authorize modifications.

While above-grade conditions may be obvious from observing the site, subgrade conditions may not be evident. It is recommended that subsurface investigations be done at the project site to determine soil conditions necessary for design and conditions of the subgrade to support the load of the proposed wall. It is also a good practice for the geotechnical engineer to discuss the geology of the region, and previous use of the property. Two areas of concerns should be reported:

1. Buried pipes, utility trenches, and previous use of the site
2. Fill zones on the site

When building over buried utilities, the utility trenches may not be well compacted resulting in the wall settling. The structural performance of the wall may not be compromised, but the dip in the wall will be noticeable. When building over construction fills, the soils may not be uniformly compacted and there is a chance that differential settlements or bearing problems may occur. The site engineer should note these items in the geotechnical report and give options for correction. Proof rolling of the foundation before placing the leveling pad may identify areas of weak soils or areas that need correction that will have to be reported to the SRW design engineer and to be addressed with the geotechnical engineer of the project.

Table 1—Gravity SRW Design Heights for Various Unit, Soil and Wall Properties
(refer to cases on Figure 1 and design parameters on next page)

Level conditions w/50 psf surcharge—Cases 13 and 14							
Unit width, in. (mm)	ϕ (deg)	Retained unit weight = 110 pcf (1,762 kg/m³)			Retained unit weight = 120 pcf (1,922 kg/m³)		
		Max. wall height, ft (m), for wall batter of:			Max. wall height, ft (m), for wall batter of:		
		5°	10°	15°	5°	10°	15°
12 (305)	28	2.0 (0.60)	2.0 (0.60)	2.6 (0.79)	1.3 (0.39)	2.0 (0.60)	2.0 (0.60)
24 (610)	28	4.6 (1.40)	5.3 (1.61)	6.6 (2.01)	4.6 (1.40)	5.3 (1.61)	6.0 (1.82)
12 (305)	34	2.6 (0.79)	3.3 (1.00)	4.0 (1.21)	2.6 (0.79)	3.3 (1.00)	4.0 (1.21)
24 (610)	34	6.0 (1.82)	7.3 (2.22)	8.0 (2.43)	6.0 (1.82)	7.3 (2.22)	8.0 (2.43)

Slope 3:1—Cases 15 and 16							
Unit width, in. (mm)	ϕ (deg)	Retained unit weight = 110 pcf (1,762 kg/m³)			Retained unit weight = 120 pcf (1,922 kg/m³)		
		Max. wall height, ft (m), for wall batter of:			Max. wall height, ft (m), for wall batter of:		
		5°	10°	15°	5°	10°	15°
12 (305)	28	2.0 (0.60)	2.0 (0.60)	2.6 (0.79)	2.0 (0.60)	2.0 (0.60)	2.0 (0.60)
24 (610)	28	4.0 (1.21)	4.6 (1.40)	5.3 (1.61)	4.0 (1.21)	4.0 (1.21)	4.6 (1.40)
12 (305)	34	2.6 (0.79)	3.3 (1.00)	4.0 (1.21)	2.6 (0.79)	3.3 (1.00)	3.3 (1.00)
24 (610)	34	6.0 (1.82)	7.3 (2.22)	8.0 (2.43)	5.3 (1.61)	6.6 (2.01)	7.3 (2.22)

Table 1: NCMA TEK 15-5B, Gravity SRW Design Heights

Design

The design of the SRWs should be done by a qualified professional. In smaller walls or where building codes do not require a design by a professional, the design may be acquired from design charts provided by the SRW system supplier. The contractor should confirm the conditions on the site match the standardized design.

Table 1: NCMA TEK 15-5B, Gravity SRW Design Heights shows some example design heights for a silty sand soil ($\phi > 28°$), and a small surcharge above the wall. The contractor should be aware the site conditions should match the tables used and that the backfill soils need to be a granular material (clays and silts don't qualify). In the article on SRW Design (Ref. 18) and the NCMA Design Manual (Ref. 7, 8, 9) the guidelines for design suggest:

- The maximum design height is around 2.5 times the depth of the unit (e.g. a 12 in. (300 mm) unit would have a design height of 30 in. (762 mm) from the leveling pad for level back slopes, no surcharges, no water, and no front slopes.)
- Maximum spacing between soil reinforcing layers should be 24 in. (600 mm) that is normally 2x the unit depth, but never exceeding 32 in. (800 mm).
- The minimum length of reinforcing should be 60% of the wall height or 4 ft (1.2 m) and for pullout extend 1 ft (300 mm) beyond the failure plane or as required by design.

Drainage

Water is always a concern with retaining walls. A good percentage of SRW wall failures are caused by groundwater not accounted for in the design. Materials such as clays and silts in the backfill are a concern and groundwater coming from the cut in the wall area. (See examples of groundwater in the back cut on Figure 3).

The designers may not have been aware of these conditions during the design. If the presence of groundwater is observed in the field, then this information should be brought to the attention of the SRW designer. In this case, the designer may decide to include a chimney drain (a gravel layer installed at the back of the reinforcement area) to capture and divert the water from the reinforced zone (See Figure 4). A normally designed SRW will not perform well with a constant source of water in the backfill. There are different solutions to deal with water in the back of the wall that are detailed in the NCMA Design Manual (Ref. 9). In cut situations it may be a good practice to install a drain at the back of the cut to intercept groundwater that may be traveling through the native ground. When groundwater exists the pipe installed behind the facing of the wall cannot be relied as the single drainage path and other measures should be included in the wall.

