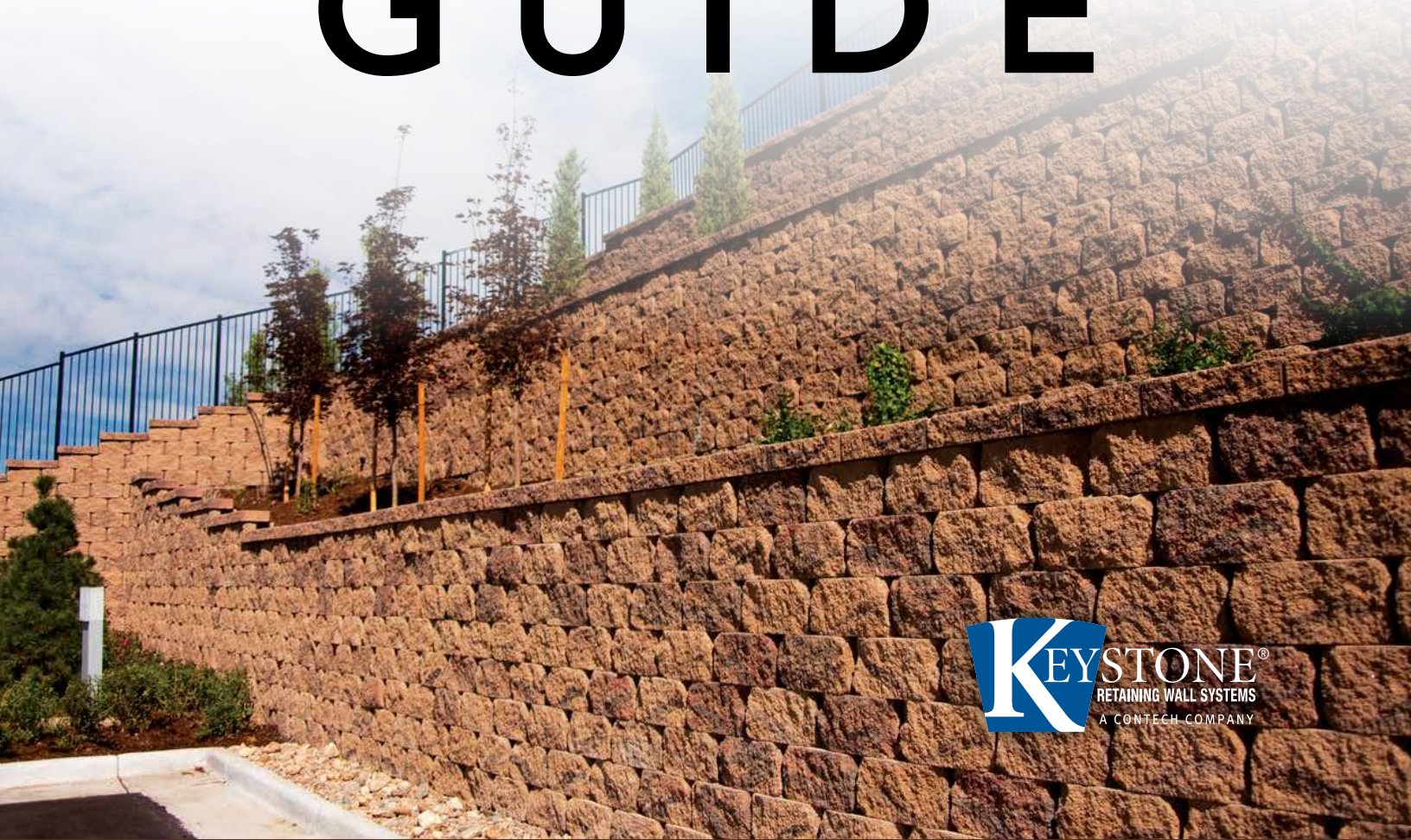




# KEYSTONE SPECIFICATION GUIDE



# THE RIGHT SOLUTION

For over 25 years, Keystone Retaining Wall Systems has set the worldwide standard in soil retention, erosion control and landscape systems. By working with the finest network of manufacturers, product developers, engineers and sales professionals in the business; Keystone ensures that its products and services offer the best site solutions for residential, commercial, recreational, industrial and governmental applications.

Architects, engineers and contractors around the world rely on Keystone's industry leading product performance and aesthetics to fulfill the unique requirements of their projects. Offering a broad family of products, Keystone has the right solution for even the most challenging structural and landscape sites.

The Keystone difference lies in its outer beauty and inner strength. Keystone's patented, interlocking fiberglass pin system ensures a positive connection from wall unit to wall unit, and between wall units and soil reinforcement. In addition, Keystone's pinned system aids in horizontal alignment, as well as providing for the ability to vary wall set-back.

