ICC-ES Evaluation Report

ESR-1959

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DIVISION: 32 00 00—EXTERIOR IMPROVEMENTS
Section: 32 32 23—Segmental Retaining Walls

REPORT HOLDER:

ANCHOR WALL SYSTEMS
5959 BAKER ROAD, SUITE 390
MINNETONKA, MINNESOTA 55345-5996
(800) 473-4452
www.anchorwall.com

EVALUATION SUBJECT

ANCHOR WALL RETAINING WALL SYSTEMS

ADDITIONAL LISTEE:

PAVESTONE COMPANY
27600 COUNTY ROAD, SUITE 90
WINTERS, CALIFORNIA 95640
(530) 795-4400
www.pavestone.com

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2009 and 2006 *International Building Code®* (IBC)

Properties evaluated:

Physical properties

2.0 USES

The Anchor Wall Retaining Wall Systems consist of modular concrete units for the construction of conventional gravity or geogrid-reinforced-soil retaining walls.

3.0 DESCRIPTION

3.1 Anchor Wall Units:

Anchor Wall concrete units are available in five configurations: Vertica, Vertica Pro, Diamond, Diamond Pro and Highland. Vertica, Vertica Pro, Diamond and Diamond Pro units have either a straight or beveled face profile; the Vertica, Vertica Pro, Diamond and Diamond Pro cap and corner units have a straight profile; the Highland units have a straight profile.

To provide setbacks/batters, the Vertica and Vertica Pro units have lugs on the top, and the Diamond, Diamond Pro and Highland units have a rear-lip system. See Figure 1 for configurations, dimensions and nominal weights. The nominal unit weights, noted in Figure 1, are to be used in design.

All units are made with normal-weight aggregates, and comply with ASTM C 1372, including having a minimum 28-day compressive strength of 3,500 psi (MPa) on the net area.

3.2 Unit Core and Drainage Fill:

Unit core and drainage fill must be ¾- to 1-inch (19- to 25-mm) crushed stones with no fines, placed inside the unit cores and between and behind the units. The unit core fill provides additional weight to the completed wall section, for stability, local drainage at the face of the structure, and a filter zone to keep the backfill soils from filtering out through the space between units.

3.3 Geogrid:

The geogrid materials listed in Table 2 are proprietary materials used to increase the height of the Anchor Wall System above the height at which the wall is stable under its self-weight as a gravity system. Geogrids are synthetic materials specifically designed for use as soil reinforcement.

4.0 DESIGN AND INSTALLATION

4.1 Design:

4.1.1 General: Structural calculations must be submitted to the code official for each wall system installation. The system must be designed as a gravity or reinforced-soil retaining wall that depends on the weight and geometry of the concrete units and soil to resist lateral earth pressures and other lateral forces. Lateral earth pressures are determined using either Coulomb or Rankine earth pressure theory. The design must include evaluation of both external and internal stability of the structure and include consideration of external loads such as surcharges and seismic forces. Minimum safety factors are 1.5 for base sliding and 2.0 for overturning (1.5 for overturning on gravity walls), and 2.0 for bearing capacity. Seismic safety factors may be 75 percent of the minimum allowable static safety factors.

A site-specific soils investigation report in accordance with 2009 IBC Section 1803 or 2006 IBC Section 1802, as applicable, is required. The soils investigation report must specify the soil-reinforcement and interaction coefficients, including the coefficient of interaction for pullout and coefficient of direct sliding; and the applicable safety factors for the determination of the ultimate tensile strength, long-term design strength and allowable tensile strength of the geogrid. The soils investigation report must also specify safety factors for tensile rupture and pullout of the geogrid from the soil. The design of the Anchor Wall retaining wall must be based on accepted geotechnical principles for gravity and soil-reinforced structures.

4.1.2 Gravity Retaining Walls: The gravity wall system relies on the weight and geometry of the Anchor Wall units to resist lateral earth pressures. Gravity wall design is based on standard engineering principles for modular concrete retaining walls. Inter-unit shear capacity equations are provided in Table 1.

4.1.3 Geogrid-reinforced Retaining Walls:

4.1.3.1 General: The geogrid-reinforced soil system relies on the weight and geometry of the Anchor Wall units and the reinforced soil mass to act as a coherent gravity mass to resist lateral earth pressures. The design of a reinforced soil structure is specific to the Anchor Wall unit selected, soil reinforcement strength and soil interaction, soil strength properties, and structure geometry. Figure 2 shows typical component details.

