LEGACY REPORT

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ICC Evaluation Service, Inc.
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Business/Regional Office # 5360 Workman Mill Road, Whittier, California 90601 # (562) 699-0543
Regional Office # 900 Montclair Road, Suite A, Birmingham, Alabama 35213 # (205) 599-9800
Regional Office # 4051 West Flossmoor Road, Country Club Hills, Illinois 60478 # (708) 799-2305

Legacy report on the 1997 *Uniform Building Code*™ and the 2000 *International Building Code*®

DIVISION: 02—SITE CONSTRUCTION
Section: 02830—Retaining Walls

ANCHOR DIAMOND PRO SEGMENTAL RETAINING WALL (SRW)

ANCHOR WALL SYSTEMS, INC.
5959 BAKER ROAD, SUITE 390
MINNETONKA, MINNESOTA 55345

PAVESTONE COMPANY
4835 LBJ FREEWAY, SUITE 700
DALLAS, TEXAS 75244-6072

1.0 SUBJECT

Anchor Diamond Pro Segmental Retaining Wall (SRW).

2.0 DESCRIPTION

2.1 General:

Anchor Diamond Pro Segmental Retaining Wall (SRW) consists of dry-stacked concrete units and optional geosynthetic soil-reinforcement material. Anchor Diamond Pro SRW structures constructed without geosynthetic soil-reinforcement are gravity retaining walls that rely solely on the weight of the dry-stacked concrete units to resist destabilizing forces generated by the retained soil and any surcharge or seismic loads. Refer to Figure 1A. Anchor Diamond Pro SRW structures constructed with geosynthetic soil-reinforcement are gravity retaining walls, having an increased mass created by the geosynthetic reinforced-soil mass located behind the dry-stacked concrete units, that resist destabilizing forces generated by the retained soil and any surcharge or seismic loads. Refer to Figure 1B.

2.2 Materials:

2.2.1 SRW Concrete Units: The Anchor Diamond Pro SRW concrete units are available as either straight-face or bevel-face units, as shown in Figure 2. Straight-face units weigh 76 pounds (34 kg), and have a density of 130 pcf (2082 kg/m^3). Bevel-faced units weigh 72 pounds (33 kg), and have a density of 130 pcf (2082 kg/m^3). Refer to Figure 2 for details. The angle of wall inclination is about 7.1 degrees from vertical towards the backfill as determined by the 1-inch (25 mm) setback per course provided by the rear lip of the concrete unit. Both units must comply with minimum compressive strength and maximum water absorption requirements specified in UBC (1997 *Uniform Building Code*™) Standard 21-4, where the minimum 28-day compressive strength is 3,000 psi (21 MPa) on the net area and the maximum water absorption is 7 percent. Block tolerances must comply with Section 21.406 of UBC Standard 21-4, and with the recommendations specified in the National Concrete Masonry Association's (NCMA) publication titled *TEK 2-4 Specification for Segmental Retaining Wall Units*.

2.2.2 Geosynthetic Material: Geosynthetic materials are high-tensile-strength polymeric woven or knitted materials. When installed in accordance with this report, the geosynthetic material extends through the dry-stacked Diamond Pro concrete units and into the compacted soil to create a composite gravity mass structure. Geosynthetic reinforcements must be stored at temperatures not lower than –10°F (–23°C); and must not be in contact with wet cement, epoxy or other adhesive materials. To prevent UV degradation, the geosynthetic material must not be subjected to prolonged exposure to sunlight. Geosynthetic reinforcements that are compatible with the Anchor Diamond Pro concrete units bear the product names Mirafi, Raugrid, or Strata, and may be described as follows:

1. **Mirafi®:** The Mirafi 3XT, 5XT, and 8XT, manufactured by TC Mirafi, consist of polyester yarns with an acrylic latex coating, woven into a grid shape sheet.
2. **Raugrid:** Raugrid geogrids 3/3-20, 4/2-15, 6/3-15, and 8/3-20, manufactured by Luckenhaus North America, Inc., consist of polyester yarns with a PVC coating, woven into a grid shape sheet.
3. **Strata:** Strata geogrids 200, 300, and 500, manufactured by Strata Systems, Inc., consist of polyester yarns saturated with a PVC coating, precision knitted into a dimensionally stable, grid shape sheet.