## KEYSTONE® STANDARD

The Keystone Standard is an American original and remains the industry leader. The Keystone Standard unit's height-to-depth ratio delivers a structurally sound, engineered wall system with superior construction stability, durability, and strength. This product is the preferred choice for tall walls and critical structures.



94 - 106 lbs (43 - 48 kg)

Standard I



92 - 97 lbs (42 - 44 kg)

Tri-Plane

Standard II



82 - 93 lbs (37 - 42 kg)

Standard III

Face Area • 1 sq. ft. per unit  
8" h x 18" w x 18 - 21" d  
(203 x 457 x 457 - 533 mm)

Straight Split

102 - 114 lbs (46 - 52 kg)



99 - 105 lbs (45 - 48 kg)



85 - 96 lbs (39 - 44 kg)



Supporting products that can be used with both the Standard and Compac units.



2 Connection Pins  
required per unit



8" 90° Corner unit  
Face Area • 1 sq. ft.  
8" h x 18" w x 9" d  
(203 x 457 x 228 mm)  
96 - 102 lbs (44 - 46 kg)



8" 90° Corner unit\*  
Face Area • .83 sq. ft.  
8" h x 15" w x 6" d  
(203 x 381 x 152 mm)  
44 - 48 lbs (20 - 22 kg)

\*Left & right corner units available.



# KEYSTONE® COMPAC

Featuring unrivaled aesthetic options, cost saving versatility and proven wall performance; the Keystone Compac retains its position as the most specified unit on the market. An installer's favorite, the Compac's lighter weight and shorter tail design make it easy to handle.

Face Area • 1 sq. ft. per unit  
8"h x 18"w x 12"d  
(203 x 457 x 305 mm)



76 - 81 lbs (34 - 37 kg)

Compac II



67 - 72 lbs (30 - 33 kg)

Compac III

Tri-Plane

Straight Split

84 - 89 lbs (38 - 40 kg)



71 - 76 lbs (32 - 34 kg)



Alternative face options available:

Hewnstone



Victorian



Random Score



\* Note: Unit colors, dimensions, weight, and availability will vary by manufacturer.



The KeySteel SQ FT Panel System is a high performance retaining wall system designed specifically for use in transportation and tall walls with high load applications. This system has been used extensively for structures supporting railroads, multi-story buildings, bridge approach and abutments, and mining applications. The KeySteel SQ FT Panel System has been evaluated by HITEC (CERF report #40478) and found to be in accordance with the high standards of the AASHTO bridge specification manual. The system utilizes the Keystone KeySteel SQ FT Panel and inextensible KeyStrip soil reinforcement.

Face Area • 1 sq. ft. per unit  
 8" h x 18" w x 12" d  
 (203 x 457 x 305 mm)  
 90 - 95 lbs (41 - 43 kg)



Steel Pins



Fiberglass Pins

2 required per unit  
 (steel pins required at reinforcement locations)



Tri-Plane



Straight Split



The KeyGrid System has been developed, designed and tested to meet the highest standards of the transportation market. The System was evaluated by HITEC and found to be in accordance with the most current AASHTO LRFD Bridge Design Specifications and Federal Highway Administration design requirements for transportation applications. The system utilizes the patented Keystone Compac II unit and Miragrid® XT geogrids.



Tri-Plane



Straight Split

Face Area • 1 sq. ft. per unit  
 8" h x 18" w x 12" d  
 (203 x 457 x 305 mm)  
 76 - 89 lbs (34 - 40 kg)



2 Connection Pins  
 required per unit



# 133<sup>KEYSTONE</sup>ELITE<sup>®</sup>

The Keystone 133Elite is perfect for large wall applications. The 8" x 24" face dimension creates a larger-scale appearance, aesthetically matching the larger wall look while reducing the number of units required to complete the job. From corners to sweeping curves, the Keystone 133Elite is able to satisfy a wide array of design requirements. Quite simply, the Keystone 133Elite is the best combination of strength, beauty and efficiency on the market.



**Hewnstone**

**Face Area • 1.33 sq. ft. per unit**  
 8" h x 24" w x 11.5 - 12" d  
 (203 x 610 x 292 - 305 mm)  
 92 - 97 lbs (42 - 44 kg)



**Random Score**

*\*Note: Units shown have chamfer on three sides.*



**133Elite<sup>®</sup> 90° Hewnstone Corner\***

8" h x 18" w x 6" d  
 (203 x 457 x 152 mm)  
 53 - 57 lbs (24 - 26 kg)

