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Legacy report on the 1997 *Uniform Building Code™*

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

KEYSTONE RETAINING WALL SYSTEM

KEYSTONE RETAINING WALL SYSTEMS, INC.
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MINNEAPOLIS, MINNESOTA 55435

ANGELUS BLOCK COMPANY, INC.
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1.0 SUBJECT

Keystone Retaining Wall System.

2.0 DESCRIPTION

2.1 General:

The Keystone Retaining Wall System utilizes modular concrete units for the construction of gravity or reinforced soil retaining walls. The wall system units are assembled in a running bond pattern, except for the Country Manor units, which are assembled in a random bond pattern. The wall system units are assembled without mortar or grout, utilizing high-strength fiberglass pins for shear connections, mechanical connections of reinforcing geogrid, and unit alignment. The system may include horizontal layers of structural geogrid reinforcement in the backfill soil mass.

2.2 Components:

2.2.1 Keystone Units: Keystone concrete units are available in five basic configurations: Standard, Compac, Compac II, Country Manor and Cap. See Figure 1 for dimensions and nominal weights. The units are made with normal-weight aggregates. Standard, Compac, Compac II and Cap units have either a straight or three-plane split face. Country Manor units have a straight face. Cap units are half-height units without pin holes in the top surface. The nominal unit weights, noted in Figure 1, are to be used in design.

Standard, Compac and Compac II units have four holes each for installation of two fiberglass connection pins. Country Manor units have six holes each for installation of two fiberglass connection pins. The Small Country Manor Unit has three holes, for installation of one fiberglass connection pin. See Figure 1 for typical unit configurations.

All units comply with ASTM C 1372, including a minimum 28-day compressive strength of 3,000 psi (20MPa) on the net area. 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 building official for approval prior to construction.

2.2.2 Fiberglass Pins: Pultruded fiberglass pins provide alignment of the units during placement, positive placement of the geogrid reinforcement, and inter-unit shear strength. The angle of wall inclination (batter) is determined by the location of the fiberglass pins placed during assembly. See Figure 1. The connection pins are 0.5 inch (12.7 mm) in diameter and 5.25 inches (133 mm) long, and have a minimum short beam shear strength of 6,400 psi (44 MPa).

2.2.2.1 Standard, Compac and Compac II Units: The pin placement in the rear pin holes in every course provides a minimum wall inclination of 7.1 degrees from vertical toward the backfill [1 inch (25.4 mm) minimum setback per course]. Pin placement alternating between the front and rear pin holes on vertically adjacent rows provides a wall inclination of approximately 3.6 degrees from vertical toward the backfill [$^1/_2$ inch (13 mm) minimum setback per course]. The pin placement during assembly in the front pin hole provides a wall inclination of approximately 0.5 degree from vertical toward the backfill [$^1/_8$ inch (3 mm) minimum setback per course].

2.2.2.2 Country Manor Units: The pin placement in the rear pin holes in every course provides a wall inclination of approximately 9.5 degrees from vertical toward the backfill [1 inch (25.4 mm) setback per course]. The pin placement during assembly in the middle pin hole provides a wall inclination of approximately 0.5 degree from vertical toward the backfill [$^1/_8$ inch (3 mm) minimum setback per course].

2.2.3 Drainage Core Fill: Drainage core fill is $^1/_2$ inch to $^3/_4$ inch (12 mm to 20 mm) of clean, crushed-stone material that is placed between and behind the units. The 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 face between units. Drainage core fill is required for all installations and shall extend back a minimum of 2 feet (610 mm) from the outside or front face of the wall.

2.2.4 Geogrid: Geogrid soil reinforcement is required to increase the height of the Keystone Wall System above the height at which the wall is stable under its self-weight as a gravity system. Geogrids are synthetic materials manufactured from high-tenacity polyester (PET), high-density polyethylene (HDPE), or polypropylene (PP) polymers specifically designed for use as soil reinforcement. Geogrid reinforcement materials specifically recognized for use with the Keystone Retaining Wall System and the manufacturers are as follows:

1. Huesker Corp. — PET “Fortrac” geogrids
2. Strata Systems, Inc. — PET “Stratagrid” geogrids
   — PET “Merex” geogrids
3. T.C. Mirafi — PET “Miragrid” geogrids
4. Tensar Corp. — HDPE “UX Series” geogrids
   — HDPE “UXK Series” geogrids
   PP “BX Series” geogrids

Geogrids must be stored at temperatures higher than -10˚F (-23˚C). Contact with mud, wet cement, and epoxy or other adhesive materials must be avoided. Prolonged exposure of geogrid materials to sunlight must be avoided because the materials are subject to ultraviolet (UV) degradation.