2.2.3 Backfill Soil: Backfill used in the reinforced soil mass must consist of appropriate material placed in compacted lifts. The backfill soil properties, lift thickness and degree of compaction are determined by the soils engineer. A drainage aggregate layer and drain tile must be installed in the system to prevent buildup of hydrostatic pressures behind the wall. The drainage provisions must be determined by the soils engineer and approved by the building official.

2.3 Design:

2.3.1 General: The design of gravity and reinforced-soil retaining SRW systems must be based on the guidelines outlined in the NCMA *Design Manual for Segmental Retaining Walls* (second edition), dated 1997. A copy of the NCMA design manual must be made available to the building official upon request.

The design must consider both external and internal stability, along with consideration of external loads generated

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by surcharges and seismic activity. Lateral earth pressures must be determined using the Coulomb theory. Seismic loads must be analyzed by the method outlined in the NCMA *Segmental Retaining Walls—Seismic Design Manual* (first edition), dated 1998. A copy of the NCMA seismic design manual must be made available to the building official upon request.

Structural calculations must be submitted to the building official for each retaining wall structure. Minimum safety factors are 1.5 for sliding, 2.0 for external overturning, 2.0 for bearing capacity, 1.5 for internal shear capacity, and 1.3 for overall global stability. Required seismic safety factors are no less than 75 percent of the minimum allowable static safety factors.

2.3.2 Conventional (Non-reinforced-soil) SRW Structure Design: Design of conventional (non-reinforced-soil) SRW structures must consider base sliding, overturning, bearing capacity, internal shear capacity, and overall global stability. The internal sliding resistance between SRW concrete units due to interface shear capacity, V_u, must be calculated from the following formula (refer to Section 4.6 of the NCMA *Design Manual for Segmental Retaining Walls*):

$$V_u = a_u + W_w \tan \lambda_u$$

where:

a_u = Apparent shear capacity adhesion = 962 lb/ft (14,045 N/m).

λ_u = Apparent peak interface friction angle between SRW units = 26°.

W_w = Total weight of column of dry-stacked SRW units between surface and hinge height calculated relative to the sliding surface, lb/ft (N/m).

2.3.3 Reinforced-soil SRW Structure Design: Design of reinforced-soil SRW structures must consider external, internal, and local stability of the SRW structure.

2.3.3.1 External stability: External stability design must consider base sliding, overturning, bearing capacity, and global stability:

1. For base sliding design details, refer to Section 5.5.2 of the NCMA *Design Manual for Segmental Retaining Walls*.
2. For overturning design details, refer to Section 5.5.3 of the NCMA *Design Manual for Segmental Retaining Walls*.
3. For bearing capacity and settlement design details, refer to Section 5.5.4 of the NCMA *Design Manual for Segmental Retaining Walls*.
4. For global/overall slop stability design details, refer to Section 5.2.7 of the NCMA *Design Manual for Segmental Retaining Walls*.

2.3.3.2 Internal stability: Internal stability design must be carried out to evaluate the integrity of the reinforced zone as a monolithic composite comprised of geosynthetic reinforcement, compacted soil, and SRW concrete units. Tensile forces to be resisted by the horizontal reinforcement layers must be calculated using Coulomb lateral earth pressure theory. Tensile overstress, pullout, and internal sliding failure modes of the SRW structure must be examined, as follows:

1. Tensile overstress: The applied force in any geosynthetic reinforcement must not exceed the allowable working stress level, T_a, for the proprietary geosynthetic reinforcement specified in Tables 1, 2, and 3 of this evaluation report. Refer to Section 5.6.2 of the NCMA *Design Manual for Segmental Retaining Walls* for design details.
2. Pullout: Refer to Tables 1, 2, and 3 for typical allowable values for the coefficient of interaction, C_i, for each proprietary geosynthetic reinforcement material referenced in this evaluation report. Refer to Section 5.6.3 of the NCMA *Design Manual for Segmental Retaining Walls* for pullout design details.
3. Internal sliding: Refer to Tables 1, 2, and 3 for typical allowable values for the coefficient of direct sliding, C_{ds}, for the geosynthetic materials referenced in this evaluation report. Refer to Section 5.6.4 of the NCMA *Design Manual for Segmental Retaining Walls* for internal sliding design details.