4.1.3.2 Structural Analysis: Structural analysis must be based on accepted engineering principles and the IBC. The analysis must include all items noted in Sections 4.1.3.2.1 and 4.1.3.2.2 of this report. All contact surfaces of the units must be maintained in compression.

4.1.3.2.1 External Stability Analysis:

1. The minimum length of the reinforced mass is 0.6 times the height of the wall (as measured from the top of the leveling pad to the top of the wall) or as required to satisfy a safety factor of 1.5 on sliding at the base, whichever is greater.
2. The minimum safety factor for overturning the reinforced mass is 2.0, considering the mass as a rigid body rotating about the toe of the wall.
3. Global stability analysis must be provided for walls with slopes below the toe of the wall, walls on soft foundations, walls that will be designed for submerged conditions, or tiered walls.
4. After completion of the internal stability analysis and geogrid layout, sliding along each respective geogrid layer must be checked, including shearing through the connection at the wall face.

4.1.3.2.2 Internal Stability Analysis:

1. Geogrid spacing must be based on local stability of the Anchor Wall units during construction. Vertical spacing is typically limited to two times the depth of the unit.
2. Tension calculations for each respective layer of reinforcing must be provided. Tension is based on the earth pressure and surcharge load calculated from halfway to the layer below to halfway to the layer above. Calculated tension must not exceed the allowable geogrid strength.
3. Connection capacity must be checked for each connection of geogrid to the Anchor Wall (see Table 2). The calculated connection capacity must be equal to or greater than the calculated tension for each layer.
4. A calculation check must be made on pullout of the upper layers of geogrid from the soil zone beyond the theoretical Coulomb or Rankine failure plane. The pullout capacity must be equal to or greater than the calculated tension after the applicable geogrid interaction and sliding coefficient adjustment factors are applied.

4.2 Installation:

The wall system units are assembled in a running bond pattern, except for the Highland Stone units, which are assembled in a random bond pattern. The wall system units are assembled without mortar or grout, and are stacked and aligned at the design setback/batter using the vertical lip at the lower rear edge, except for the Vertica and VerticaPro units which have alignment lugs on the top surface. The system may include horizontal layers of structural geogrid reinforcement in the backfill soil mass. Requirements for installation of the Anchor Wall Retaining Wall System are as follows:

1. Excavate for leveling pad and reinforced fill zone.
2. Inspect excavations for adequate bearing capacity of foundation soils and observation of groundwater conditions by a qualified geotechnical engineer.
3. Install a minimum 6-inch-thick (152 mm) leveling pad of crushed stone, compacted to at least 90 percent of the maximum dry density as determined by ASTM D 1557 (95 percent per ASTM D 698). (An unreinforced concrete pad in accordance with 2009 IBC Section 1809.8 or 2006 IBC Section 1805.4.2.3, as applicable, may be utilized in place of the crushed stone pad.)
4. Install the first course of Anchor Wall units, ensuring units are level from side to side and front to back.
5. Units with cores must be filled with unit core drainage fill described in Section 3.3 of this report. The unit core drainage fill is required for all installations and must extend back a minimum of 6 inches (152 mm) from the back of the unit. See Figure 2.
6. Clean the top surface of the units to remove loose aggregate.
7. At designated elevations per the design, install geogrid reinforcing to within 1 inch (25.4 mm) of the outer face of the wall. Check to ensure the proper orientation of the geogrid reinforcement is used so the strong direction is perpendicular to the face. Adjacent rolls are placed side by side; no overlap is required. Geogrids are pulled taut to remove slack from the geogrid before placing backfill. The entire length is pulled taut to remove any folds or wrinkles.
8. Place and compact backfill over the geogrid reinforcing layer in appropriate lift thickness to ensure compaction. Backfill used in the reinforced fill mass must consist of suitable fine-grained or course-grained soil placed in lifts compacted to at least 90 percent of the maximum dry density as determined by ASTM D 1557 (95 percent per ASTM D 698). The backfill soil properties, lift thickness, and degree of compaction must be determined by the soils engineer based on site-specific conditions. In cut-wall applications, if the reinforced soil has poor drainage properties, a granular drainage layer of synthetic drainage composite should be installed to prevent buildup of hydrostatic pressures behind the reinforced soil mass. Provisions for adequate subsurface drainage must be determined by the soils engineer. The reinforced backfill must be placed and compacted no lower than the top unit-elevation to which geogrid placement is required.

