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TEK 18-11B

INSPECTION GUIDE FOR SEGMENTAL RETAINING WALLS

INTRODUCTION

Segmental retaining walls (SRWs) are gravity retaining walls which can be classified as either: conventional (structures that resist external destabilizing forces due to retained soils solely through the self-weight and batter of the SRW units); or geosynthetic reinforced soil SRWs (composite systems consisting of SRW units in combination with a mass of reinforced soil stabilized by horizontal layers of geosynthetic reinforcement materials). Both types of SRWs use dry-stacked segmental units that are typically constructed in a running bond configuration. The majority of available SRW units are dry-cast machine-produced concrete.

Conventional SRWs are classified as either single depth or multiple depth. The maximum wall height that can be constructed using a single depth unit is directly proportional to its weight, width, unit-to-unit shear strength and batter for any given soil and site geometry conditions. The maximum height can be increased by implementing a conventional crib wall approach, using multiple depths of units to increase the weight and width of the wall.

Reinforced soil SRWs utilize geosynthetic reinforcement to enlarge the effective width and weight of the gravity mass. Geosynthetic reinforcement materials are high tensile strength polymeric sheet materials. Geosynthetic reinforcement products may be geogrids or geotextiles, although most SRW construction has used geogrids. The geosynthetic reinforcement extends through the interface between the SRW units and into the soil to create a composite gravity mass structure. This enlarged composite gravity wall system, comprised of the SRW units and the reinforced soil mass, can provide the required

resistance to external forces associated with taller walls, surcharged structures or more difficult soil conditions.

Segmental retaining walls afford many advantages, including design flexibility, aesthetics, economics, ease of installation, structural performance and durability. To function as planned, SRWs must be properly designed and installed. Inspection is one means of verifying that the project is constructed as designed using the specified materials.

This TEK is intended to provide minimum levels of design and construction inspection for segmental retaining walls. The inspection parameters follow the Design Manual for Segmental Retaining Walls (ref. 1) design methodology. This information does not replace proper design practice, but rather is intended to provide a basic outline for field use by installers, designers and inspectors.

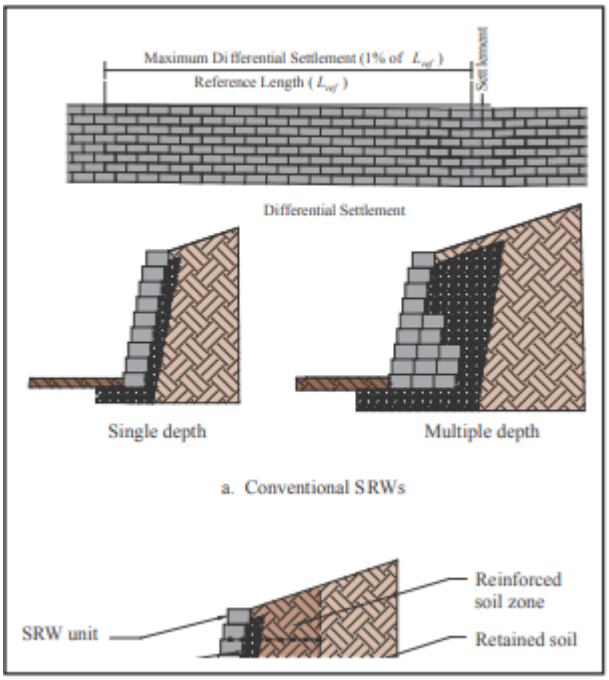


Figure 1–Segmental Retaining Wall Systems

INSPECTION

Many masonry projects of substantial size require a quality assurance program, which includes the owner's or designer's efforts to require a specified level of quality and to determine the acceptability of the final construction. As part of a quality assurance program, inspection includes the actions taken to ensure that the established quality assurance program is met. As a counterpart to inspection, quality control includes the contractor's or manufacturer's efforts to ensure that a product's properties achieve a specified requirement. Together, inspection and quality control comprise the bulk of the procedural requirements of a typical quality assurance program.