2.3.3.3 Local stability: Local stability design of an SRW structure investigates the interaction with, and connection of, SRW units to the geosynthetic reinforcement. Three local-stability failure modes must be examined, as follows:

1. Facing connection: The interface between the SRW units and the geosynthetic material must have sufficient connection strength (limit state) and stiffness (serviceability state) such that the reinforcement does not pull through the SRW units or rupture.

   Limit State Analysis: The ultimate (limit state) connection strength is governed by the following formula (refer to Table 4 of this evaluation report and Section 5.7.1 of the NCMA *Design Manual for Segmental Retaining Walls* for design details):

$$T_{ultconn(n)} = a_{cs} + W_w(n)\tan\lambda cs$$

where:

a_{cs} = The apparent minimum limit-state connection strength between the SRW units and the geosynthetic reinforcement, lb/ft (N/m). Refer to Table 4 of this evaluation report for a_{cs} typical values associated with each proprietary geosynthetic reinforcement material referenced in this evaluation report.

λ_{cs} = The apparent limit-state angle of friction for the connection of the geosynthetic reinforcement to SRW units (deg). Refer to Table 4 of this evaluation report for typical λ_{cs} values associated with each proprietary geosynthetic reinforcement material referenced in this evaluation report.

$W_{w(n)}$ = The weight of the stacked SRW units, lbs (N).

Serviceability State Analysis: The serviceability connection strength established for $^3/_4$-inch (19.1 mm) deformation, $T_{conn@3/4(n)}$, is governed by the following formula (refer to Table 4 of this evaluation report and Section 5.7.1 of the NCMA *Design Manual for Segmental Retaining Walls* for design details):

$$T_{conn3/4(n)} = a'_{cs} + W_{w(n)}\tan\lambda'_{cs}$$

where:

a'_{cs} = The apparent minimum serviceability-state connection strength between the SRW units and the geosynthetic reinforcement, lb/ft (N/m). Refer to Table 4 of this evaluation report for typical a'_{cs} values associated with each proprietary geosynthetic reinforcement material referenced in this evaluation report.

λ'_{cs} = The apparent serviceability-state angle of friction for the connection of the geosynthetic reinforcement to SRW units (deg). Refer to Table 4 of this evaluation report for typical λ'_{cs} values associated with each proprietary geosynthetic reinforcement material referenced in this evaluation report.

$W_{w(n)}$ = The weight of the stacked SRW units, lbs (N).

2. Bulging: Refer to Section 5.7.2 of the NCMA *Design Manual for Segmental Retaining Walls* for bulging design details.
3. Maximum unreinforced height: Refer to Section 5.7.3 of the NCMA *Design Manual for Segmental Retaining Walls* for maximum unreinforced height design details.

2.4 Installation:

The SRW concrete units must be supported by an approved foundation subgrade that is level and that consists of at least 6 inches (152 mm) of granular fill compacted to at least 95 percent of the soil's maximum dry density as determined by ASTM D 698. Specific foundation requirements for each site must be determined by the soils engineer and approved by the building official.

The SRW concrete units are installed such that the angle of wall inclination is approximately 7.1 degrees from the vertical towards the backfill. Concrete units must be aligned using the vertical lip at the lower rear edge, and are set back 1 inch (25 mm) from the lower units, guided by the lip. Geosynthetic reinforcement is placed at the elevations and orientation specified on the approved building plans. The geosynthetic reinforcement material in the design strength direction must be one continuous piece of material. The backfill must be placed and compacted to a level about $^{3}/_{4}$ inch (19 mm) below the top block elevation where geosynthetic reinforcement material placement is required.

The reinforcement is embedded a minimum of 10 inches (255 mm) into the SRW concrete units. The roll or strength direction of the reinforcement must be placed perpendicular to the wall units. After unrolling, the geosynthetic reinforcement material is hand-pulled until taut, flat and free of wrinkles. Adjacent geosynthetic reinforcement material rolls must be butted together side-by-side without overlap, and splices must be avoided.

