EARTH RETAINING SYSTEMS WITH PRECAST CONCRETE OR CONCRETE MASONRY UNITS

IR 16-3

References:
California Code of Regulations (CCR) Title 24, Part 2, California Building Code (CBC)
2001 CBC, Section 1611A.6
2007 CBC, Section 1806A.1
2010 CBC, Section 1807A.2
Discipline: Structural

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This Interpretation of Regulations (IR) is intended for use by the Division of the State Architect (DSA) staff, and as a resource for design professionals, to promote more uniform statewide criteria for plan review and construction inspection of projects within the jurisdiction of DSA which includes State of California public elementary and secondary schools (grades K-12, community colleges) and state-owned or state-leased essential services buildings. This IR indicates an acceptable method for achieving compliance with applicable codes and regulations, although other methods proposed by design professionals may be considered by DSA.

This IR is reviewed on a regular basis and is subject to revision at any time. Please check the DSA web site for currently effective IRs. Only IRs listed in the document at http://www.dgs.ca.gov/dsa/Resources/IRManual.aspx at the time of plan submittal to DSA are considered applicable.

* Indicates alternative 2010 CBC sections that community colleges can use, per 2010 CBC Section 1.9.2.2.

Purpose: The purpose of this Interpretation of Regulations (IR) is to provide guidelines for segmental retaining wall (SRW) systems. ←

1. General: Gravity type retaining walls assembled of precast concrete or concrete masonry units, referred to as SRW, may be accepted for use on school building projects as an alternative to conventional retaining systems. Approval of SRW systems requires compliance with the conditions of this IR and acceptance by the Division of the State Architect (DSA).

SRW systems consist of facing units anchored to a reinforced soil mass that provides gravity load for resistance to overturning and lateral sliding. Geosynthetic grid materials (geogrid) are used to anchor the facing units and to reinforce the soil mass. Only soil-reinforced SRW systems will be acceptable for use on public schools, state-owned or state-leased essential services buildings or California Community College projects. The reinforced soil mass may consist of cohesive or cohesionless soil, subject to the recommendations of a geotechnical report.

Retaining walls less than four feet above the top of the foundation and not supporting a surcharge do not require review and approval by DSA as stated in Title 24, Part 1, Section 4-314 under the definition of "school buildings." However, such walls shall meet the manufacturer's specifications and the applicable design and wall system requirements described below.

2. Geotechnical Requirements: A California licensed geotechnical engineer, in accordance with the 2010 CBC, Section 1803A (Section 1802A in the 2007 CBC, or Section 1804A in the 2001 CBC), shall prepare a soil investigation report for each project site. Recommendations for preparation of the reinforced soil mass and slope stability above and below the retaining wall (if necessary) shall be addressed in the report.

2.1 Lateral Pressure: For projects submitted under the 2010 CBC, the design of all SRW systems shall include lateral pressure due to earthquake motion, per Section 1803A.5.12-1. For projects submitted under the 2001 or 2007 CBC, earthquake effects shall be included for walls higher than 12'.

3. Design Requirements: Design of the SRW systems shall comply with the National Concrete Masonry Association (NCMA) *Design Manual for Segmental Retaining Walls*, 3rd edition (DM-3) that is based on the Coulomb earth-pressure theory, American

Association of State Highway and Transportation Officials (AASHTO) *Standard Specifications for Highway Bridges,* 17th Edition, 2002, (based on the Rankine earth-pressure theory), or *AASHTO LRFD Bridge Design Specifications*, 5th Edition, 2010.

3.1 Earthquake Motion: For projects submitted under the 2010 CBC, seismic analysis will be required for all walls, in accordance with Section 1807A.2. For projects submitted under the 2001 or 2007 CBC, seismic analysis will be required for walls greater than 12'-0" above the top of the foundation.

Seismic analysis shall be based on the Mononabe-Okabe theory and shall comply with the documents referenced in Section 3 above. The design shall include the effect of all surcharge loads, potential settlement and sloping soil conditions for both gravity and seismic analyses.

Structures shall not be supported by SRW systems. See minimum setback requirements in Section 4.2 below.