SRW UNIT PROPERTIES

SRW units comply with the requirements of ASTM C1372, Standard Specification for Dry-Cast Segmental Retaining Wall Units (ref. 2), which governs dimensional tolerances, finish and appearance, compressive strength, absorption, and, where applicable, freeze-thaw durability. These requirements are briefly summarized below. A more thorough discussion is included in **TEK 2-4B**, Segmental Retaining Wall Units (ref. 3). The user should refer to the most recent edition of ASTM C1372 to ensure full compliance with the standard.

- Dimensional tolerances: ±⅛ in. (3.2 mm) from the specified standard overall dimensions for width, height and length (waived for architectural surfaces).

- Finish and appearance:
  - free of cracks or other defects that interfere with proper placement or significantly impair the strength or permanence of the construction (minor chipping excepted),
  - when used in exposed construction, the exposed face or faces are required to not show chips, cracks or other imperfections when viewed from at least 20 ft (6.1 m) under diffused lighting,
  - 5% of a shipment may contain chips 1 in. (25.4 mm) or smaller, or cracks less than 0.02 in. (0.5 mm) wide and not longer than 25% of the nominal unit height,
  - the finished exposed surface is required to conform to an approved sample of at least four units, representing the range of texture and color permitted.

- Minimum net area compressive strength: 3,000 psi (20.7 MPa) for an average of three units with a minimum of 2,500 psi (17.2 MPa) for an individual unit. When higher compressive strengths are specified, the tested average net area compressive strength of three units is required to equal or exceed the specified compressive strength, and the minimum required single unit strength is:
  - the specified compressive strength minus 500 psi (3.4 MPa) for specified compressive strengths less than 5,000 psi (34.4 MPa), or
  - 90% of the specified compressive strength when the specified compressive strength is 5,000 psi (34.4 MPa) or greater.

- Maximum water absorption:
  - 18 lb/ft³ (288 kg/m³) for lightweight units (< 105 pcf (1,680 kg/m³))
  - 15 lb/ft³ (240 kg/m³) for medium weight units (105 to less than 125 pcf (1,680 to 2,000 kg/m³))
  - 13 lb/ft³ (208 kg/m³) for normal weight units (≥ 125 pcf (2,000 kg/m³ or more))

- Freeze-thaw durability—In areas where repeated freezing and thawing under saturated conditions occur, freeze-thaw durability is required to be demonstrated by test or by proven field performance. When testing is required, the units are required to meet the following when tested in accordance with ASTM C 1262, Standard Test Method for Evaluating the Freeze-Thaw Durability of Manufactured Concrete Masonry Units and Related Concrete Units (ref. 4):

- weight loss of each of five test specimens at the conclusion of 100 cycles ≤ 1% of its initial weight; or

- weight loss of each of four of the five test specimens at the end of 150 cycles ≤ 1.5 % of its initial weight.

DESIGN CHECKLIST

Date of inspection: _____ Contractor: _____

Project name: _____ Engineer: _____

Address: _____ Inspector: _____

The SRW design should be reviewed for general conformance with applicable standards. Based on the design concepts presented in Design Manual for Segmental Retaining Walls, the following guidelines are recommended. Specific guidelines for conventional (i.e., without geosynthetic reinforcement) and for soil-reinforced SRWs are in addition to the general requirements below.

✓	TASK	INDUSTRY RECOMMENDATION
	Wall	Determine retaining wall location, heights, length, top and bottom grades.
	Structures and utilities	Determine structures and utilities that influence the retaining wall and that could be located within the reinforced soil of the wall. Keep them beyond the geosynthetic-reinforced soil zone of the SRW or provide for them in the design.
	Wall loading conditions	Determine location and type(s) of loads above the wall, including dead and live loads, to complete the design.
	Water	Review plans to determine all potential water sources in and around the SRW. Reroute water away from the retaining wall.
	Global stability	Determine if the site conditions or project requirements will make necessary a global stability analysis. If it is necessary, coordinate with the project's geotechnical engineer.
	Seismic design requirements	Determine if seismic design is necessary. If necessary, the project's geotechnical engineer will provide the design parameters.

