NCMA TEK

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INSPECTION GUIDE FOR SEGMENTAL RETAINING WALLS

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INTRODUCTION

Segmental retaining walls (SRWs) are gravity retaining walls which can be divided into two groups. Conventional SRWs are structures that resist external destabilizing forces, due to retained soils, solely through the self-weight and batter of the SRW units. Geosynthetic reinforced soil SRWs are 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 typically dry-cast machine-produced concrete.

Conventional SRWs are separated into single depth and multiple depth categories. 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 or metallic reinforcement to enlarge the effective width and weight of the gravity mass, although the use of metallic reinforcement is not discussed in this TEK. 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 designed, 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* (refs. 1, 2) 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.

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 C 1372, *Standard Specification for Dry-Cast Segmental Retaining Wall Units* (ref. 3), 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. 4).

- Dimensional tolerances: $\pm 1/8$ in. (3.2 mm) from the speci-

fied standard overall dimensions for width, height and length (waived for architectural surfaces).

- Finish and appearance:
  - free of cracks or other defects that interfere with the 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 must 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 height of the unit,
  - the finished exposed surface must 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.
- Maximum water absorption:
  - 18 lb/ft^3 (288 kg/m^3) for lightweight units
  - 15 lb/ft^3 (240 kg/m^3) for medium weight units
  - 13 lb/ft^3 (208 kg/m^3) for normal weight units
- Freeze-thaw durability—In areas where repeated freezing and thawing under saturated conditions occur, freeze-thaw durability must be demonstrated by test or by proven field performance. When testing is required, the units must 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. 5):
  - 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 conclusion of 150 cycles ≤ 1.5 % of its initial weight.

ENGINEERING REQUIREMENTS

Engineered Versus Non-engineered Retaining Walls

The *International Building Code*, Section 105 (refs. 6, 7), requires a building permit for earth retaining structures over 4 ft (1,219 mm) in total height. 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 listed in Table 1.

For tiered or terraced walls (i.e., those incorporating multiple walls to create a change in grade) NCMA suggests the following (Figure 1b illustrates the various design distances).

1. If the total combined height is less than 6 ft (1,829 mm) and the horizontal spacing between walls is at least twice the height of the lower wall (i.e., $H < 6$ ft (1,829 mm) and $D \geq 2h_1$), follow Method 1 in Table 1.
2. In other cases, follow Method 2 in Table 1.

Foundation Evaluation

For walls founded on native sandy soils, dense silts and low plasticity stiff clays, and which are less than 6 ft (1,829 mm) in total height, local experience and visual inspection may be sufficient for design recommendations. For taller walls, walls founded on soft soil deposits, or walls founded on fill soils, test borings and/or a more detailed subsurface investigation may be required. For soft soils, organic soils, peat, high plasticity clay soil or for building over fill soils, professional engineering assistance is required. The reader is referred to *Design Manual for Segmental Retaining Walls* for more detailed classifications of these soil types.

DESIGN CHECKLIST

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., those that do not incorporate geosynthetic reinforcement) and for soil-reinforced SRWs are in addition to the general requirements below.

General Requirements/All SRWs

- Granular leveling pad: minimum depth 6 in. (152 mm), extending 6 in. (152 mm) beyond the front and rear of the unit.
- Drainage aggregate: 6 to 12 in. (152 - 305 mm) minimum of drainage aggregate behind units. Drainage aggregate is typically $^1/_2$ - $^3/_4$ in. (13 - 19 mm) clean, free-draining crushed stone or crushed gravel.
- Embedment depth (H_{emb}): minimum 6 in. (152 mm) or $^1/_{20}$ the exposed wall height (H_{exp}).

Conventional SRWs

- Wall height: not to exceed manufacturer's design chart maximums, or 2.5 times the unit depth [e.g. 2.5 ft (762 mm)

Table 1—Design Guidance for Segmental Retaining Walls

Design method	Wall height	Allowable soil & foundation conditions	Recommended engineering required
Method 1: Non-engineered	Less than 6 ft (2 m) from leveling pad to top of wall	Sand/gravel, silty sands, silt/lean clays	Use design chart provided by SRW system supplier.
Method 2: Engineered	More than 6 ft (2 m) from leveling pad to top of wall	Sand/gravel, silty sands, silt/lean clays	Have the design section reviewed by a registered design professional.

max. wall height for a 1 ft (305 mm) deep unit; 5 ft (1524 mm) maximum wall height for a 2 ft (610 mm) deep unit].

Geosynthetic-Reinforced SRWs

- Geosynthetic soil reinforcement: type, number of layers, layer length, and layer elevations clearly noted on the drawings or in the contract documents.
- Length of geosynthetic reinforcement (L): minimum of 60% of the total wall height (H) or 4 ft (1,219 mm), whichever is greater.
- Vertical spacing of geosynthetic reinforcement: Experience indicates that reinforcement spacing should be limited to a maximum of 24 in. (610 mm). Closer reinforcement spacing may be necessary in poor soil conditions. However, although some proprietary systems are capable of supporting larger spacing between reinforcement layers, at no time should the reinforcement spacing exceed 32 in. (813 mm).
- Height of unreinforced units at top of wall: maximum of twice the unit depth.
- Soil backfill compacted to 95% maximum dry density per standard Proctor moisture-density relationship (90% Modified Proctor Density) and compacted in 8-in. (203-mm) maximum height lifts. Moisture content of fill within +1/-3 percent of the optimum moisture content.