Also the designer and contractor should evaluate surface water of every project and address surface drainage as needed. It is very common to include a drainage swale behind the face

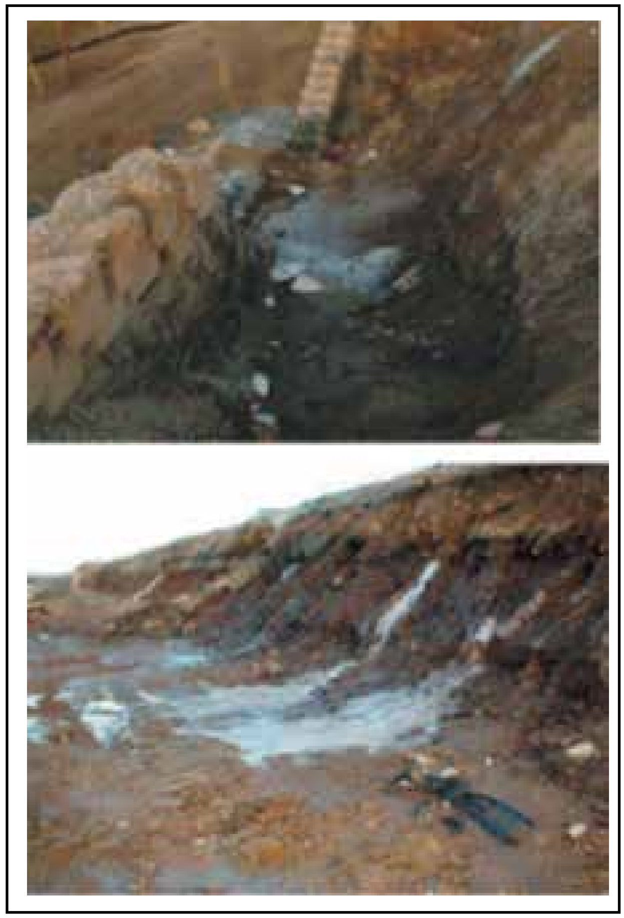

Figure 3. Groundwater (Koerner, Ref. 13)

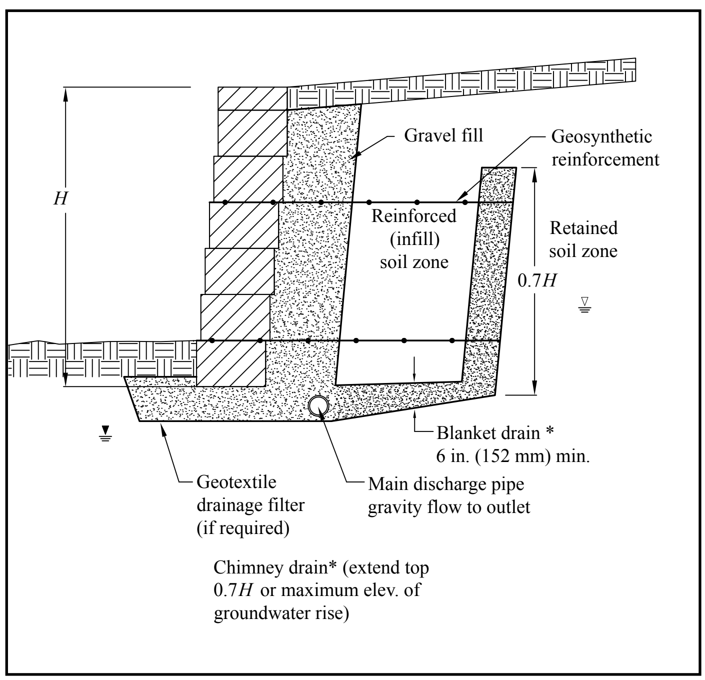

Figure 4. Chimney Drain Example (Ref. 13)

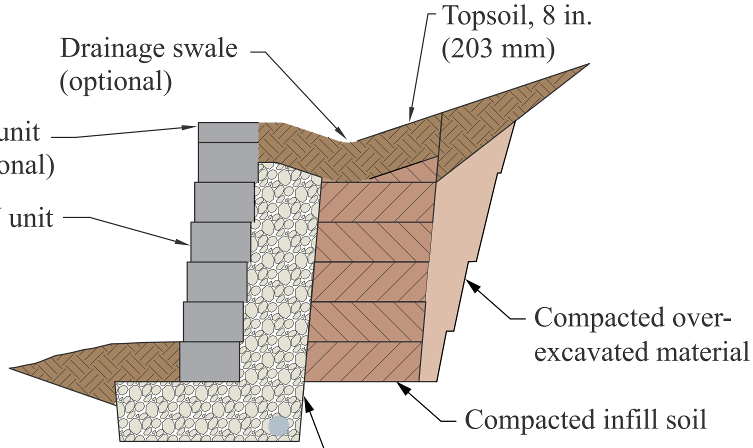

Figure 5. Drainage Swale Used for Surface Drainage (Ref. 9)

of the wall (see Figure 5) and if necessary a second swale behind the reinforcement. Regardless of the type of wall, SRW, concrete panel wall, or reinforced concrete wall, structure not specifically designed for water applications would likely fail by movement or overturning because the water's hydrostatic pressure (load increases to about 2 times the original load).

MATERIALS

A good percentage of problems in the field are caused when materials specified are switched intentionally or they change naturally and no longer meet the needed specifications during the construction process. Soil changes, by far, are some of the most common problems and can have the biggest impact in the behavior of the system.

Gravel Fill

The gravel fill material is placed inside, between and behind the SRW facing units and helps with the compaction close to the SRW units, and to evacuate incidental water in that area. The recommend material for this area is a well-draining clean crushed stone. The NCMA specifications are shown in Table 1.

Table 1: Gravel Fill

Gravel fill shall be a clean crushed stone or granular fill meeting the following gradation as determined in accordance with ASTM D 422 (Ref. 24):

Sieve Size	Percent Passing
1 in.	100
3/4 in.	75 - 100
No. 4	0 - 60
No. 40	0 - 50
No. 200	0 - 5

Note the percent fines (Sieve size < No. 200) is less than 5%.

The leveling pad may be constructed with the gravel fill or with a crushed stone base material depending on the drainage needs in the wall.

Reinforced Fill

The reinforced fill is a compacted structural fill placed behind soil-reinforced SRW units to the tail end of the reinforcement placed behind the wall. The NCMA specifications recommend backfill materials with no more than 35% fines and organic materials are not allowed.