2.3 Design:

2.3.1 General: The system is designed as a gravity or reinforced-soil retaining wall that depends on the weight and geometry of the mass 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. External stability analyses are similar to those required for conventional retaining walls. Minimum safety factors are 1.5 for 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. Internal stability analyses of reinforced soil structures must consider the maximum allowable reinforcement tension, pull-out resistance of the reinforcement behind the active failure zone, and the connection strength of geogrid reinforcement to the Keystone unit. Table 1 shows the allowable design strengths, T_a, for the geogrids. The design strengths in the table have been reduced by a safety factor of 1.5. Additional safety factors that have been incorporated into the table include the creep reduction factor, and factors considering chemical and biological damage and installation (in sand) damage. Soil interaction and direct sliding coefficients are described in Table 2. Inter-unit shear capacity equations are described in Table 3.

A foundation investigation in accordance with UBC (1997 *Uniform Building Code*™) Section 1804 is required for each site. The foundation investigation determines the soil properties and recommended values for design. The design of the Keystone wall is based on accepted geotechnical principles for gravity and soil-reinforced structures. Specifics of design are found in the Keystone Design Manual dated March 2001.

Keystone Retaining Wall Systems are designed as follows:

2.3.1.1 Gravity Retaining Walls: The gravity wall system relies on the weight and geometry of the Keystone units to resist lateral earth pressures. Gravity wall design is based on standard engineering principles for modular concrete retaining walls. The maximum height of retaining walls constructed using Keystone Standard, Compac, Compac II and Country Manor units is shown in Figure 2 for different soil and back slope combinations. Typical design heights are 2.5 to 3 times the depth of the unit being used.

2.3.1.2 Geogrid-reinforced Retaining Walls: The geogrid reinforced soil system relies on the weight and geometry of the Keystone 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 Keystone unit selected, soil reinforcement strength and soil interaction, soil strength properties, and structure geometry. The maximum practical height above the wall base is approximately 50 feet (15 m). Figure 3 shows typical component details.

2.3.2 Structural Analysis: Structural calculations must be submitted to the building official for each wall system installation. Structural analysis shall be based on accepted engineering principles, the Keystone Design Manual dated March 2001, and the UBC. The analysis must include all items noted in Sections 2.3.2.1 and 2.3.2.2, and must follow the design methodology of the Keystone Design Manual dated March 2001. All contact surfaces of the units must be maintained in compression. The shear resistance between units is provided by fiberglass pins in each course, and is determined by the equations in Table 3.

2.3.2.1 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.

2.3.2.2 Internal Stability:

1. Geogrid spacing is based on local stability of the Keystone units during construction. Vertical spacing is typically limited to 2 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 tensions must not exceed T_a for each respective layer. See Table 1.
3. Connection capacity shall be checked for each geogrid-to-Keystone connection (see Table 4). 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 reinforcing 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 applying the adjustment factors shown in Table 2.

2.4 Installation:

Requirements for installation of the Keystone 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 6-inch-thick (150 mm) leveling pad of crushed stone, compacted to 75 percent relative density as determined by ASTM D 4564. (An unreinforced concrete pad in accordance with UBC Section 1923 may be utilized in place of the crushed stone pad.)
4. Install the first course of Keystone units, ensuring units are level from side to side and front to back. Adjacent Keystone units are placed so pin holes are approximately 12 inches (305 mm) on center.
5. Install the fiberglass pins described in Section 2.2.2 in the proper alignment holes for batter selection.
6. Fill the unit cores with drainage core fill described in Section 2.2.3.
7. Clean the top surface of the units to remove loose aggregate.
8. At designated elevation per the design, install geogrid reinforcing. All geogrid reinforcement is installed by placing it over the fiberglass pin. 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. A grooved Compac unit, modified as shown in Figure 1, must be used when Tensar UXK1400, UXK1500 and UXK1600 geogrids are installed in walls constructed using Compac units.
9. Pull taut to remove slack from the geogrids before placing backfill. Pull the entire length taut to remove any folds or wrinkles.
10. Place and compact backfill over the geogrid reinforcing layer in appropriate lift thickness to ensure compaction.
11. Repeat placement of units, core fill, backfill, and geogrids as shown on plans to finished grade.
12. Backfill used in the reinforced fill mass must consist of suitable fine-grained or coarse-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 shall 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.
13. Stack and align units using the structural pin connection between vertically adjacent units at the design setback batter. The completed wall is built with alignment tolerances of 1.5 inches (40 mm) in 10 feet (3048 mm) in both the horizontal and vertical directions.
14. When required by the design, geogrid reinforcement is placed at the elevations specified in the design. The reinforced backfill must be placed and compacted no lower than the top unit-elevation to which geogrid placement is required.