9. Report placement of units at the design setback/batter, core fill, backfill, and geogrids, as shown on plans, to finished grade.

4.3 Special Inspection:

Special inspection must be provided in accordance with IBC Section 1704.5. The inspector's responsibilities include verifying the following:

1. The modular concrete unit dimensions.
2. Anchor Wall unit identification of compliance with ASTM C 1372, including compressive strength and water absorption, as described in Section 3.1 of this report.
3. Foundation preparation.
4. Anchor Wall unit placement, including alignment and inclination.
5. Geosynthetic reinforcement type (manufacture and model number) and placement.
6. Backfill placement and compaction.
7. Drainage provisions.

5.0 CONDITIONS OF USE

The Anchor Wall Retaining Wall Systems described in this report comply with, or are suitable alternatives to what is specified in, the code indicated in Section 1.0 of this report, subject to the following conditions:

5.1 The systems are designed and installed in accordance with this report, the manufacturer's published installation instructions, and accepted engineering principles. If there is a conflict between this report and the manufacturer's published installation instructions, this report governs.

5.2 The wall design calculations are submitted to, and approved by, the code official. The calculations must be prepared by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed.

5.3 A site-specific soils investigation in accordance with 2009 IBC Section 1803 or 2006 IBC Section 1802, as applicable, as noted in Section 4.1.1 of this report, must be provided for each project site.

5.4 In areas where repeated freezing and thawing under saturated conditions occur, evidence of compliance with freeze-thaw durability requirements of ASTM C 1372 must be furnished to the code official for approval prior to construction.

5.5 Special inspection must be provided for backfill placement and compaction, geogrid placement (when applicable), and block installation, in accordance with Section 4.3 of this report.

5.6 Details in this report are limited to areas outside of groundwater. For applications where free-flowing groundwater is encountered, or where wall systems are submerged, the installation and design of systems must comply with the recommendations of the soils engineer and the appropriate sections of the NCMA Design Manual for Segmental Retaining Walls, and must be approved by the code official.

5.7 Under the 2009 IBC, project specifications for soil and water conditions that have sulfate concentrations identified in ACI 318-08 Table 4.2.1 as severe or very severe, shall include mix designs for the concrete masonry and grout that comply with the content of ACI 318-08 Table 4.3.1. See 2009 IBC Section 1904.5.

5.8 Under the 2006 IBC, project specifications for soil and water conditions that have sulfate concentrations identified in ACI 318-05 Table 4.3.1 as severe or very severe, shall include mix designs for the concrete masonry and grout that comply with the content of ACI 318-05 Table 4.3.1. See 2006 IBC Section 1904.3.

5.9 This report evaluates only the connection strength of the geogrid material when attached to the concrete units. Physical properties of the geogrid material or its interaction with the soil have not been evaluated.

6.0 EVIDENCE SUBMITTED

Data in accordance with the ICC-ES Acceptance Criteria for Segmental Retaining Walls (AC276), dated October 2004 (editorially revised May 2011).

7.0 IDENTIFICATION

Each pallet of concrete units is identified with the manufacturer's name (Pavestone Company) and address, the name of the product, and the evaluation report number (ESR-1959).

TABLE 1—INTER-UNIT SHEAR RESISTANCE EQUATIONS[1]

UNIT		PEAK CONNECTION STRENGTH (pounds/linear foot)		SERVICEABILITY CONNECTION STRENGTH (pounds/linear foot)	
		Equation	**Maximum**	**Equation**	**Maximum**
WITHOUT GEOGRID					
Vertica		F = 6530 + 0.91 N	10170	F = 1625 + 0.17 N	2250
Vertica Pro		F = 4650 + 0.37 N	7009	F = 2323 + 0.19 N	3494
Diamond		F = 2179 + 0.58 N	3055	F = 1532 + 0.27 N	1804
Diamond Pro		F = 83 + 2.04 N	2485	F = 118 + 1.56 N	1682
		F = 2299 +0.19 N	2485 to 3043	F = 1323 + 0.36 N	1682 to 2760
Highland		F = 876 + 1.21 N	2689	F = 456 + 0.63 N	1363
WITH GEOGRID					
Vertica	Miragrid 3XT	P = 5138 + 0.92 N	8816	P = 1037 + 0.35 N	2446
	Miragrid 8XT	P = 6516 + 0.36 N	7940	P = 1557 + 0.15 N	2141
Vertica Pro	Miragrid 3XT	P = 5416 + 0.14 N	6368	P = 2144 + 0.24 N	3624
	Miragrid 10XT	P = 3414 + 0.42 N	6216	P = 1980 + 0.26 N	3694
Diamond	Miragrid 3XT	P = 1661 + 0.45 N	2332	P = 1322 + 0.39 N	1837
	Miragrid 5XT	P = 1505 + 0.61 N	2365	P = 1173 + 0.39 N	1752
Diamond Pro	Miragrid 3XT	P = 1077 + 0.08 N	1397	P = 401 + 0.21 N	1241
	Miragrid 8XT	P = 811 + 0.36 N ??	1617	P = 557 + 0.19 N	1317
Highland	Miragrid 3XT	P = 1162 + 0.74 N	2271	P = 728 + 0.36 N	1268
	Miragrid 5XT	P = 980 + 0.52 N	1695	P = 648 + 0.38 N	1201