Table 2: Reinforced Fill

Sieve Size	Percent Passing
1 in.	100
No. 4	20 - 100
No. 40	0 - 60
No. 200	0 - 35*

* The plasticity index of the fine fraction of the reinforced soil (PI) shall be less than 20 tested in accordance to ASTM D4318, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils (Ref. 4); taller applications may require PI < 5 to 10.

* Transportation specifications require no more than 15% fines and PI< 6.

Authors Berg (Ref. 6) and Koerner (Ref. 13) recommend that this specification be converted to a more free draining fill to reduce the likelihood of problems in the wall. NCMA (Ref. 9) has shown that walls can be built with high fines content soil and perform well, even when they were designed to fail (the walls in the Geocomp study were designed to fail under hydrostatic load, but did not fail structurally). Figure 6: NCMA Test Wall Gradation, shows the gradation of the soil used in the NCMA test Wall Y with 60% passing the No. 200 sieve (almost double the NCMA recommendation on fines content) and the control Wall X . There was more movement in the segmental retaining wall Y than was noted in the walls with better fill materials (Wall X), but it still performed well. *When fine grained soils are used, drainage and compaction must be addressed specifically. The use of clay fines should be avoided.*

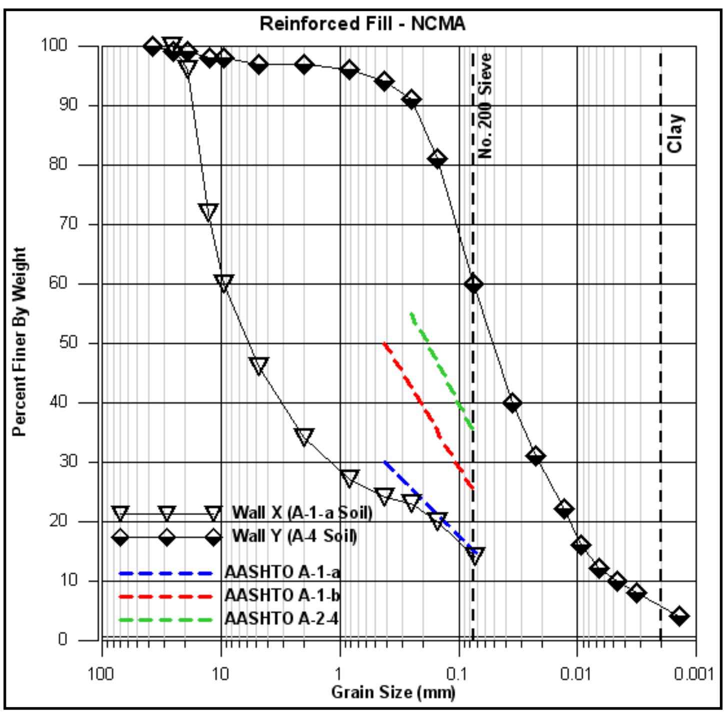

Figure 6. NCMA Test Wall Gradation (Ref. 11)

CONSTRUCTION

Compaction

Due to the nature of the SRW systems, compaction is a very important part in the construction process to increase density and soil strength, and reduce the settlement in the soil. The compaction is achieved by applying a load (energy) to the soil placed in adequate lifts. The soil strength properties are a function of density, i.e. a loose soil is weaker than a dense soil. Settlement is caused when the soil compresses under its own weight, or its own weight plus any surcharge load, to form a more dense structure. A well compacted fill soil could settle anywhere between 0.5% to 1% of its total height (i.e. a 10 ft (3 m) wall could experience 3/4 in (20 mm) to 1.5 in. (40 mm) settlement) under self-weight. A loose soil will settle much more causing serious problems that could lead to the failure of the wall.

NCMA recommends placing the fill in 6 to 8 in. (152 to 203 mm) lifts, compacting each lift to meet the specified densities usually equivalent to a minimum 95% of standard proctor density (ASTM D698, Ref. 17). 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.

Poor compaction practices, such as the increase in the lift thickness, or not compacting at all to speed construction (see Figure 2) causes big settlements in the fill (i.e. some walls have shown between 3% to 5% in partially compacted walls, see Figure 7), not compacting behind the SRW