2.5 Special Inspection:

Special inspection is required in accordance with UBC Section 1701.5.7.1. The special inspector's responsibilities include verifying the following:

1. The modular concrete unit dimensions.
2. Concrete unit identification compliance.
3. Foundation preparation.
4. Concrete unit placement, including alignment and inclination.
5. Geosynthetic reinforcement type and placement.
6. Backfill placement and compaction.
7. Drainage provisions.

2.6 Identification:

Each pallet of blocks is identified with the manufacturer's name (Angelus Block Company or RCP Block and Brick) and address, the name of the product, the unit type, and the evaluation report number (ER-4599). Each roll of geogrid is identified by the geogrid manufacturer's name and address (see Section 2.2.4), the name of the product, and the product designation. Fiberglass pins are provided with each shipment of blocks, with a letter of certification by Keystone.

3.0 EVIDENCE SUBMITTED

Reports of tests on geogrid strength, geogrid durability, geogrid-soil interaction, geogrid pull-out, and unit shear; engineering calculations; installation instructions; reports of testing per ASTM C 1372; and quality control manuals.

4.0 FINDINGS

That the Keystone Retaining Wall System complies with the 1997 *Uniform Building Code*™ (UBC), subject to the following conditions:

4.1 The system is designed and installed in accordance with this report; the Keystone Design Manual, dated March 2001; the manufacturer's instructions; and accepted engineering principles.

4.2 The Keystone Design Manual, dated March 2001, is submitted to the building official upon request.

4.3 The wall design calculations are submitted to and approved by the building official.

4.4 A foundation investigation in accordance with UBC Section 1804 is provided for each project site.

4.5 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 building official for approval prior to construction.

4.6 Special inspection is provided for foundation conditions, reinforced backfill placement, and structural geogrid installation in accordance with UBC Section 1701.7.5.1, Section 2.5 of this report, and the Keystone Design Manual dated March 2001.

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

TABLE 1—GEOGRID PROPERTIES

GEOGRID	WEIGHT (oz/yd^2)	ULTIMATE TENSILE STRENGTH, T_{ult} (MARV) (lbs/ft)	LONG-TERM DESIGN STRENGTH, LTDS (lbs/ft)	ALLOWABLE STRENGTH, T_a (lbs/ft)
Strata Systems				
Stratagrid SG 150	6.0	1560	800	533
Stratagrid SG 200	9.5	2720	1395	930
Stratagrid SG 300	10.0	3000	1540	1027
Stratagrid SG 500	12.5	4600	2360	1573
Stratagrid SG 600	14.5	7400	3800	2533
Strata Systems				
Merex UL 25	4.1	1919	995	663
Merex UL 45	5.2	3118	1616	1077
Merex UL 55	6.2	3700	1918	1279
Merex UL 70	7.4	4796	2487	1658
Merex UL 90	8.9	6304	3268	2179
Merex UL 120	11.3	8359	4334	2889
TC Mirafi				
Miragrid 2XT	7.5	2000	839	559
Miragrid 3XT	8.2	2800	1328	885
Miragrid 5XT	9.0	3590	1733	1155
Miragrid 7XT	10.2	4350	2157	1438
Miragrid 8XT	11.4	6230	3089	2059
Miragrid 10XT	14.3	8300	4116	2744
Huesker				
Fortrac 20/13-20	5.0	1500	729	486
Fortrac 35/20-20	7.0	2400	1207	805
Fortrac 55/30-20	9.0	3700	1767	1178
Fortrac 80/30-20	14.0	5380	2570	1713
Fortrac 110/30-20	16.0	7400	3535	2357
Tensar				
BX1200	5.0	1975	505	337
UX1400SB	14.9	3700	1333	889
UX1500SB	23.1	6000	2190	1460
UX1600SB	30.5	8000	2857	1905
UXK1400	10.6	4720	1876	1251
UXK1500	16.7	7550	2857	1905
UXK1600	21.6	9850	3771	2514

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

Notes:
T_{ult} (MARV) = Wide width tensile strength (mean average roll value) per ASTM D 4595.
LTDS = Long-term design strength, including creep, durability, and installation-in-sand reduction factors.
T_a = Working stress design strength, including overall factor of safety of 1.5

TABLE 2—GEOGRID INTERACTION AND SLIDING COEFFICIENTS, C_i and C_{DS}

SOIL TYPE (USC[1])	PEAK INTERNAL FRICTION ANGLE, Φ (degrees)	C_i and C_{DS}
Crushed stone, gravel (GW, GM)	> 32	0.90
Sand, gravel, silty sands (SW, SM, SP)	> 28	0.80
Sandy silt, lean clay (SC, ML, CL)	> 25	0.70

[1]USC: Universal Soil Classification System.