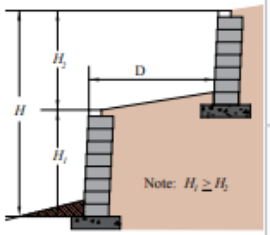
SITE PLAN REVIEW

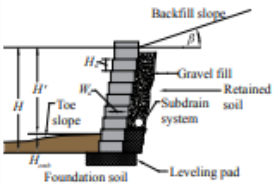
IS ENGINEERING NECESSARY? The 2012 International Building Code (ref. 5), Section 105.2, requires a building permit for earth retaining structures over 4 ft (1,219 mm) in total height

or less if they support a surcharge. In addition, many local building codes or officials require a design prepared by a design professional, although there are many locations without provisions for engineered design. Where there is no specific requirement, NCMA suggests the guidelines in Table 1. Note that local code or ordinances supersede industry recommendations.

✓	DESIGN METHOD	WALL HEIGHT	ALLOWABLE SOIL & FOUNDATION CONDITIONS	RECOMMENDED ENGINEERING REQUIRED
	Method 1: Non-engineered	≤ 4 ft (1,219 mm) from leveling pad to top of wall	Sand/gravel, silty sands, silt/lean clays	Use design chart provided by SRW system provider.
	Method 2: Engineered	> 4 ft (1,219 mm) from leveling pad to top of wall	Sand/gravel, silty sands, silt/lean clays	Have the design section reviewed/prepared by a registered professional.

TABLE 1—DESIGN GUIDANCE FOR SEGMENTAL RETAINING WALLS

For Tiered Walls 	1. If the total combined height is less than 4 ft (1,219 mm), the horizontal spacing between walls (D) is at least twice the height of the lower wall (i.e., $H < 4$ ft (1,219 mm) and $D > 2H_1$), and no surcharges are imposed on the walls, follow Method 1 in Table 1. Where: H_1 is the total height of the lower tier and D is the distance between the front of the lower tier to the front of the upper tier.
	2. In other cases, follow Method 2 in Table 1.

✓	TASK	INDUSTRY RECOMMENDATION
	Gravity or conventional SRWs (without reinforcement)	Wall height: not to exceed manufacturer's design chart maximums.
	Height of unreinforced units at top of wall	As determined from crest toppling design evaluation with a minimum 1.5 factor of safety.
	Embedment depth 	A minimum soil cover should be provided in front of the retaining wall following the recommendation as summarized below for different front slopes and project conditions but never less than 6 in. (152 mm). **Table 2: Minimum Wall Embedment Depth, H_{emb}**

Slope in front of wall	Minimum H_{emb} to top of leveling pad
Horizontal (walls)	$H'/20$
Horizontal (abutments)	$H'/10$
3H:1V	$H'/10$
2H:1V	$H'/7$
Minimum embedment	0.5 ft (152 mm)
Note: H' is the exposed height of the SRW. The global stability could also control the embedment depth when front slopes are present.	

HEIGHT OF THE WALL

✓	TASK	INDUSTRY RECOMMENDATION
	If $H < 4$ ft (1,219 mm) and soils are good (native sandy soils, dense silts, and low plasticity stiff clays)	Local experience can be applied for design recommendations.
	If $H > 4$ ft (1,219 mm) or soft foundation soils are present	Subsurface exploration is necessary to provide friction angle, cohesion and unit weight for wall design.
	Soft soils, organic soils, peat, high plasticity clay or silt soil or for building over fill soils	Professional engineering assistance is required.