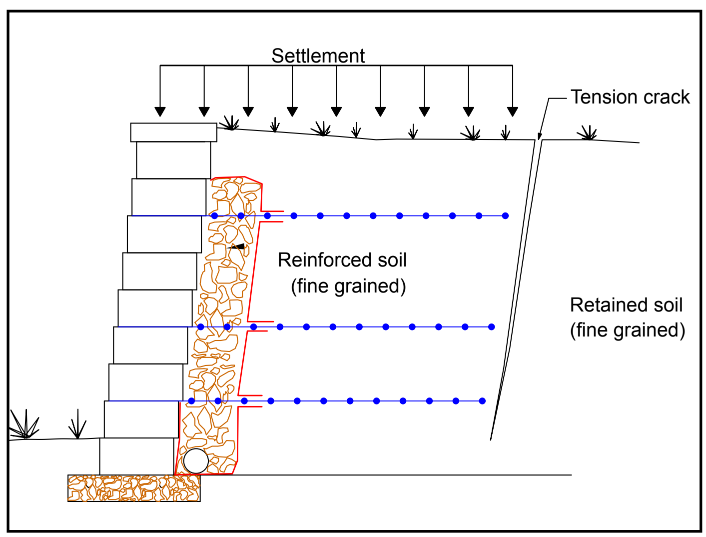

Figure 7. Failure Due to Poor Compaction behind the Reinforcement

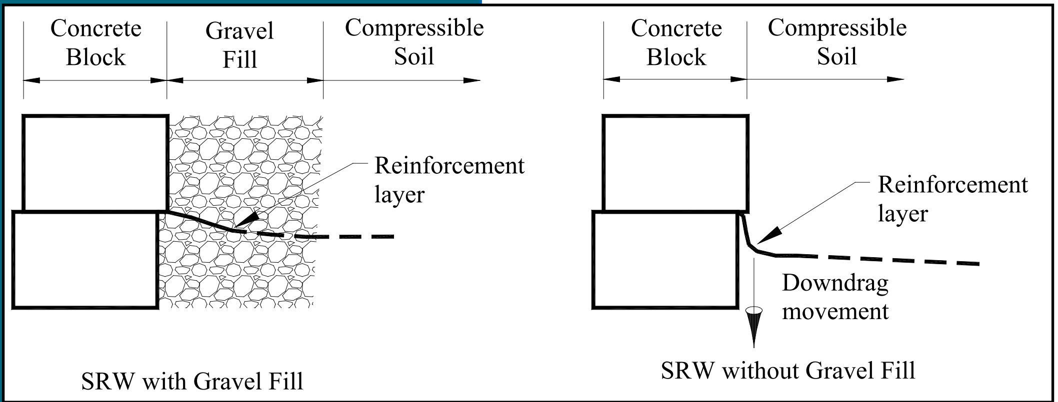

Figure 8. Drag-down on SRW Reinforced Walls

units may also cause downdrag of the geogrid (see Figure 8).

Another observed problems are the outward movement of the facing caused by the use of big equipment too close to the wall face and the development of a tension crack behind the reinforcement due to the lack of compaction in the area that ultimately will allow for damaging water to infiltrate.

Compaction Testing

Compaction testing is used to verify that the soils are being placed meet the density specified. The compaction equipment used has limitations and the reader must be aware that the compaction testing only verifies the density of the soils at the surface (6 in. (150 mm) to 8 in. (200 mm)). If thicker lifts are proposed/used, the testing agency should dig down and test the bottom portion of the fill lift. Another technique that may cause issues later is the practice of only testing in the back of the reinforced zone where big equipment is used, we must emphasize that the compaction requirements are the same for all regions in the wall regardless of the compaction equipment used. Please note, we do not recommend fill and compaction lifts of over 8 in. (200 mm) in any case.

A good practice in soil placement is to place the first 8 in. (200 mm) lift and make about three passes with the compaction equipment over the soil. Compaction testing is performed and if the fill passes, then this procedure is used for the rest of the construction. If the test does not pass, more passes will be necessary or a thinner lift thickness until consistent, passing results are obtained. Further compaction testing during construction confirms the procedure established is valid and verifies requirements of the specification; it does not confirm the whole soil fill is placed to specification requirements. Remember that this procedure is only applicable if there are no changes in the material, equipment and moisture conditions.

Fill Placement

We have spoken about fill placement in the preceding paragraphs, but it cannot be emphasized enough for good performance. The fills should be placed in 6 in. (150 mm) to 8 in. (200 mm) lift thicknesses or less if the equipment is small. The fill should be placed from the wall face proceeding backward toward the tail of the soil reinforcement and compacted parallel to the facing from the front of the wall to the tail of the reinforcement. By placing fills in this manner the soil reinforcing is tensioned, the SRW-geogrid connection is engaged as the slack is pushed toward the tail.

We know that the soil fill will settle under its own weight anywhere between 0.5% to 1% of the wall height. The NCMA Design Manual recommends a gravel fill zone behind the SRW units to create a transition between the rigid, uncompressible face and the soil (See Figure 8). This zone provides drainage at the face, but more importantly it is a stiffer layer that reduces compaction effort necessary to compact well at the face and reduces the amount of drag down at the face that potentially lead to performance problems.

Compaction Loading

Compaction loading on the wall is not verified specifically by NCMA or by the transportation markets but it is indirectly addressed by specifying that “heavy compaction equipment shall not be used closer than 3 ft (1 m) from the wall.” Why? Because if large compaction equipment is used the wall face will lean forward whether it is an SRW facing, a concrete panel facing, or a rigid reinforced concrete wall; compaction forces can be large and each system has different limitations.

The U.S. Army Corps of Engineers has addressed compaction loading in their design manual DM7 (Ref. 16). Figure 9: Compaction Stresses, shows the relationship of horizontal loading to the location can compaction effort of the equipment used. While designers use the dotted line (active earth pressure line) in design and calculations, the contractor has to deal with the solid line during construction. How does the contractor deal with the loading?

- Move the compaction equipment back further from wall,
- Use a larger stone fill area, or
- Reduce or eliminate compaction at the face.

Table 3: FS for Overturning by Compaction for 2 ft (600 mm) Lifts

Overturning on a 2 ft (600 mm) Compaction Hight		
$M_o =$	205	ft lbf
$M_r =$	225	ft lbf
$FS_{ot} =$	1.10	

Table 4: FS for Overturning with 16 in. (406 mm) Lifts

Overturning on a 16 in. (406 mm) Compaction Hight		
$M_o =$	121	ft lbf
$M_r =$	174	ft lbf
$FS_{ot} =$	1.44	

If Figure 9 – Compaction Stresses is assumed correct and a small compactor is used on the 3 ft (1 m) closest to the face of the wall and a 2 ft (600 mm) lift, the factor of safety of overturning is 1.1. If a 16 in. (400 mm) lift is used with the same compactor 1 ft (300 mm) from the face the factor of safety is 1.4. FHWA, in the development of the GRS-IBS system (Ref. 3), specifies a layer of reinforcement on EVERY course (8 in. (200 mm)). Does it appear there was some wisdom with that option? It is also know that contractors prefer the large block units (21 in. (500 mm)) over the standard 12 in. (300 mm) SRW unit because the units are more stable during construction. Does there seem to be some logic in that choice? The bigger units cost more thus more emphasis on the smaller units, but are the benefits not fully realized? Although deeper units provide more stability during construction fill and compaction lifts of no more than 8 in. (200 mm) is still required. (See Table 1: NCMA TEK 15-5B, Gravity SRW Design Heights. Design heights (stability) are greatly increased with larger units.)