CONSTRUCTION INSPECTION

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.

It is good practice to have the retaining wall location verified by the owner's representative. Existing and proposed finish grades shown on the drawings should be verified to ensure the planned design heights are in agreement with the topographic information from the project grading plan. 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 compaction equipment and procedures used during construction. To prevent overtopping during construction, heavy equipment should not be operated within 3 ft (914 mm) of the rear of the wall. Manually-operated compaction devices, such as vibrating plate compactors, should be used within this zone to ensure proper installation while maintaining safety requirements. Reinforced soil can be compacted with walk-behind or self-propelled riding compaction equipment.

Site Conditions

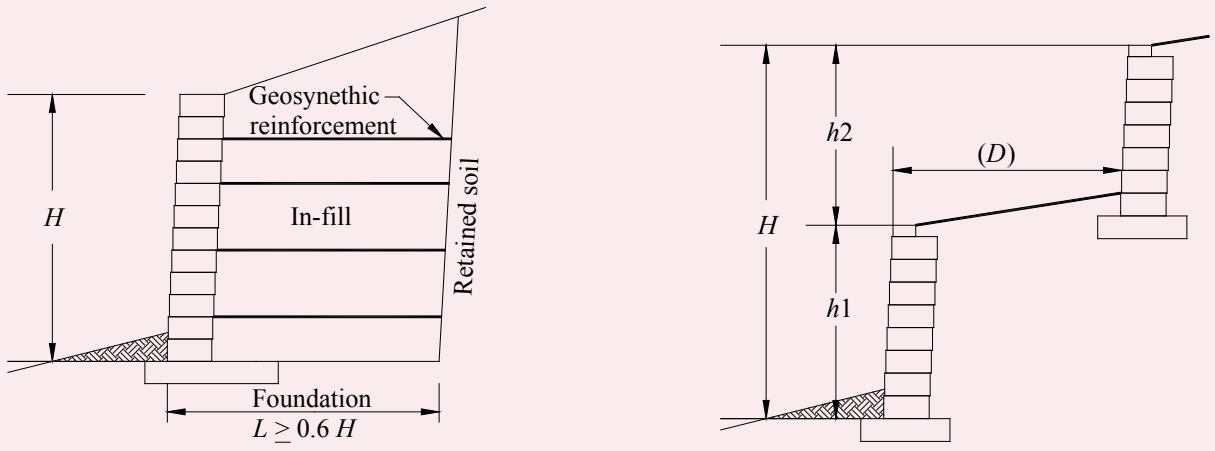
- Soil and fill material: not frozen
- Foundation soil: matches or exceeds soil type and strength assumed in the design
- Retained soil: matches or exceeds soil type and properties assumed in the design
- Wall height: does not exceed design height
- Slopes (toe and top): no steeper than that assumed in the design
- Loading: does not exceed that assumed in the design

Materials

- Drainage aggregate: clean, $^1/_2$ to $^3/_4$ in. (12 to 18 mm), angular gravel (less than 5% fines)
- SRW Unit: approved unit manufacturer, proper size and weight, conforms to ASTM C 1372
- Shear connectors: if pins or clips are used for unit interlock, they must be those made expressly for the SRW units used in the project
- Drainage pipe: specified material type and minimum properties
- Geosynthetic reinforcement: specified type (any substitutions must be approved by the project engineer)

Installation

- Leveling pad: placed to plan dimensions and compacted
- Drainage aggregate: placed to thickness and depth shown on plans



(a) Single Wall (b) Tiered or Terraced Wall

Figure 1—Segmental Retaining Wall Geometry and Site Condition Parameters

- Drainage collection pipe: placed at plan location, sloped to create gravity flow of water
- Fill placement and compaction:
  - maximum 8 in. (203 mm) thick lifts
  - soil compacted to 95% maximum dry density per standard Proctor moisture-density relationship
  - moisture content of fill within +1/-3 percent of the optimum moisture content.
  - no heavy, self-propelled compaction equipment within 3 ft (914 mm) of the rear of the wall
- 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 aggregate each course
  - shear connection between units properly engaged per SRW manufacturer's details
  - curves and corners installed per SRW manufacturer's details
- Geosynthetic reinforcement placement:
  - of the specified type and size
  - placed horizontally at plan location
  - proper length (L) as shown on plans
  - placed in proper orientation, per geosynthetic manufacturer's details (highest strength direction placed perpendicular to the wall face)
  - placed to front of SRW unit and connected between units per manufacturer's details
  - nominally tensioned to remove any slack or wrinkles prior to backfilling
  - no excessive damage, for example tracked equipment has not been driven directly on geosynthetic
  - curves and corners installed per plan details or geosynthetic manufacturer's details
- Cap unit: adhered with specified adhesive.

REFERENCES

1. *Design Manual for Segmental Retaining Walls (Second Edition)*, TR 127A. National Concrete Masonry Association, 1997.
2. *Design Manual for Segmental Retaining Walls (Third Edition)*, TR 127B. National Concrete Masonry Association, available spring 2008.
3. *Standard Specification for Dry-Cast Segmental Retaining Wall Units*, ASTM C 1372-04e2. ASTM International, Inc., 2004.
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6. *International Building Code* 2003. International Code Council, 2003.
7. *International Building Code* 2006. International Code Council, 2006.