FOUNDATION SOILS EVALUATION

✓	TASK	INDUSTRY RECOMMENDATION
	Soil type and properties should be carefully determined and provided properties should be monitored during construction to ensure the design parameters are met.	• Granular soils are recommended for SRW construction. • As industry standard, NCMA recommends soils having less than 35% fines. • For soils with more fines than recommended by NCMA (greater than 35% fines) and low plasticity (PI < 20), a geotechnical engineer should be involved in the design to ensure proper definition of soil strength properties and verification that the soils are not susceptible to time dependent movement, i.e. soil creep. • High plasticity silts and clay and organic soils (MH, CH, OH, OL and peats) are not recommended for SRW construction.

SOILS

✓	TASK	INDUSTRY RECOMMENDATION
	Recommended gradation	• Densely compacted gravel or unreinforced low strength concrete unless otherwise necessary. • Avoid pea gravel (poorly graded single size round gravel).
	Dimensions	• Minimum 12 in. (305 mm) wider than the SRW unit and 6 in. thick.
	Leveling pad placement	• In situations where gravity flow of the wall underdrain is unattainable, the leveling pad may be constructed of a densely-graded, impermeable soil to preclude saturation; the drain pipe is then located at the toe of wall above the finish grade.

LEVELING PAD

✓	TASK	INDUSTRY RECOMMENDATION
	Recommended gradation	• Clean, ½ to ¾ in. (12 to 19 mm), angular or well-graded gravel with less than 5% fines.
	Gravel fill placement	• Place aggregate in the cores of the SRW units (if applicable). • Between the units. • Place aggregate minimum 12 in. (305 mm) behind the SRW units.

GRAVEL FILL

✓	TASK	INDUSTRY RECOMMENDATION
	Minimum physical requirements	• Perforated or slotted PVC or corrugated HDPE pipe manufactured in accordance with ASTM F405 or ASTM F758. Do not use sock pipe.
	Dimensions	• Minimum 3 in. (76 mm) diameter.
	Drainage pipe placement	• Sloped to provide gravity flow. • Daylight at a maximum of 50 ft (15.2 m) or tie to storm system to evacuate water. • The pipe & gravel fill may be wrapped with geotextile to function as a filter (French drain).

DRAINAGE PIPE

✓	TASK	INDUSTRY RECOMMENDATION
	Recommended gradation	• Reinforced fill should be 1 in. (25 mm) minus, granular soil with less than 35% fines. Material classified as SM or better. Plasticity Index (PI) of fines less than 20. • Provide soil friction angle and unit weight used for the wall design.
	Reinforced soil placement	• Compacted to a minimum of 95% maximum dry density per standard Proctor moisture-density relationship (90 to 92 % Modified Proctor Density). • Compacted in 6 to 8 in. (152 to 203 mm) maximum height lifts without exceeding the unit height, H_u. • One compaction test every 500 ft² (46 m²) of wall.

REINFORCED SOIL

✓	TASK	INDUSTRY RECOMMENDATION
	Recommended gradation	• Granular soils are preferred but it is also common to use local soil that can be compacted adequately. • Provide soil friction angle and unit weight used for the wall design.
	Retained soil placement	• Compacted to meet the specified densities or a minimum of 95% maximum dry density per standard Proctor moisture-density relationship. • Compacted in 8 in. (203 mm) maximum lift height. • One compaction test every 500 ft² (46 m²) of wall.

RETAINED SOIL

✓	TASK	INDUSTRY RECOMMENDATION
	Plans	• Type, number of layers, layer length, and layer elevations clearly noted on the drawings or in the contract documents.
	Length of geosynthetics	• Minimum of 60% of the total wall height, *H*, or 4 ft (1,219 mm), whichever is greater.
	Vertical spacing of geosynthetic reinforcement	• Maximum of 24 in. (610 mm). • Closer reinforcement spacing may be necessary in poor soil conditions. • Although some proprietary systems indicate capability of supporting larger spacing between reinforcement layers, the NCMA *SRW Design Manual* limits this spacing to 32 in. (813 mm). • For modular blocks less than or equal to 10 in. (254 mm) in depth, it is recommended that the maximum vertical spacing be no more than twice the depth of the unit.
	Note: When structures interfere with the reinforcement installation, they must be addressed with site-specific details (e.g. drop boxes, culverts, etc.).	