TABLE 3—INTER-UNIT SERVICE-STATE SHEAR RESISTANCE[1]

UNIT	SHEAR STRENGTH
Standard	F = 1548 + 0.31 N
Compac	F = 769 + 0.51 N
Compac II	F = 1263 + 0.12 N
Country Manor	F = 92 + 0.81 N

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

[1]The inter-unit service-state shear resistance, F [lb/linear foot (N/m)], of the Keystone units at any depth is a function of the pin strength and normal load, N [lb/linear foot (N/m)], of Keystone units determined from laboratory test results in accordance with the above equations.

TABLE 4—GEOGRID-TO-BLOCK PULLOUT RESISTANCE EQUATIONS

GEOGRID	PEAK CONNECTION STRENGTH (pounds/linear foot)		SERVICEABILITY CONNECTION STRENGTH (pounds/linear foot)	
	Equation	Maximum	Equation	Maximum
KEYSTONE STANDARD UNIT				
Strata Systems				
Stratagrid SG 200	P = 835 + 0.73 N	1566	P = 795 + 0.23 N	1013
Stratagrid SG 300	P = 650 + 0.45 N	2000	P = 500 + 0.27 N	1100
Stratagrid SG 500	P = 1591 + 0.62 N	2759	P = 994 + 0.21 N	1702
Stratagrid SG 600	P = 1417 + 0.62 N	3409	P = 878 + 0.18 N	1791
Strata Systems				
Merex UL25	P = 1119 + 0.03 N	1211	P = 919 + 0.02 N	941
Merex UL45	P = 1398 + 0.31 N	1822	P = 1104 + 0.14 N	1576
Merex UL55	P = 1851 + 0.25 N	2676	P = 1202 + 0.16 N	1792
Merex UL70	P = 1055 + 0.97 N	2807	P = 950 + 0.12 N	1443
Merex UL90	P = 1454 + 0.93 N	3604	P = 975 + 0.47 N	2283
Merex UL120	P = 964 + 0.90 N	3722	P = 1018 + 0.27 N	2175
TC Mirafi Geogrid				
Miragrid 3XT	P = 1595 + 0.00 N	1595	P = 822 + 0.14 N	1302
Miragrid 5XT	P = 600 + 0.29 N	1644	P = 484 + 0.14 N	915
Miragrid 7XT	P = 1137 + 0.36 N	2284	P = 781 + 0.27 N	1720
Miragrid 8XT	P = 958 + 0.47 N	1897	P = 334 + 0.51 N	1398
Miragrid 10XT	P = 1226 + 0.53 N	2896	P = 1000 + 0.21 N	1766
Huesker Geogrid				
Fortrac 20/13-20	P = 500 + 0.75 N	750	P = 400 + 0.60 N	700
Fortrac 35/20-20	P = 700 + 0.75 N	1050	P = 500 + 0.60 N	900
Fortrac 55/30-20	P = 950 + 0.87 N	2300	P = 650 + 0.72 N	2000
Fortrac 80/30-20	P = 1200 + 1.0 N	2800	P = 900 + 0.72 N	2100
Fortrac 110/30-20	P = 2000 + 0.78 N	4145	P = 1342 + 0.42 N	2846
Tensar Geogrid				
UX1400SB	P = 700 + 0.89 N	2500	P = 400 + 0.70 N	2100
UX1500SB	P = 1000 + 0.89 N	4400	P = 700 + 0.89 N	2750
UX1600SB	P = 1100 + 0.89 N	4500	P = 800 + 0.60 N	3000
KEYSTONE COMPAC UNIT				
Strata Systems				
Stratagrid SG 150	P = 444 + 0.60 N	1259	P = 358 + 0.38 N	878
Stratagrid SG 200	P = 889 + 0.31 N	1624	P = 519 + 0.14 N	767
Stratagrid SG 300	P = 550 + 0.25 N	2000	P = 400 + 0.16 N	1100
Stratagrid SG 500	P = 802 + 0.51 N	2174	P = 446 + 0.29 N	1000
Stratagrid SG 600	P = 850 + 0.25 N	2800	P = 500 + 0.16 N	1800
Strata Systems				
Merex UL25	P = 501 + 0.29 N	1115	P = 445 + 0.19 N	795
Merex UL45	P = 463 + 0.65 N	1381	P = 324 + 0.55 N	1192
Merex UL55	P = 841 + 0.40 N	1692	P = 626 + 0.34 N	1443
Merex UL70	P = 965 + 0.47 N	2229	P = 766 + 0.34 N	1649
Merex UL90	P = 897 + 0.58 N	2546	P = 723 + 0.38 N	1719