3.1.1 Seismic Acceleration Coefficient: Horizontal acceleration shall be computed per Section 9.4 of NCMA DM-3 and the maximum design lateral deflection ($d_{seismic}$) used to determine the horizontal acceleration coefficient shall not exceed 10A, where A is the specified horizontal peak ground acceleration as defined by NCMA DM-3 Section 9.4. Where structures or fire access lanes adjacent to the wall would be impacted by wall movement, design the walls for $d_{seismic} = 0$, unless a detailed analysis acceptable to DSA is performed which considers the soil movement and the impact to these elements.

3.2 Design Submittal: The wall design shall be prepared under the general responsible charge of a California registered structural engineer.

Complete design calculations and details of the retaining system shall be submitted to DSA for review and approval with the contract drawings and specifications. Deferred approvals will not be permitted. Design drawings shall include the following information:

3.2.1 Locations and elevations of the top and bottom of all wall sections including the foundations, minimum wall embedment, and water table.

3.2.2 Geogrid type, location and embedment lengths behind the interior face of the block units. Provide a plan view showing the geogrid layout at wall "corners" or "bends" in accordance with Section 5.8 of this IR.

3.2.3 Soil gradation requirements, assumed soil design properties (such as density, soil friction angle, etc. for reinforced and retained fills) and placement/compaction specifications for all backfill materials and block unit fill material, including any special compaction or construction equipment considerations based upon proximity to wall face.

3.2.4 Location and size of all holes or openings cut into the geogrid.

3.2.5 A global stability analysis, per NCMA DM-3 Section 12.4, stamped and signed by a California registered geotechnical or civil engineer. Where the analysis indicates soil displacement, any structure or fire access lane in front or behind the wall shall be able to withstand this displacement; otherwise soil strengthening shall be provided to limit the displacement to a tolerable level or relocate these elements beyond the critical slip plane.

4. Wall Height Limitations and Setback:

4.1 SRW systems without a qualifying evaluation report per IR A-5 shall be limited to a maximum height of 10’-0" above the top of the foundation and are subject to DSA acceptance, during plan review, as an alternative per Title 24 Part 1 Section 4-304.

4.2 The building foundation shall not impose any load on the SRW. The minimum setback shall be 1 horizontal to 1 vertical projection from the tail of the lowest geogrid.

5. Wall System Requirements.

5.1 All SRW block units shall have a mechanical interlocking mechanism between adjacent units, such as formed lips, pins or keys that will resist horizontal movement out of the plane of the wall. The geogrid shall be mechanically anchored to the block units through the use of aggregate interlock, pins, pipes, etc. Formed lips in block units will not provide adequate anchorage unless configured to mechanically engage the geogrid.

Adequacy of the mechanical interlock must be maintained if separation in block courses due to settlement of the lower course, uplift of the upper course or bulging of the surface between geogrid layers occurs. The design performance objective of SRW's is to limit course separations to 1/4" maximum for the life of the wall.

5.2 Installation of SRW systems shall be in conformance with the manufacturer's instructions and the NCMA *Design Manual for Segmental Retaining Wall*s or AASHTO *Highway Specifications* provisions.

5.3 Acceptable geogrid suppliers and grid types shall be identified and their allowable long-term design strength and pullout of grid-to-block values provided.

5.4 Design factors of safety for systems and design criteria shall be based on Table 5-2 of NCMA *Design Manual for Segmental Retaining Walls*. Tables 5-1 and 5-2 also provide other wall design criteria such as minimum width of reinforced zone, minimum wall embedment, minimum anchorage length of geogrid in wall blocks, and maximum wall batter. Design for systems based on AASHTO *Standard Specifications for Highway Bridges* shall be equivalent to the NCMA Design Manual.

5.5 The backfill materials for reinforced soil mass, retained soil, and foundation soil shall be placed and compacted, and the drain gravel shall be placed, as required by the DSA approved documents and 2010 CBC, Section 1803A.1 (Section 1802A.1 in the 2007 CBC, or Section 1804A.1 in the 2001 CBC).