For **SI:** 1 lb/linear ft. = 14.6 N/m.

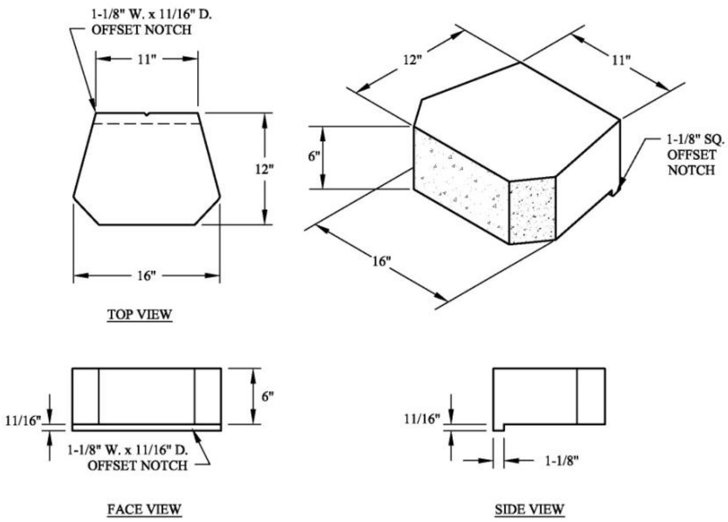
[1]The inter-unit service-state shear resistance, F [lb/linear foot of block (N/m)], of the Anchor Wall units at any depth is a function of the superimposed normal (applied) load, N [lb/linear foot of block (N/m)].

TABLE 2—GEOGRID-TO-BLOCK PULLOUT RESISTANCE EQUATIONS[1]

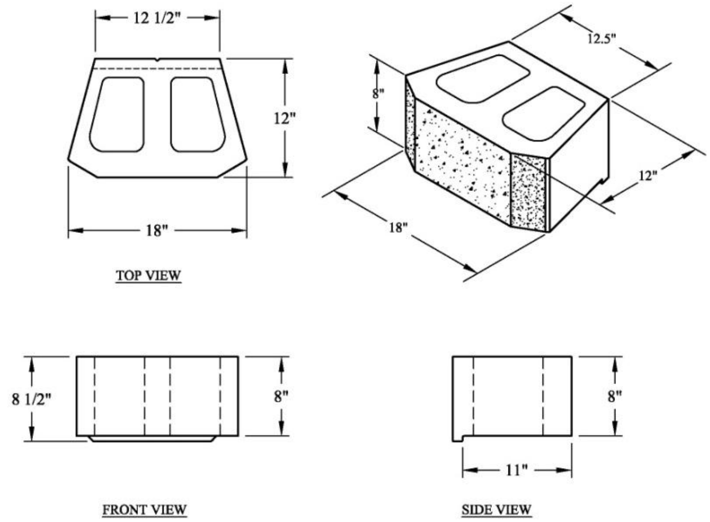
GEOGRID		PEAK CONNECTION STRENGTH (pounds/linear foot)		SERVICEABILITY CONNECTION STRENGTH (pounds/linear foot)	
		Equation	**Maximum**	**Equation**	**Maximum**
Vertica	Miragrid 3XT	P = 873 + 0.27 N	1940	P = 663 + 0.21 N	1480
	Miragrid 8XT	P = 944 + 0.28 N	2040	P = 618 + 0.30 N	1810
Vertica Pro	Miragrid 3XT	P = 1153 + 0.45 N	2275	P = 752 + 0.23 N	1322
		P = 2283 - 0.004 N	2275 to 2261	P = 1357 - 0.014 N	1322 to 1264
	Miragrid 10XT	P = 1707 + 0.35 N	3983	P = 1331 + 0.20 N	2598
Diamond	Miragrid 3XT	P = 757 + 0.27 N	1159	P = 504 + 0.24 N	859
	Miragrid 5XT	P = 930 + 0.42 N	1525	P = 547 + 0.35 N	1069
Diamond Pro	Miragrid 3XT	P = 889 + 0.48 N	1370	P = 698 + 0.20 N	1482
		P = 800 + 0.29 N	1370 to 1578		
	Miragrid 8XT	P = 607 + 1.32 N	1928	P = 144 + 1.45 N	1595
		P = 1786 + 0.01 N	1928 to 2354	P = 1514 + 0.08 N	1595 to 1835
Highland	Miragrid 3XT	P = 779 + 0.46 N	1428	P = 477 + 0.41 N	1103
	Miragrid 5XT	P = 970 + 0.37 N	1519	P = 575 + 0.42 N	1206