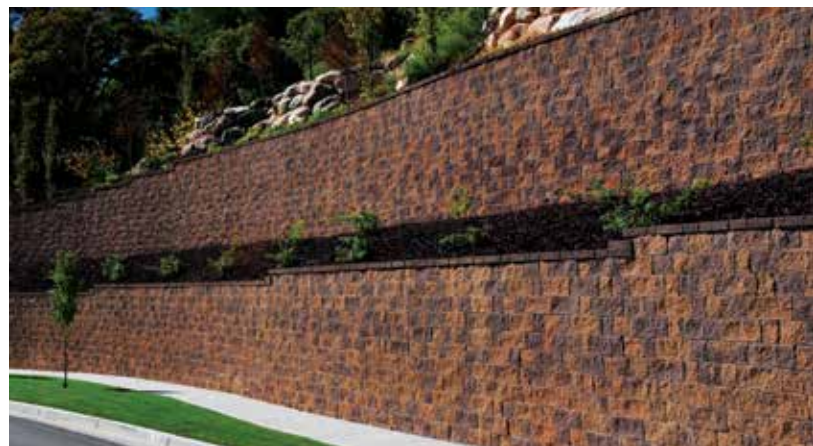
*\*Left & right corner units available.*



**2 Shouldered Pins required per unit**

## KEYSTONE CENTURY WALL<sup>®</sup>

Designed specifically for medium to large wall loading conditions, Keystone Century Wall combines the distinctive look and character of a natural stone three-piece system\* with superior structural integrity. For projects where aesthetics are paramount; Keystone Century Wall allows you to build with confidence.



**Large unit**

**Face Area • 1 sq. ft.**  
 8" h x 18" w x 12" d  
 (203 x 457 x 305 mm)  
 82 - 87 lbs (37 - 39 kg)



**Medium unit**

**Face Area • .62 sq. ft.**  
 8" h x 11" w x 12" d  
 (203 x 279 x 305 mm)  
 54 - 58 lbs (24 - 26 kg)



**Small unit**

**Face Area • .38 sq. ft.**  
 8" h x 7" w x 12" d  
 (203 x 177 x 305 mm)  
 41 - 45 lbs (19 - 20 kg)



**1 to 2 Shouldered Pins required per unit**

*\*In select markets, Half-Century Wall (4" h) units are available to combine with the 8" versions; to achieve an ashlar pattern wall design.*

# KEYSTONE® Country Manor®

Keystone Country Manor offers the appearance of rustic, hand-laid stone walls with the strength and ease of installation provided by the latest in dry-stacked, modular, pin-connected technology. With three finished sides on each unit, Country Manor offers endless building possibilities.



### 3 - piece Country Manor



**Unit 16/14**

16" Face Area • .66 sq. ft.  
14" Face Area • .58 sq. ft.  
6"h x 16"/14"w x 10"d  
(152 x 406/355 x 254 mm)  
60 - 65 lbs (27 - 29 kg)



**Unit 12/10\*\***

12" Face Area • .50 sq. ft.  
10" Face Area • .42 sq. ft.  
6"h x 12"/10"w x 10"d  
(152 x 305/254 x 254 mm)  
47 - 51 lbs (20 - 23 kg)



**Unit 6/4**

6" Face Area • .25 sq. ft.  
4" Face Area • .17 sq. ft.  
6"h x 6"/4"w x 10"d  
(152 x 152/101 x 254 mm)  
21 - 24 lbs (10 - 11 kg)



**Keystone Country Manor Cap Unit**

\*3"h x 12"/10"w x 11"d  
(76 x 305/255 x 279 mm)  
27 - 30 lbs (12 - 14 kg)

### Optional Country Manor Unit Sizes\*



**Unit 8/6**

8" Face Area • .33 sq. ft.  
6" Face Area • .25 sq. ft.  
6"h x 8"/6"w x 10"d  
(152 x 203/152 x 254 mm)  
30 - 33 lbs (14 - 15 kg)



**Unit 10/8**

10" Face Area • .42 sq. ft.  
8" Face Area • .33 sq. ft.  
6"h x 10"/8"w x 10"d  
(152 x 254/203 x 254 mm)  
38 - 42 lbs (17 - 19 kg)



**Unit 12/12\*\***

12" Face Area • .50 sq. ft.  
6"h x 12"/12"w x 10"d  
(152 x 305/305 x 254 mm)  
51 - 55 lbs (23 - 25 kg)  
(90° ends for vertical stacking capability)



1-2 Shouldered Pins  
required per unit

*\*The number of units in the Keystone Country Manor system vary by manufacturer.*

*\*\*The use of unit cores vary by manufacturer.*

*Contact your local representative for further details.*



# KEYSTONE Stonegate® COUNTRY MANOR®

Reminiscent of the walls found scattered throughout the European countryside, Keystone Stonegate Country Manor features a smooth, weathered stone appearance. Stonegate delivers all of the best features of the original Keystone Country Manor, with a refined look.