GEOSYNTHETIC REINFORCEMENT

✓	TASK	INDUSTRY RECOMMENDATION
	Minimum requirements	• Meeting ASTM C1372 minimum requirements.
	Shear connectors: pins, clips, or lugs	• Use those made expressly for the SRW units used in the project.

SEGMENTAL RETAINING WALL (SRW) UNIT

CONSTRUCTION CHECKLIST

Date of inspection: _____ Contractor: _____

Project name: _____ Engineer: _____

Address: _____ Inspector: _____

- In addition to inspection, the success of any segmental retaining wall installation depends on complete and accurate field information, careful planning and scheduling, the use of specified materials and proper construction procedures (for further details on SRW construction, see NCMA SRW Installation Guide).

- When engineering is provided, the contract documents and specifications must be used to determine compliance of the layout, materials, and construction. For walls not requiring engineering, NCMA guidelines are recommended.

- Materials delivered to the site should be accompanied by the manufacturer's certification that the materials meet or exceed the specified minimum requirements.

- As with any structure used to retain soil, careful attention should be paid to the soil properties, compaction equipment, and procedures used during construction. Heavy equipment should not be operated within 3 ft (914 mm) of the rear of the wall face. Manually-operated compaction devices, such as vibrating plate compactors with a minimum weight of 250 lb (113 kg), should be used within this zone to achieve the design densities.

- Soil type and properties should be carefully monitored during construction to ensure the design parameters are met.

✓	TASK	INDUSTRY RECOMMENDATION
	Wall location	Retaining wall location should be verified and approved by the owner/owner's representative.
	Grades	Existing and proposed finish grades shown on the drawings should be in agreement with the topographic information from the project grading plan.
	Structures or utilities	Structures or utilities in the project should agree with the information used for the design and should be incorporated as they will affect the retaining wall.
Note: If conditions vary from the specified construction documents, the designer will need to be notified to evaluate a solution and authorize modifications.		

LAYOUT

✓	TASK	INDUSTRY RECOMMENDATION
	Reinforced soil and fill material	Fill materials should match gradation shown on the approved retaining wall plans or specifications for reinforced fill material. Maximum particle size should be limited to 1 in. (25 mm) and no more than 35% should pass the #200 Sieve, unless noted otherwise. Material should be non-plastic and not frozen. Soil shear strength properties should be verified prior to construction.
	Foundation soil	Shear strength and bearing capacity (foundation support) properties should be verified prior to construction. Material should not be frozen.
	Retained soil	Shear strength properties should be verified prior to construction. Material should not be frozen.
	Wall height	Does not exceed design height or manufacturer chart.
	Slopes (toe and top)	No steeper than that assumed in the design.
	Loading	Does not exceed that assumed in the design.
	Water conditions	Routed away from the wall except on predetermined water applications.
Note: If site conditions vary from the specified construction documents, the designer will need to be notified to evaluate a solution and authorize modifications.		

SITE CONDITIONS

✓	TASK	INDUSTRY RECOMMENDATION
	Gravel fill	Gradation should be within limits specified in approved retaining wall plans or specifications (gravels and sands are preferred). Maximum particle size should be $^{3}/_{4}$ in (19 mm) and no more than 5% shall pass the #200 sieve, unless noted otherwise.
	SRW unit	Specified manufacturer, size, setback, weight and finish, conforms to project specifications or ASTM C1372 min.
	Shear connectors	If pins or clips are used for unit interlock,use those made expressly for the SRW units used in the project and use the correct quantities.
	Drainage pipe	Should match specified material type and minimum properties.
	Geosynthetic reinforcement	Should match the specified type; strength and length must be clearly labeled identifying the product name and manufacturer per ASTM D4873, to ensure proper materials are being used.
	Reinforced soil	Should match or exceed soil type, and gradation should be within the limits specified by the design engineer (gravels and sands are preferred).
	Retained soil	Should match or exceed soil type and gradation should be within limits specified in approved retaining wall plans or specifications (gravels and sands are preferred).
Note: Any material substitution must be approved by the Retaining Wall Design Engineer.		