Geogrid Placement

The NCMA specifications and general construction specifications indicate the reinforcing material should be placed where specified to the front of the SRW unit to fully engage the connection between the unit and the geogrid. The specifications are also clear and the geogrid should be placed so the strength direction is into the fill zone and perpendicular to the face of the wall. (Figure 2 – Poor Installation shows a problem we have seen in the field where the geogrid reinforcement is installed in the wrong direction).

The maximum spacing between geogrid layers is recommended to be 24 in. (600 mm), but never exceeding 32 in. (800 mm) for deep units, and for modular blocks that are less than or equal to 10 in. (254 mm) in depth, it is recommended that the maximum vertical spacing of the reinforcement layers be no more than twice the depth of the unit. When these recommendations are overlooked due to errors or intentional changes during construction, the wall face will move causing problems in the long run (see Figure 20).

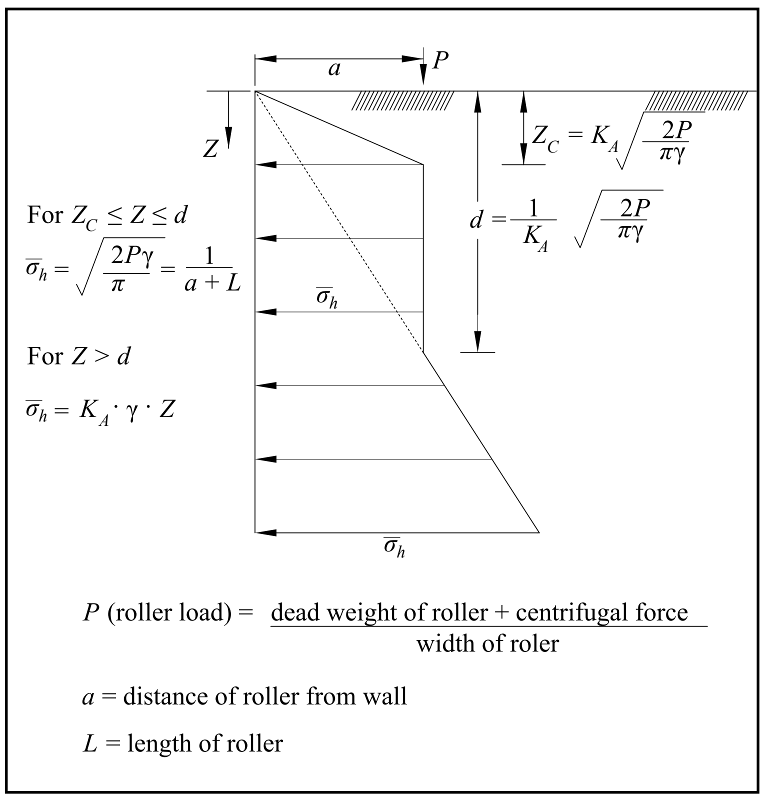

Figure 9. Compaction Stresses (Ref. 16)

Changes to the Design Height

Figure 10. Unsupported Wall

The design of SRWs can only be accomplished with complete wall geometry in addition to soil conditions and surcharges on the wall. The designer should be notified of any changes to the design such as wall geometry and loading conditions. For example, we often see the following items occurring in construction:

1. To save money, the wall face is kept short and a steep slope is constructed above the wall, or
2. The wall is constructed and found to be too short for what was intended, so additional face units are place to get to the desired height.

Steep Slope Options

Option 1 may sound like a good idea, but the reinforcing length (minimum 60% L/H) is based on a level wall condition. Increasing the slope above the wall will increase the length of the necessary reinforcing length to 80% or 100% of the wall height, so what is saved on the facing is spent on extra excavation and soil reinforcing. This also may not have been in the initial design, and thus the factors of safety no longer conform to industry standards. Option 1 has also been done where the slope angle is steeper than the internal friction angle of the backfill soils, thus the slope is unstable and may fail causing damage to the underlying retaining wall. The contractor needs to be aware of these conditions, as does the wall designers.

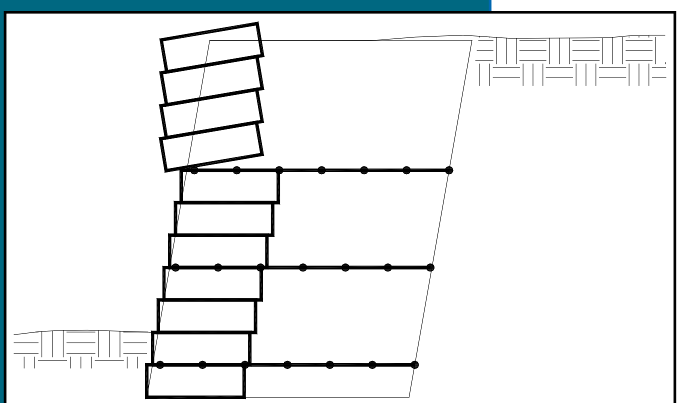

Figure 11. SRW Failed Because the Upper Layer of Geogrid is Missing

Top of Wall Failure

The second option is probably seen more often where just a "few more units" will get the wall to a better height. Figure 10 and Figure 11 show how the top units can tumble down due to the absence of reinforcement at the top of the wall. The maximum stable unreinforced height for any segmental retaining wall system is determined in the design and cannot be overlooked without consequences.

CONSTRUCTION TECHNIQUE

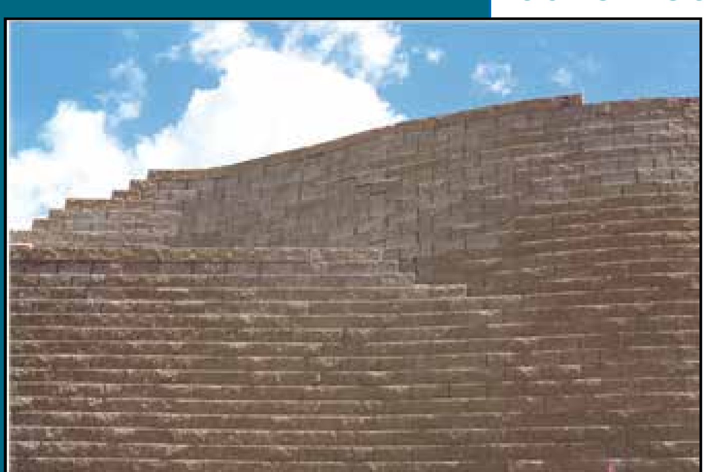

Figure 12. Partially Terraced Wall

Construction and techniques are harder to document and, unfortunately, construction items not well documented may present a wall that performs structurally (holds back the soil), but does not look very good. The following are some of the wall features that require special attention in the field.