(*Continued*)

TABLE 4—GEOGRID-TO-BLOCK PULLOUT RESISTANCE EQUATIONS—(Continued)

GEOGRID	PEAK CONNECTION STRENGTH (pounds/linear foot)		SERVICEABILITY CONNECTION STRENGTH (pounds/linear foot)	
	Equation	Maximum	Equation	Maximum
KEYSTONE COMPAC UNIT—(Continued)				
TC Mirafi				
Miragrid 2XT	P = 213 + 0.55 N	1314	P = 302 + 0.23 N	680
Miragrid 3XT	P = 695 + 0.21 N	1128	P = 469 + 0.19 N	882
Miragrid 5XT	P = 763 + 0.23 N	1459	P = 564 + 0.27 N	1293
Miragrid 7XT	P = 443 + 0.67 N	1571	P = 289 + 0.55 N	1182
Miragrid 8XT	P = 635 + 0.38 N	1780	P = 444 + 0.34 N	1465
Miragrid 10XT	P = 752 + 0.65 N	1988	P = 518 + 0.62 N	1760
Huesker				
Fortrac 20/13-20	P = 372 + 0.23 N	716	P = 338 + 0.16 N	684
Fortrac 35/20-20	P = 809 + 0.31 N	1557	P = 809 + 0.12 N	1115
Fortrac 55/30-20	P = 983 + 0.51 N	2453	P = 919 + 0.32 N	1957
Fortrac 80/30-20	P = 1000 + 0.47 N	2979	P = 1000 + 0.36 N	2525
Tensar				
UX1400SB	P = 600 + 0.80 N	2600	P = 400 + 0.70 N	2100
UX1500SB	P = 800 + 1.10 N	3800	P = 700 + 0.89 N	2750
UXK1400[1]	P = 85 + 1.80 N	2945	P = 351 + 1.23 N	1500
UXK1500[1]	P = 100 + 2.14 N	5000	P = 100 + 2.14 N	2500
UXK1600[1]	P = 421 + 2.25 N	5000	P = 652 + 1.48 N	2350
KEYSTONE COMPAC II UNIT				
Strata Systems				
Stratagrid SG 150	P = 798 + 0.34 N	1576	P = 593 + 0.27 N	1184
Stratagrid SG 200	P = 707 + 0.93 N	1754	P = 928 + 0.10 N	1250
Stratagrid SG 300	P = 980 + 0.62 N	1913	P = 980 + 0.19 N	1490
Stratagrid SG 500	P = 626 + 1.15 N	2000	P = 770 + 0.42 N	1705
Strata Systems				
Merex UL25	P = 605 + 0.34 N	1073	P = 598 + 0.32 N	1013
Merex UL45	P = 696 + 0.53 N	1920	P = 755 + 0.40 N	1609
Merex UL55	P = 889 + 0.58 N	2222	P = 721 + 0.62 N	2159
Merex UL90	P = 1462 + 0.60 N	3213	P = 676 + 0.36 N	1674
TC Mirafi				
Miragrid 2XT	P = 800 + 0.29 N	1452	P = 800 + 0.29 N	1452
Miragrid 3XT	P = 811 + 0.36 N	1617	P = 571 + 0.45 N	1593
Miragrid 5XT	P = 1200 + 0.38 N	2050	P = 691 + 0.55 N	1941
Miragrid 7XT	P = 1173 + 0.40 N	2222	P = 622 + 0.47 N	1948
Miragrid 8XT	P = 960 + 0.84 N	2490	P = 691 + 0.73 N	2280
Huesker				
Fortrac 35/20-20	P = 916 + 0.57 N	1576	P = 743 + 0.16 N	1040
Fortrac 55/30-20	P = 1166 + 0.70 N	2518	P = 1096 + 0.23 N	1808
Fortrac 80/30-20	P = 819 + 0.31 N	2663	P = 1032 + 0.31 N	1957
KEYSTONE COUNTRY MANOR UNIT				
Strata Systems				
Stratagrid SG 150	P = 377 + 0.47 N	950	P = 327 + 0.48 N	932
Stratagrid SG 200	P = 550 + 0.43 N	1238	P = 311 + 0.38 N	903
Strata Systems				
Merex UL25	P = 330 + 0.36 N	846	P = 261 + 0.32 N	757
Merex UL45	P = 602 + 0.36 N	1204	P = 287 + 0.44 N	1010
Huesker				
Fortrac 20/13-20	P = 427 + 0.18 N	702	P = 310 + 0.23 N	675
Tensar				
BX1200	P = 474 + 0.42 N	1142	P = 494 + 0.36 N	1045

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

[1] Compac units with grooves, as shown in Figure 1, must be used with Tensar UXK geogrids.