For **SI:** 1 lb/linear ft. = 14.6 N/m.

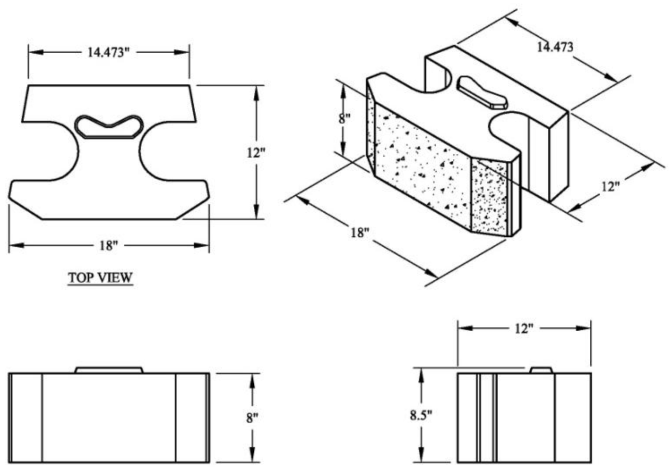
[1] Where N = superimposed normal (applied) load (lb/linear foot of geogrid).



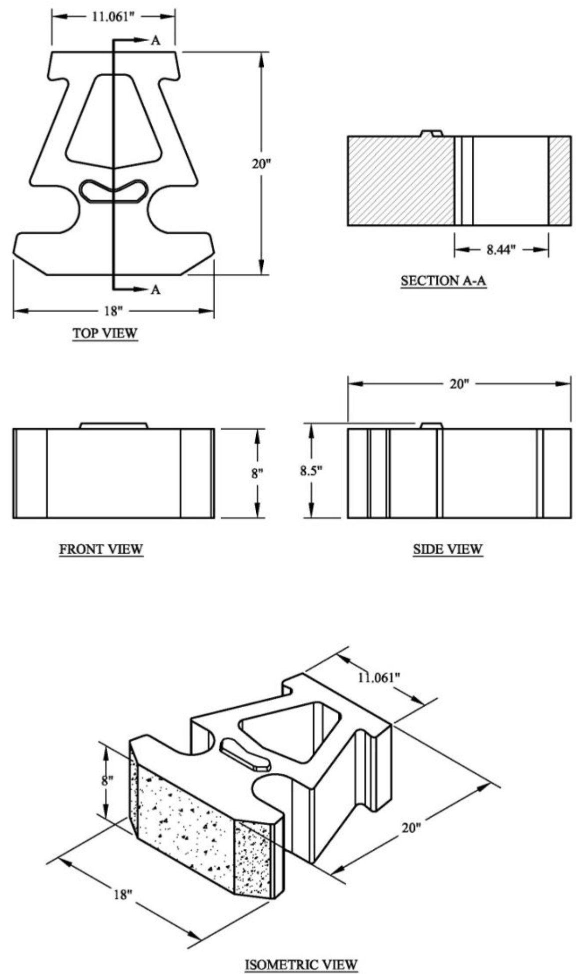
Diamond® Retaining Walls



Diamond Pro® Retaining Walls