Partially Terraced Walls

A partially terraced wall is a structure where the two terraces (upper and lower) come back together to form a taller wall. Figure 12 – Partially Terraced Wall shows a tall wall where the center part of the wall came out to form a planting area.

Figure 13. 90 Degree Corner

Figure 14. Convex Curve
(Courtesy of Keystone Retaining Walls)

A concern in this type of application is that the concrete facing units are rigid and do not compress under a load where the soil backfill will settle (i.e. 0.5% to 1% of the wall height). As the backfill settles the wall above it settles and forms a dip on the upper terrace causing cracking and opening of wall units. The wall will still perform well but may have aesthetic issues.

90 Degree Corners and Convex Curves

90-degree corners on any structure concentrate stresses that depending on the system have to be addressed. For example, in a reinforced concrete wall extra tension steel is placed across the corner to handle the stresses. SRWs have little strength for tension along the face with just a frictional connection between units. In a 90-degree corner, active earth pressure is pushing both sides of the wall out, causing tension in the corners. The result may be cracking in the corner as the wall adjusts to the new loads or the joints start to open.

A solution is the use of a radius corner and using as much clean gravel behind the facing units as possible to reduce the loads.

Another solution in a 90-degree corner is for the contractor to cut each unit at 45 degrees and glue them together for a 90-degree corner. Again, not the ideal option, the earth pressures will push the units apart leaving an open gap in the corner. Most SRW products have special units for 90-degree corners.

Terraced Walls

A terraced wall is where one wall sits above and back from a lower wall (See Figure 15). When the setback