MATERIALS

✓	TASK	INDUSTRY RECOMMENDATION
	Leveling pad	Placed to maintain the dimensions, embedment depth, H_{emb} (6 in. (152 mm) min.) and compaction in plans. Avoid using round gravel of one size (pea gravel). Start construction at leveling pad's lowest point.
	Gravel fill	Placed and properly compacted according to approved documents in, between, and behind the SRW units to thickness and depth shown on plans. Placed 12 in. (305 mm) minimum from the back of the SRW unit.
	Drainage collection pipe	Placed at plan location and sloped to create gravity flow of water. The particular elevation of the pipe should be determined by the wall designer to meet the site-specific needs and guarantee the adequate evacuation of water. If pipe daylighting is used, use 50 ft (15.2 m) maximum.
	Reinforced fill placement and compaction	• Maximum 8 in. (203 mm) thick lifts, • soil compacted to 95% min.imum Standard Proctor Density (ASTM D698) or specifications, whichever is more stringent, • no heavy, self-propelled compaction equipment within 3 ft (914 mm) of the wall face units, • compacted at the same time as the gravel fill.
	Retained soil placement and compaction	• Maximum 8 in. (203 mm) thick lifts, • soil compacted to meet specifications including minimum density and within specified moisture content limits, • no heavy, self-propelled compaction equipment within 3 ft (914 mm) of the wall face units, • compacted at the same time as the reinforced fill.
	SRW unit installation	• Units level from front-to-back and from side-to-side, • proper alignment and batter, • if unit is cored, unit cores filled with appropriate aggregate each course, • shear connection between units properly engaged per SRW manufacturer's details, • curves and corners installed per SRW manufacturer's details, • no more than one course can be installed at a time before backfilling, • allow for shimming using a max. ⅛ in. (3mm) nominal geogrid or asphalt shingles, only at courses of block where primary layers of reinforcement are not present. Support (whether shingles or geogrid) should be continuous on problem areas.
	Geosynthetic reinforcement placement	• Placed horizontally at plan location—ensure wall face gravel fill is level with, or slightly above top of SRW unit, • clean debris off top of unit, • cut specified geosynthetic type to the length shown on plans, • placed to front of SRW unit with Strength Direction perpendicular to wall face, • geogrid location on the wall unit is as specified in the retaining wall drawings and is consistent with location as noted in laboratory connection testing per ASTM D6638, • ensure 100% coverage (geogrids placed one next to the other) without overlapping at the facing • place shear connectors, if applicable, as recommended by the manufacturer, • place SRW unit on top of geosynthetic, • move SRW unit to engage shear connectors and establish proper setback, • pull geosynthetic reinforcement taut, removing wrinkles or folds, and • hold or stake throughout fill placement process, • no damage; for example, tracked equipment has not been driven directly on geosynthetic, • curves and corners installed per plan details or geosynthetic manufacturer's details.
	Backfilling over reinforcement	• Place gravel fill for wall face in and between SRW units as required and compact, • place infill soil, • min. 6 in. (152 mm) of backfill before operating tracked equipment on top of reinforcement, • compact gravel fill, • compact infill soil (reinforced fill) parallel to the wall face, from face to tail of the grid. This stiffens the wall face and minimizes deformation from large compaction equipment. It also ensures the infill is fully compacted at the interface between the gravel fill and infill
	Cap unit:	Adhered with specified adhesive.
	Grading:	Finish grade for positive drainage away from wall face (drainage swale optional). Place topsoil and vegetate slopes above and around wall terminations.
Note: Any material substitution must be approved by the project engineer.		