SRW concrete units may be assembled with an inside or outside curved layout. Minimum inside curve radius is 7 feet (2134 mm), and minimum outside curve radius is 5 feet (1524 mm) for the beveled unit and 7 feet (2134 mm) for the straight unit.

2.5 Special Inspection:

Special inspection must be observed in accordance with Section 1701.5.7.1 of the UBC and Section 1704.5 of the 2000 *International Building Code*® (IBC). The inspector's responsibilities include verifying the following:

1. SRW concrete unit dimensions.
2. SRW concrete unit compliance with UBC Standard 21-4 (ASTM C 90-99), including compressive strength and water absorption as described in Section 2.1 of this report.
3. Foundation preparation.
4. SRW concrete unit placement, including alignment and inclination.
5. Geosynthetic reinforcement placement.
6. Backfill placement and compaction.

2.6 Identification:

A label affixed to each shipping pallet of the SRW concrete units identifies the manufacturer's name (Anchor Wall Systems, Inc.), the product name (Anchor Diamond Pro Segmental Retaining Wall), and the ICBO ES evaluation report number (ER-5809). The geosynthetic reinforcement material is identified by labels stating the manufacturer's name, the product designation, and the strength direction.

3.0 EVIDENCE SUBMITTED

Data in accordance with the ICC-ES Interim Criteria for Concrete and Concrete Masonry Wall Systems (AC15), dated January 2001, and quality control manuals.

4.0 FINDINGS

The Anchor Diamond Pro Retaining Wall Systems comply with the 1997 *Uniform Building Code*™ (UBC) and the 2000 *International Building Code*® (IBC), subject to the following conditions:

4.1 The systems are designed and installed in accordance with this evaluation report; the manufacturer's published instructions; and the National Concrete Masonry Association's *Design Manual for Segmental Retaining Walls* (second edition) dated 1997, and *Segmental Retaining Walls—Seismic Design Manual* (first edition) dated 1998. Copies of these manuals must be supplied to the building official upon request.

4.2 Special inspection is required for backfill placement and block installation in accordance with Section 2.5 of this report.

4.3 A foundation investigation in accordance with Section 1804 of the UBC or Section 1802 of the IBC is provided for each project site.

4.4 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 such systems shall comply with the appropriate sections of the NCMA *Design Manual for Segmental Retaining Walls* and the recommendations of the soils engineer, and must be approved by the building official.

4.5 The Anchor Diamond Pro SRW concrete units are manufactured by the additional listee identified in this evaluation report (Pavestone Company) at their manufacturing plants located in Las Vegas, Nevada, and Winters, California.

This report is subject to re-examination in two years.

TABLE 1—PHYSICAL PROPERTIES FOR MIRAFI GEOSYNTHETIC REINFORCEMENT[1]

PROPERTY		GRADE OF MIRAFI GEOSYNTHETIC REINFORCEMENT MATERIAL		
		3XT	**5XT**	**8XT**
Weight (oz/yd^2)		6.0	7.5	8.5
Allowable Tension, T_a (lb/ft)		885	1155	2059
Coefficient of Interaction, C_i	ML and CL soil classification	0.7 - 0.8	0.7 - 0.8	0.7 - 0.8
	SM, SP, and SW soil classification	0.8 - 0.9	0.8 - 0.9	0.8 - 0.9
	SW, GP, and GW soil classification	0.9 - 1.0	0.9 - 1.0	0.9 - 1.0
Coefficient of Direct Sliding, C_{ds}	ML and CL soil classification	0.7	0.7	0.7
	SM, SP, and SW soil classification	0.8	0.8	0.8
	SW, GP, and GW soil classification	0.9	0.9	0.9

For **SI:** 1 mil = 0.0254 mm, 1 oz/yd^2 = 33.9 g/m^2, 1 lb/ft = 14.6 N/m.

[1]The values for T_a, C_i, and C_{ds} specified in this table are typical values. Actual values used in design must be approved by the soils engineer of record and the building official.