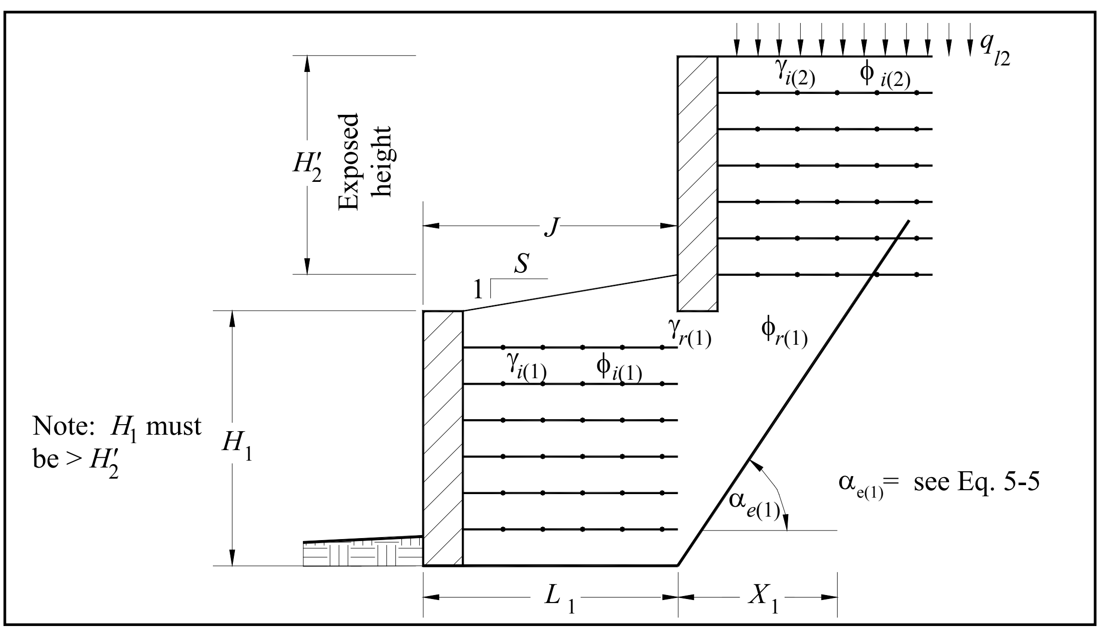

Figure 15. NCMA Terraced Wall

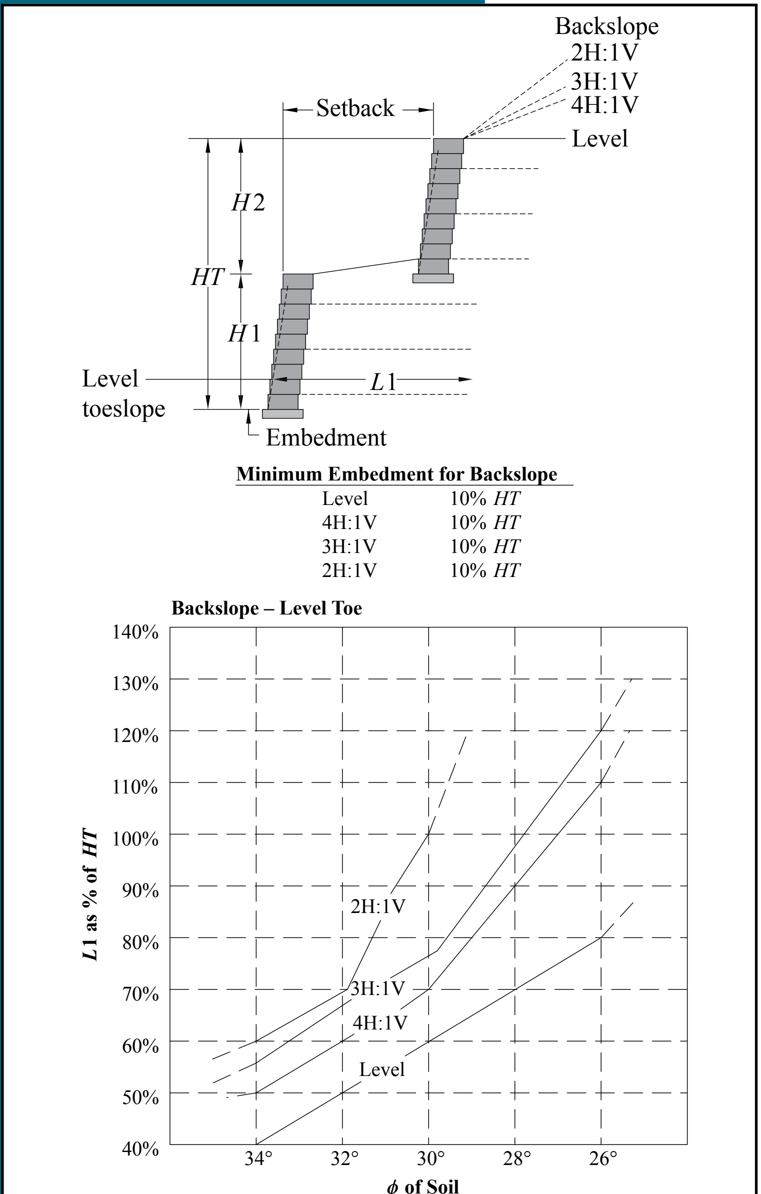

Figure 16. Terraced Wall Design Chart,(Ref. 27)

of the upper wall is more than twice the height of the lower wall (the lower wall must be the tallest), the internal design of the lower wall is not affected by the upper wall and they are both considered independent structures. Unfortunately, to get around the code requirements for design (walls taller than 4 ft (1.2 m) some contractors install two 4 ft (1.2 m) walls, one above the other with a small distance between the tiers. Each wall, designed as an independent 4 ft (1.2 m) wall. As a result, the load from the upper wall loads the area behind the lower wall causing a sliding failure on the lower wall, or a global failure.

For a terraced wall design, a global stability analysis is required. The length of geogrids in the lower wall can easily be at least 70% of the TOTAL wall height. Only a global stability analysis can confirm the final design. NCMA recommends that for tiered walls closer than 2 times the height of the lower wall the system be engineered and a global stability analysis be done (see TEK 18-11B).

NCMA has a few TEK on global stability and Terraced Wall design (Ref. 25). There is other literature that is available, but a reference from an NCMA member company makes some good points (Ref. 27). A wall with a level toe and a sandy backfill (ϕ = 30°) will require a minimum of 70% of the total wall height for reinforcing lengths in the bottom wall. A wall with a slope above the walls will require 70% to 100% of the total wall height. It is assumed that H1 ≃ H2 ≃ Setback. Thus a 4 ft (1.2 m) wall with 4 ft (1.2 m) geogrids may not perform well to meet a suggested value of 70% of 8 ft (2.6 m) total height, or 5.6 ft (1.7 m) would be a minimum length. If you looked at two 8 ft (2.6 m) walls, 60% of the base wall is 4.8 ft (1.5 m) versus 70% of 16 ft (4.9 m) or 11 ft (3.4 m). With taller walls the error accelerates quickly.

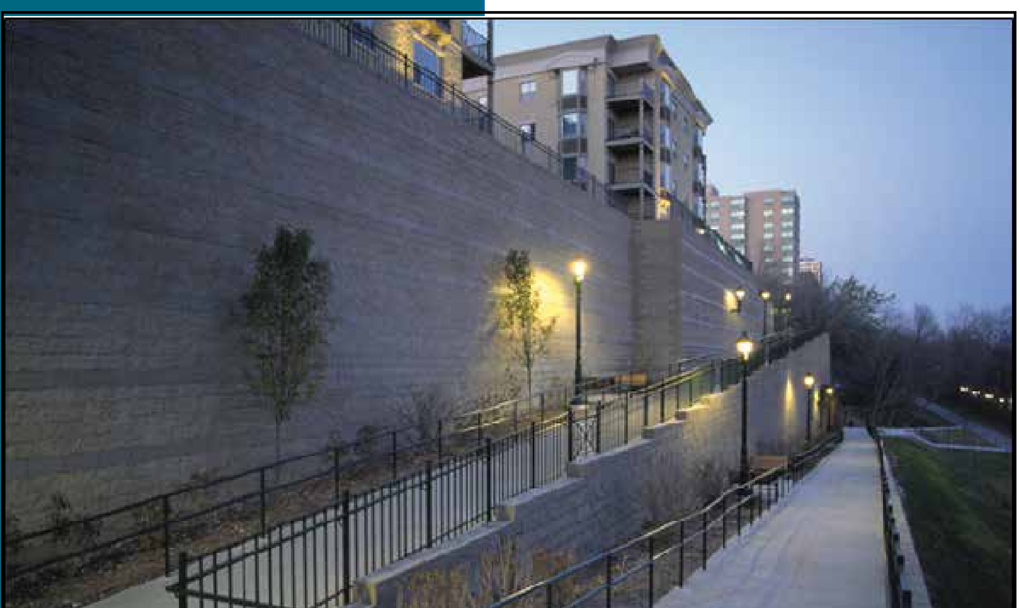

Figure 17. Terraced Design

Figure 17 – Terraced Design, shows a 50 ft (15.2 m) tall SRW successfully designed and built as a terraced wall that is performing as designed. The theory may sound difficult, but with the right tools and knowledge it is technically straight forward to have a great project.