INSTALLATION

As with any constructed work, some deviation from construction drawing alignments will occur. As opposed to cast-in-place concrete walls, alignment of SRWs can be simply corrected or modified during construction. Based upon examination of numerous completed SRWs, the following recommended maximum tolerances can be achieved with good construction techniques:		
	Vertical control	± 1.25 in. (32 mm) maximum over a 10 ft (3 m) distance; 3 in. (75 mm) maximum
	Horizontal location control	straight lines: ± 1.25 in. (32 mm) over a 10 ft (3 m) distance; 3 in. (75 mm) maximum
	Rotation	from established plan wall batter: ± 2°
	Settlement	the max. differential settlement between two locations should not exceed 1% of the distance between the two reference points on the length of wall

CONSTRUCTION INSPECTION

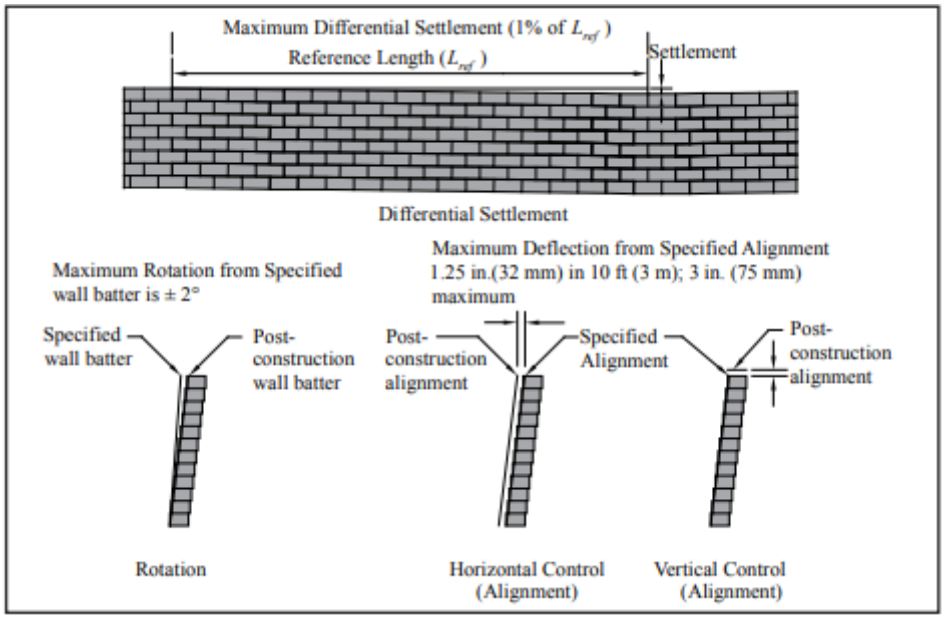


Figure 2–Recommended Maximum SRW Construction Tolerances

Some post-construction movement, and gapping and cracking of blocks may be present that is not necessarily a sign of imminent failure, especially if horizontal and vertical alignment is maintained.

INSPECTOR COMMENTS:

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References

1. Design Manual for Segmental Retaining Walls (Third Edition), TR 127B. National Concrete Masonry Association, 2009.

2. Standard Specification for Dry-Cast Segmental Retaining Wall Units, ASTM C1372-11. ASTM International, Inc., 2011.

3. Segmental Retaining Wall Units, **TEK 2-4B**. National Concrete Masonry Association, 2008.

4. Standard Test Method for Evaluating the Freeze-Thaw Durability of Dry Cast Segmental Retaining Wall Units and Related Concrete Units, ASTM C1262-10. ASTM International, Inc., 2010.

5. International Building Code. International Code Council, 2012.

6. Segmental Retaining Wall Installation Guide, TR 146. National Concrete Masonry Association, 2010.

Keywords

construction inspection quality assurance quality control retaining walls segmental retaining walls