TABLE 2—PHYSICAL PROPERTIES FOR RAUGRID GEOSYNTHETIC REINFORCEMENT[1]

PROPERTY		GRADE OF RAUGRID GEOSYNTHETIC REINFORCEMENT MATERIAL			
		3/3-20	**4/2-15**	**6/3-15**	**8/3-20**
Weight (oz/yd^2)		8.0	7.8	10.4	12.2
Allowable Tension, T_a (lb/ft)		754	976	1336	1799
Coefficient of Interaction, C_i	ML and CL soil classification	0.8	0.8	0.8	0.8
	SM, SP, and SW soil classification	0.9	0.9	0.9	0.9
	SW, GP, and GW soil classification	0.9	0.9	0.9	0.9
Coefficient of Direct Sliding, C_{ds}	ML and CL soil classification	0.7	0.7	0.7	0.85
	SM, SP, and SW soil classification	0.9	0.9	0.9	0.9
	SW, GP, and GW soil classification	0.8	0.8	0.8	0.75

For **SI:** 1 mil = 0.0254 mm, 1 oz/yd^2 = 33.9 g/m^2, 1 lb/ft = 14.6 N/m.

[1]The values for T_a, C_i, and C_{ds} specified in this table are typical values. Actual values used in design must be approved by the soils engineer of record and the building official.

TABLE 3—PHYSICAL PROPERTIES FOR STRATA GEOSYNTHETIC REINFORCEMENT [1]

PROPERTY		GRADE OF STRATA GEOSYNTHETIC REINFORCEMENT MATERIAL		
		200	**300**	**500**
Weight (oz/yd^2)		9.5	10.0	12.5
Allowable Tension, T_a (lb/ft)		852	939	1506
Coefficient of Interaction, C_i	ML and CL soil classification	0.6 - 0.7	0.6 - 0.7	0.6 - 0.7
	SM, SP, and SW soil classification	0.8 - 0.9	0.8 - 0.9	0.8 - 0.9
	SW, GP, and GW soil classification	0.9 - 1.0	0.9 - 1.0	0.9 - 1.0
Coefficient of Direct Sliding, C_{ds}	ML and CL soil classification	0.6 - 0.7	0.6 - 0.7	0.6 - 0.7
	SM, SP, and SW soil classification	0.8 - 0.9	0.8 - 0.9	0.8 - 0.9
	SW, GP, and GW soil classification	0.9 - 1.0	0.9 - 1.0	0.9 - 1.0

For **SI**: 1 mil = 0.0254 mm, 1 oz/yd^2 = 33.9 g/m^2, 1 lb/ft = 14.6 N/m.

[1]The values for T_a, C_i, and C_{ds} specified in this table are typical values. Actual values used in design must be approved by the soils engineer of record and the building official.

TABLE 4—FACING CONNECTION CAPACITY [1, 2]

GEOSYNTHETIC REINFORCEMENT		LIMIT STATE (PEAK STRENGTH) CONNECTION FORMULA (lbs/ft)		SERVICEABILITY STATE (SERVICE STRENGTH) CONNECTION FORMULA (lbs/ft)	
Brand Name	Grade	$T_{ultconn(n)} = a_{cs} + W_{w(n)}\tan\lambda_{cs}$	Max T_{cl}	$T_{conn@3/4(n)} = a'_{cs} + W_{w(n)}\tan\lambda'_{cs}$	Max T_{cs}
Mirafi	3XT	= 655 + $W_{w(n)}$tan 19°	1397	= 350 + $W_{w(n)}$tan 22°	1070
	5XT	= 765 + $W_{w(n)}$tan 13°	1233	= 135 + $W_{w(n)}$tan 27°	1150
	8XT	= 1000 + $W_{w(n)}$tan 22°	2135	= 120 + $W_{w(n)}$tan 32°	1945
Raugrid	3/3-20	= 604 + $W_{w(n)}$tan 20°	1370	= 498 + $W_{w(n)}$tan 18°	1130
	4/2-15	= 885 + $W_{w(n)}$tan 16°	1390	= 465 + $W_{w(n)}$tan 23°	1220
	6/3-15	= 640 + $W_{w(n)}$tan 33°	1600	= 527 + $W_{w(n)}$tan 24°	1440
	8/3-20	= 1000 + $W_{w(n)}$tan 27°	1900	= 663 + $W_{w(n)}$tan 54°	1515
Strata	200	= 1000 + $W_{w(n)}$tan 11°	1409	= 978 + $W_{w(n)}$tan 11°	1310
	300	= 1296 + $W_{w(n)}$tan 12°	1669	= 1093 + $W_{w(n)}$tan 16°	1650
	500	= 1453 + $W_{w(n)}$tan 6°	1716	= 972 + $W_{w(n)}$tan 4°	1163