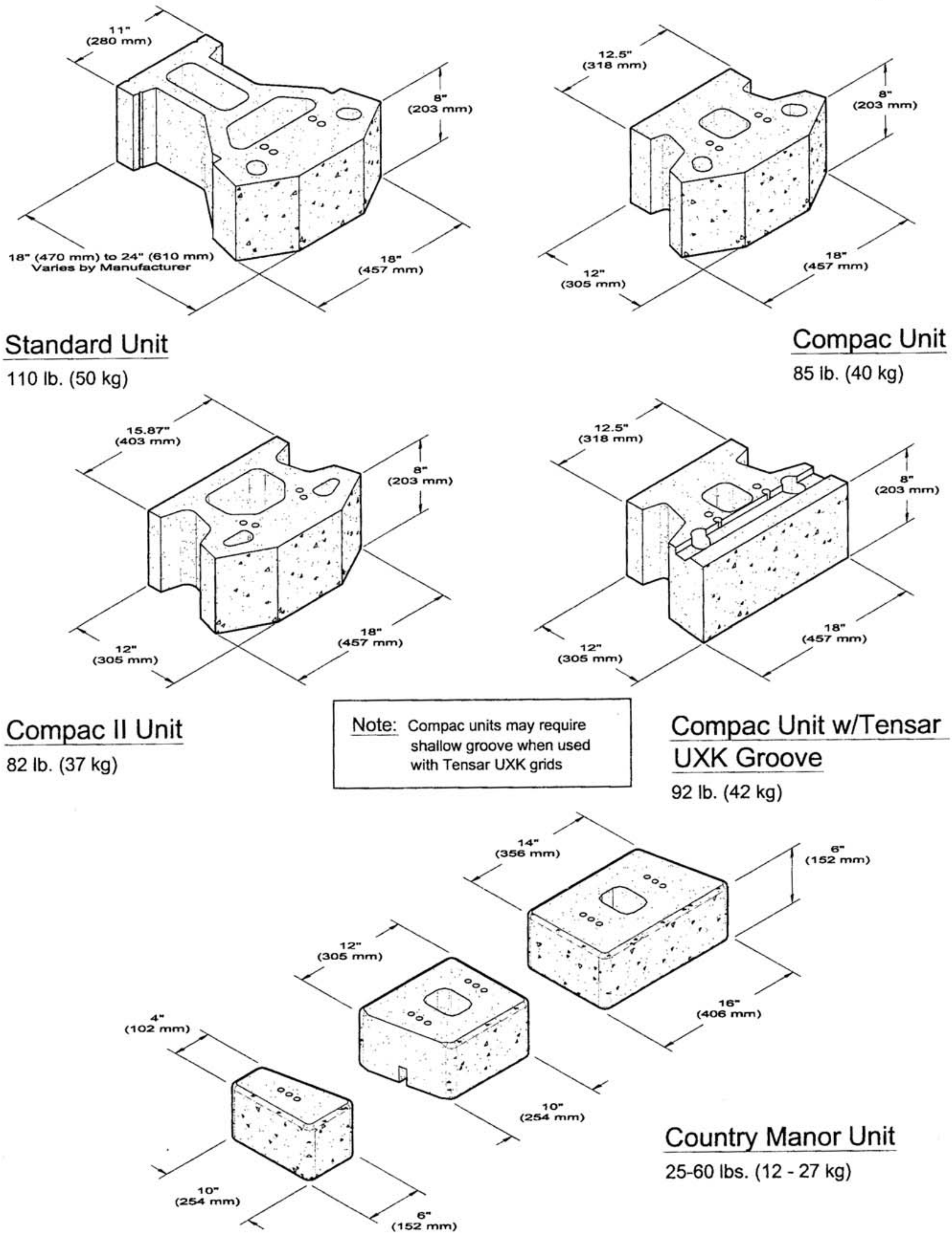
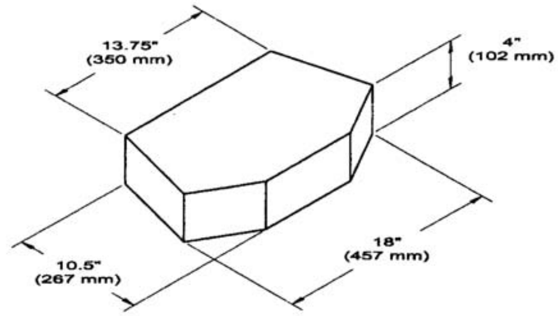