GLOBAL STABILITY

Global stability is the overall stability of the wall system, as it analyzes the soil above and below the retaining

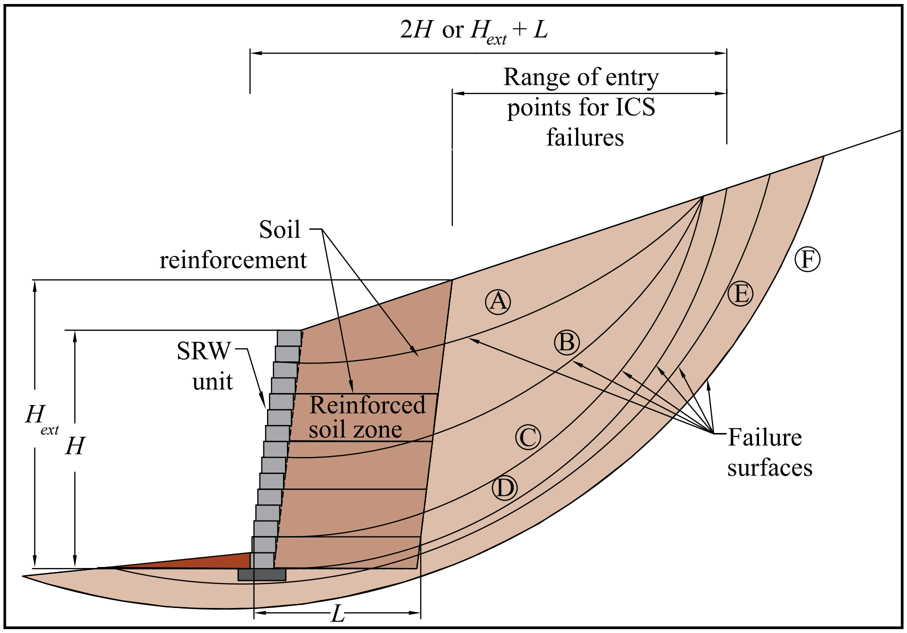

Figure 18. Global Stability Failure Surfaces (Ref. 25)

wall (See Figure 18 for potential failure planes). Global stability may control the design and should be checked when:

- groundwater table is above or within the wall height of the SRW,
- a 3H:1V or steeper slope at the toe or top of the SRW,
- for tiered SRWs,
- for excessive surcharges above the wall top,
- or seismic design, and
- when the geotechnical subsurface exploration finds soft soils, organic soils, peat, high plasticity clay, swelling or shrinking soils or fill soil (See example Failure Surface E and F on Figure 18).

The main problems seen in the field are due to the lack of appropriate analysis causing the projects to fail because they never detected and addressed a global stability problem. In global stability failures, it is not uncommon to see the soil around the wall move in a circular failure, keeping the SRW as a coherent mass (See Figure 19). Examples of problems regularly ignored are weak foundation soils, steep top and toe slopes, high loads, and tiered walls.

Figure 19. Global Stability Failure Example

The global factor of safety of an SRW is a function of: the soil characteristics, groundwater table location, site geometry (i.e., sloping toe or crest, tiered walls), and the length, strength and vertical location of soil reinforcement (geosynthetic). The effects of each of these factors will greatly influence the final design and should be analyzed with the necessary care. For more information on the subject reader is directed NCMA TEK 15-4B, Global Stability of Segmental Retaining Walls (Ref. 25).

Internal Compound Failure

Compound failures are special cases of global stability and occur when a slip plane cuts through the retained soil, the reinforced mass, and through the face of the wall (See Surface Failures A-D on Figure 18). Increased grid lengths, closer grid spacing, higher strength grids, and/or higher strength soils in the reinforced mass all increase the resistance of a potential slip plane to develop and thereby increase the factor of safety to prevent failures of this kind.

Figure 20 – Internal Compound Stability Failure, depicts a wall were the geogrid spacing was the problem and the wall face bulges.

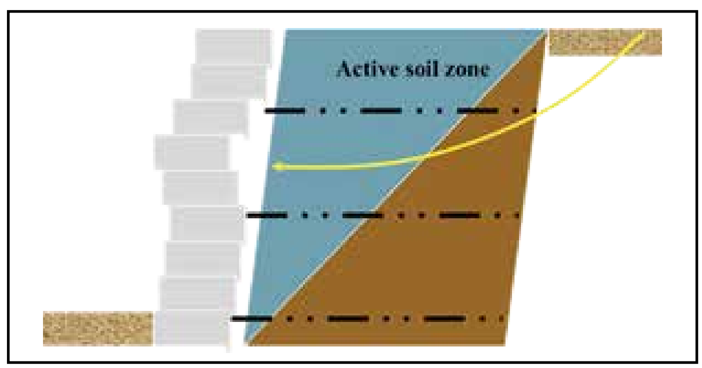

Figure 20. Internal Compound Stability Failure

SUMMARY OF CONSTRUCTION

In this article, the most common issues overlooked in the design and constructions of SRWs were discussed. It is the intention of this reference to help the reader to avoid these common mistakes and help with the successful installation of SRWs.

Figure 21. Successful SRW Applications

The success in the construction starts with the appropriate design, the selection of good quality materials and the appropriate attention to detail in the installation process. Design heights, grid lengths, spacing and site condition should meet the designed conditions; if they do not then the designer should be notified. Materials should meet the project specifications and industry recommendations. Compaction of all the soils must be done carefully and thoroughly to ensure the behavior of the soil. Details such as corners and curves should use as much gravel as possible and be compacted carefully, partially tiered walls should be carefully constructed and terraced walls should be built to meet specifications after a careful design if the walls are closer than two times the height of the lower wall (2xH1).

There are thousands of segmental retaining walls constructed around the world performing well. AASHTO has acknowledged that MSE walls (SRW is one example of this type of walls) are very stable in seismic conditions; FHWA is building bridge abutment walls with SRWs and mining companies are using them for truck loading ramps. This still doesn't consider the millions of square feet (sm) of wall built for residential and commercial applications that are installed annually with exceptional results.

NCMA and the industry are working hard to educate the contractors and designers in good practices and to understand design and performance. Every one of the problems referenced in this paper are avoidable by following industry recommendations, observing and adjusting to site conditions, and when changes were made, go back to the design professionals for advice.

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