5.6 The maximum vertical spacing of the geogrid shall be 32” or twice the depth of the block, whichever is less. An additional layer of geogrid shall be provided in the top 12" of all soil-reinforced walls. Regardless of the reinforcement spacing, compaction of the reinforced backfill/retained soil shall not exceed 8” in thickness (NCMA Design Manual for Segmental Retaining Walls, Section 5.10.1).

5.7 Drainage pipes and granular drainage backfill shall be provided between the facing units and the reinforced soil mass. The granular drainage backfill shall be composed of clean free-draining gravel materials, extending full height and length of the wall at a minimum thickness of 1'-0" and shall meet the compaction requirements specified in the manufacturer's specifications. Surface drainage at the top and bottom of the wall shall be directed away from the wall.

5.8 In retaining wall systems with corners, the geogrid layers shall be staggered at adjacent walls to avoid overlap of grids and permit planar installation at each level.

6. Testing and Inspection: Testing and inspection shall be performed by the geotechnical engineer or his qualified representative per 2010 CBC Section 1704A.7.1, and as described in Appendix A.

6.1 The concrete or concrete masonry mix design and strength evaluation for the precast units shall be in compliance with the CBC, Chapter 19A or 19* and 21A or 21*. A letter of certification shall be provided with the units indicating the manufacturer's name and address, name of product and unit type. The certification shall include applicable laboratory compressive strength and absorption test results.

6.2 Letters of certification shall be provided for the supplied geogrid, indicating the supplier's name and address, name of product and the product designation meeting the requirements of the project's design. The letter of certification shall include the roll numbers and identification procedures, sampling procedures and the results of the quality control tests which include flexural rigidity, tensile strength and modulus and junction strength for each batch of resin and each shift's production used.

6.3 Soil properties, such as soil type, soil classification, moisture content, density, compaction, shear strength, and gradation, for all backfill materials shall be tested for compliance with design properties. The geotechnical engineer shall determine the appropriate frequency for these tests. The frequency shall not be less than the following:

6.3.1 Moisture, density, and compaction (ASTM D1557): Test every 2 feet vertical at 100 feet on center in reinforced, retained and foundation zones.

6.3.2 Shear strength (ASTM D3080): One test for every backfill type and source, minimum two tests. Perform tests prior to start of backfill operation. Perform gradation tests on these samples to be used as a baseline described below.

6.3.3 Gradation (ASTM D422/ C136): One test for every 4000 square feet of wall facing area per each backfill type and source. The gradation results shall be correlated with the baseline gradation tests from the shear strength tests. The geotechnical engineer shall establish an acceptance range for these gradation tests based on the baseline tests. If a gradation test falls out of the acceptance range, a shear strength test shall be performed of the suspect backfill.

6.4 Reporting requirements – See IR 17-7

Appendix A: Required Verification and Inspection

	Verification and Inspection	Continuous	Periodic
1	Verify excavations are extended to proper depth		X
	Prior to placement of drainage fill and compacted fill, observe subgrade and verify that site has been prepared properly		X
2	Perform classification, gradation, and testing of :		
	a. Reinforced fill materials		X
	b. Retained fill materials		X
	c. Foundation fill materials		X
	d. Drainage fill materials		X
3	Inspect placement and verify use of proper material, density, and lift thicknesses of		
	a. Reinforced fill materials	X	
	b. Retained fill materials	X	
	c. Foundation fill materials	X	
	d. Drainage fill materials	X	
4	Verify compaction of:		
	a. Reinforced fill		X
	b. Retained fill		X
	c. Foundation fill		X
	d. Drainage fill		X
5	Inspect placement and leveling of leveling pad to ensure intimate contact between the units and aggregate.	X	
6	Verify block dimensions, identification, and manufacturer's certification.		X
7	Inspect block placement, alignment and inclination.	X	
8	Verify reinforcement (or geogrid) type, proper identification, and manufacturer's certification.		X
9	Inspect geogrid placement that includes elevation, length, and orientation of strong direction	X	
10	Inspect connection of grid to block, including mechanical device and overlap length.	X	
11	Verify placement of block fill, and wall embedment	X	
12	Verify wall elevations, front and back slope conditions.		X