For **SI:** 1 lb/ft = 14.6 N/m, 1 lb = 4.45 N.

[1]Where:

a_{cs} = Apparent minimum limit-state shear strength between SRW units and geosynthetic reinforcement (lb/ft).
λ_{cs} = Apparent minimum limit-state angle of friction between SRW units and geosynthetic reinforcement (degrees).
a'_{cs} = Apparent minimum serviceability-state shear strength between SRW units and geosynthetic reinforcement (lb/ft).
λ'_{cs} = Apparent minimum serviceability-state angle of friction between SRW units and geosynthetic reinforcement (degrees).
$W_{w(n)}$ = The weight of the stacked SRW units (lbs).

[2]The values for a_{cs}, λ_{cs}, a'_{cs}, and λ'_{cs} specified in this table are typical values. Actual values used in design must be approved by the soils engineer of record and the building official.

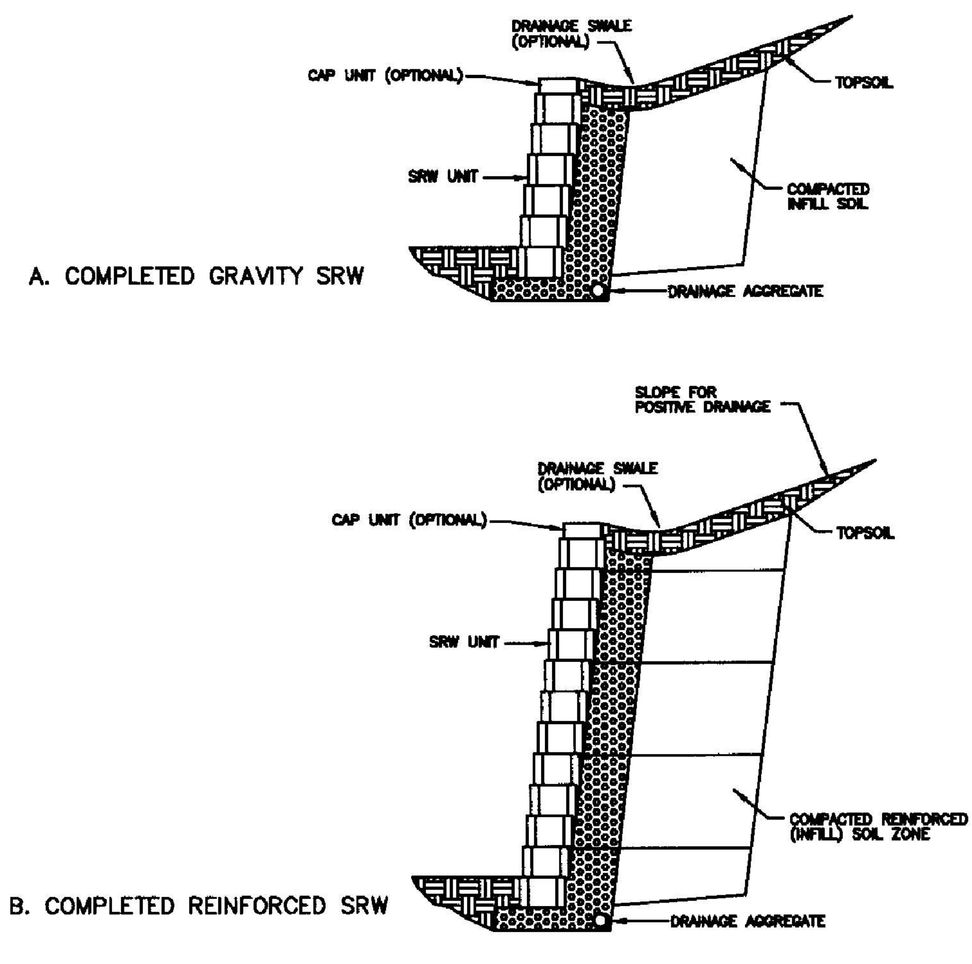

FIGURE 1—TYPICAL SEGMENTAL RETAINING WALLS

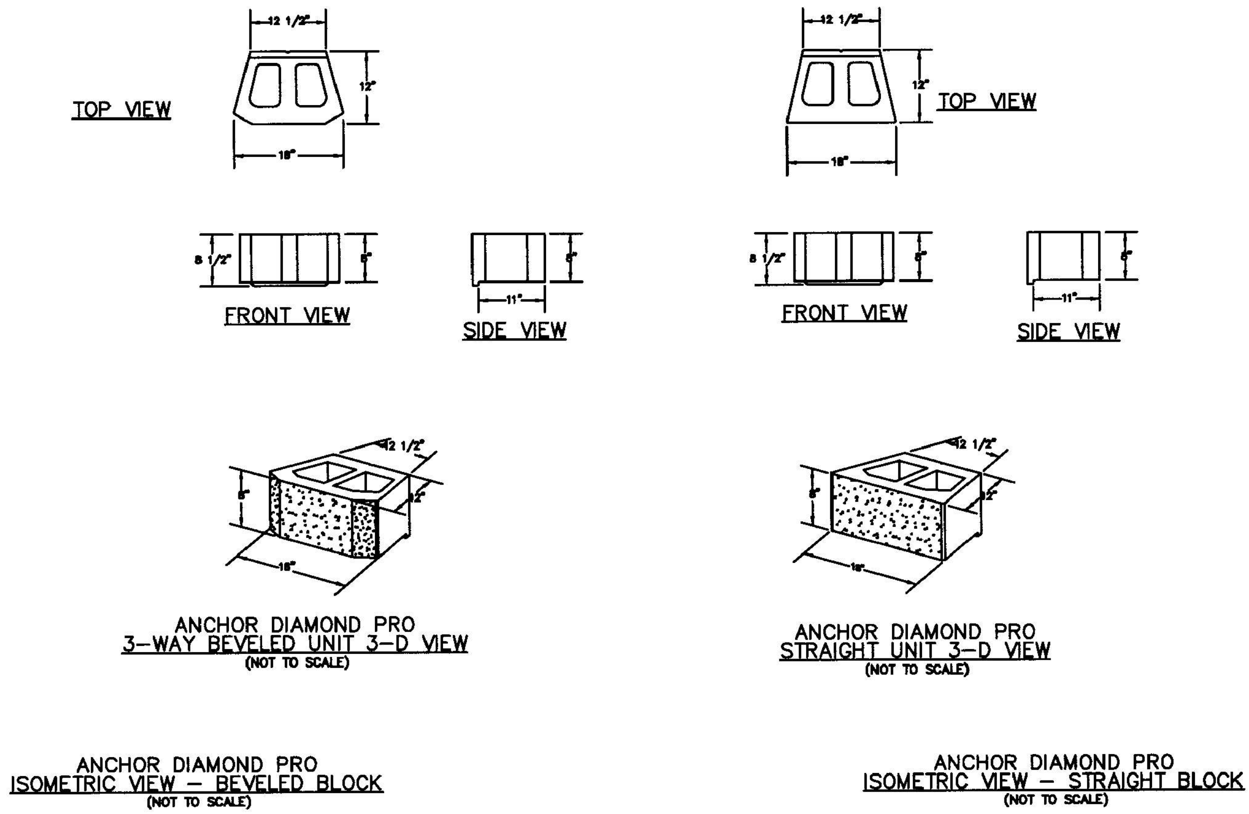

FIGURE 2—ANCHOR DIAMOND PRO SRW UNITS