FIGURE 1—KEYSTONE WALL UNITS

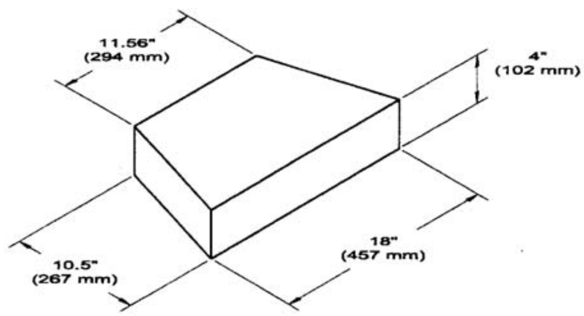
Cap Unit

45 lb. (20 kg)



Universal Cap Unit

51 lb. (23 kg)



Country Manor Cap Unit

24 lbs. (11 kg)

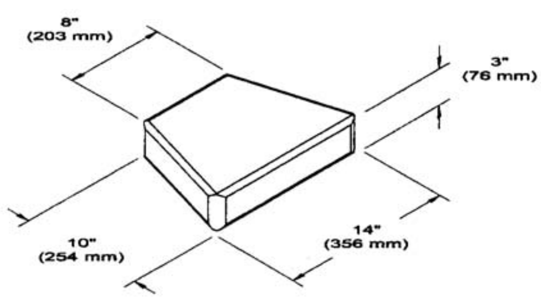
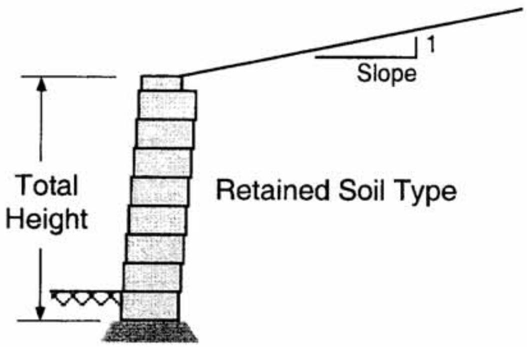


FIGURE 1—KEYSTONE WALL UNITS—(Continued)



NEAR VERTICAL WALL
(Minimum setback per unit)

STANDARD UNITS

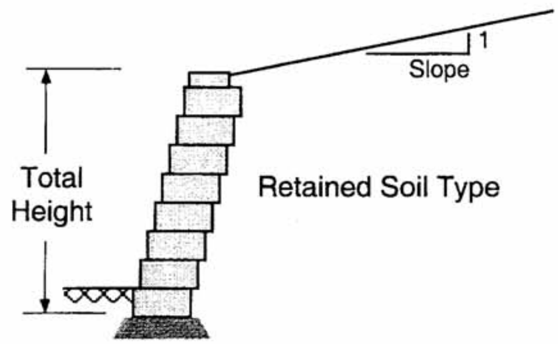
MAX. HGT.	Backslope			
Soil Type	Level	4H:1V	3H:1V	2H:1V
Sand/Gravel	5.2'	4.7'	4.6'	4.1'
Silty Sand	4.7'	4.3'	4.1'	3.6'
Silt/Lean Clay	4.4'	3.9'	3.7'	2.9'

COMPAC/COMPAC II UNITS

MAX. HGT.	Backslope			
Soil Type	Level	4H:1V	3H:1V	2H:1V
Sand/Gravel	2.9'	2.6'	2.5'	2.3'
Silty Sand	2.6'	2.4'	2.3'	2.0'
Silt/Lean Clay	2.4'	2.1'	2.0'	1.7'

COUNTRY MANOR UNITS

MAX. HGT.	Backslope	
Soil Type	Level	3H:1V
Sand/Gravel	2.0'	1.5'
Silty Sand	1.5'	1.5'
Silt/Lean Clay	1.5'	1.0'



ONE INCH SETBACK WALL
(1" min. setback per unit)

STANDARD UNITS

MAX. HGT.	Backslope			
Soil Type	Level	4H:1V	3H:1V	2H:1V
Sand/Gravel	6.8'	6.2'	5.9'	5.3'
Silty Sand	6.1'	5.5'	5.2'	4.4'
Silt/Lean Clay	5.3'	4.5'	4.1'	3.2'

COMPAC/COMPAC II UNITS

MAX. HGT.	Backslope			
Soil Type	Level	4H:1V	3H:1V	2H:1V
Sand/Gravel	3.8'	3.4'	3.3'	2.9'
Silty Sand	3.4'	3.0'	2.9'	2.4'
Silt/Lean Clay	3.0'	2.7'	2.5'	2.1'

COUNTRY MANOR UNITS

MAX. HGT.	Backslope	
Soil Type	Level	3H:1V
Sand/Gravel	3.0'	2.5'
Silty Sand	2.5'	2.0'
Silt/Lean Clay	2.0'	1.5'

Notes: Calculations assume a moist unit weight of 120 lbs/cf for all soil types. Assumed ϕ angles for earth pressure calculations are: Sand/Gravel=34°, Silty Sand=30°, and Sandy Silt/Lean Clay=26°.
Non critical structures with SF>1.5. No surcharge loadings are included.
Surcharges or special loading conditions will reduce maximum wall heights.
Sliding calculations assume a 6" crushed stone levelling pad as compacted foundation material.