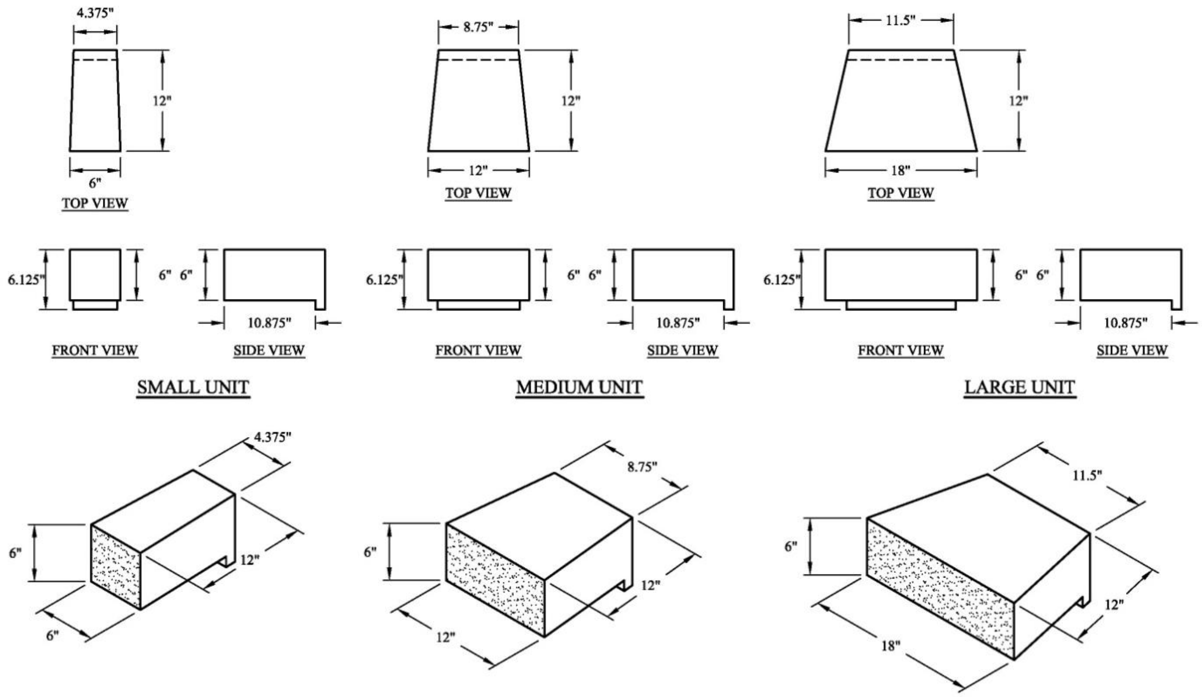
Vertica® Retaining Walls



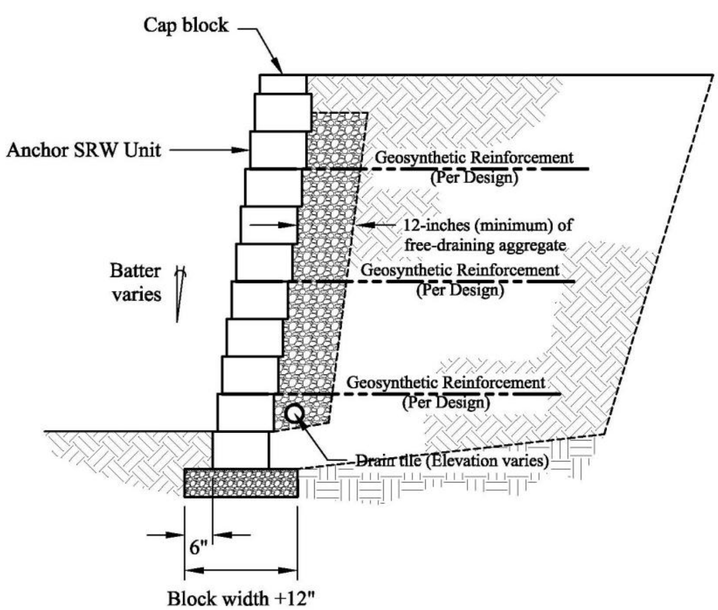
For **SI:** 1 inch = 25.4 mm.

Vertica Pro® Retaining Walls

FIGURE 1—ANCHOR WALL WALL UNITS



Highland Stone® Retaining Walls



For **SI:** 1 inch = 25.4 mm.

FIGURE 2—TYPICAL WALL SECTION