FIGURE 2—GRAVITY WALL CHARTS

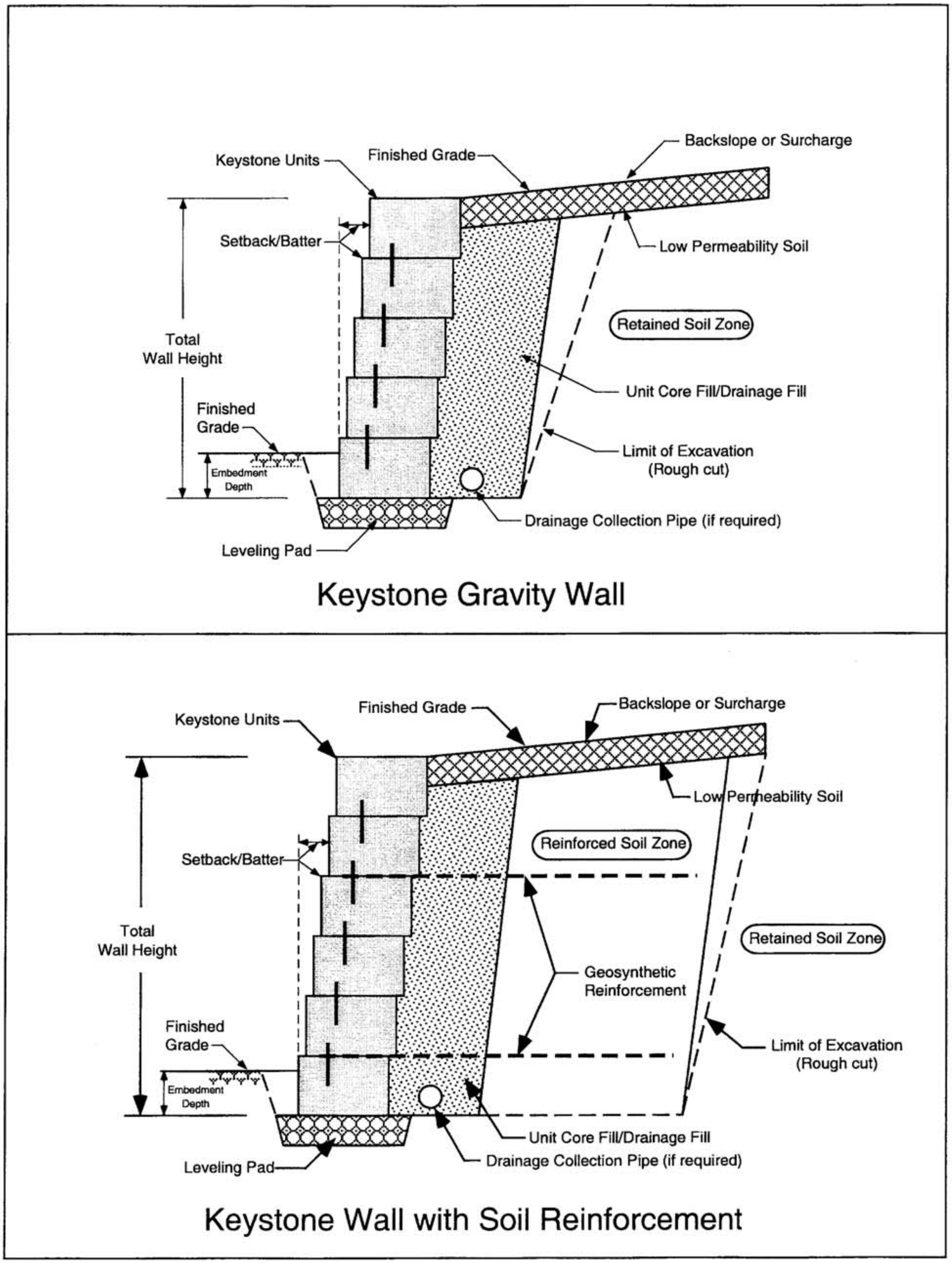


FIGURE 3—TYPICAL WALL SECTIONS