**Unit 16/14**

16" Face Area • .66 sq. ft.  
14" Face Area • .58 sq. ft.  
6"h x 16"/14"w x 10"d  
(152 x 406/355 x 254 mm)  
60 - 65 lbs (27 - 29 kg)



**Unit 12/10**

12" Face Area • .50 sq. ft.  
10" Face Area • .42 sq. ft.  
6"h x 12"/10"w x 10"d  
(152 x 305/254 x 254 mm)  
47 - 51 lbs (21 - 23 kg)



**Unit 6/4**

6" Face Area • .25 sq. ft.  
4" Face Area • .17 sq. ft.  
6"h x 6"/4"w x 10"d  
(152 x 152/101 x 254 mm)  
21 - 24 lbs (9 - 11 kg)



1-2 Shouldered Pins  
required per unit

## Gravity Walls

One of the most basic types of retaining walls, the gravity wall, relies on unit mass, depth, and setback to resist the earth pressure that is attempting to move the structure in a lateral direction. Keystone units are able to resist lateral pressure with their weight and embedment depth. The mortarless, yet structurally interconnected, Keystone units also permit water drainage to prevent hydrostatic loads. For low, non-critical applications, Keystone products can be used to build cost-effective gravity wall structures.

Maximum wall height for non-critical walls is dependent on wall batter, soil loads affecting the walls, and site conditions including drainage considerations. For more information on specific maximum gravity wall heights refer to [www.keystonewalls.com/pages/TECH\\_DesignCharts.html](http://www.keystonewalls.com/pages/TECH_DesignCharts.html).



## Reinforced Soil Walls

For taller walls, Keystone units are combined with soil reinforcement (such as geogrids, earth anchors or galvanized steel grid reinforcing) to create larger composite reinforced soil structures. With a properly designed combination, the reinforced soil mass can support greater earth pressure and surcharge loads. These composite structures have been constructed to heights over 70' (21 m) high. Call your local Keystone Representative to see which option will work best for your project.



## Geogrid

Since the 1980's, geogrid has proven successful in providing durable soil reinforcement for the retaining wall industry. Proper design methodology today incorporates laboratory tested connection strength of Keystone concrete units and specific geogrid types for reinforced retaining wall systems. Geogrids are made from high tenacity polyester yarns or high-density polyethylene.

### Key properties of geogrid include:

- High tensile strength
- Long-term creep resistance
- Open geometry for interlock
- Non-degradable
- "Off-the-shelf" availability

### The advantages of geogrid-reinforced structures include:

- Construct walls faster without waiting for forming, steel placement and curing time of site cast concrete; the wall structure and backfill are constructed at the same time.
- Eliminates the need for deep structural footing and deeper excavations.
- Provides durability; long term performance resists effects of water, micro-organisms, alkali or acidic soils.



## Soil Properties

The very purpose of a retaining wall system is to safely hold soil in place to make a grade or elevation change in the shortest possible horizontal distance. The soil's shear strength (angle of internal friction) and moist soil weight determines the design characteristics of the soil for use within the wall structure. The design properties of the geogrid zone (the retained zone of reinforced soil mass and sloping embedment soils) as well as the foundation zone (soils beneath the Keystone units and reinforced zone), must be determined. A qualified geotechnical engineer should be consulted to establish site-specific soil properties. Taller walls or difficult site conditions will typically require a more extensive geotechnical investigation including laboratory testing of soil.

*Note: Granular soils typically exhibit higher friction angles and better drainage capability, thus offer a more efficient and cost effective wall design and soil reinforcement solution. Better quality soils are more easily placed and compacted resulting in superior structure performance.*



## Engineering Properties

A retaining wall is a structural system which, when properly designed, retains a soil mass and safely supports any surcharge loadings applied to the structure. The engineering properties of the system components are determined by laboratory testing which provide the technical data necessary to complete the design in accordance with accepted design standards. Typical engineering data requirements are:

- Unit dimensions, shape/weight
- Unit to unit shear strength
- Unit to geogrid connection strength
- Geogrid long-term design strength
- Geogrid soil interaction
- Soil Design Properties
- Surcharge loadings/slope conditions

\*Keystone test data is available for all material requirements.

## Section 02834 (32 32 23) KEYSTONE CONCRETE RETAINING WALL

### PART 1: GENERAL

#### 1.01 Description

- A. Work shall consist of designing, furnishing and construction of a KEYSTONE® Retaining Wall System in accordance with these specifications and to the lines, grades, design, and dimensions shown on the plans. No alternate wall systems will be considered.
- B. Work includes preparing foundation soil, furnishing and installing leveling pad, unit drainage fill and backfill to the lines and grades shown on the construction drawings.
- C. Work includes furnishing and installing geogrid soil reinforcement of the type, size, location, and lengths designated on the construction drawings.

#### 1.02 Related Sections

- A. Section 02300 (31 00 00) - Earthwork

#### 1.03 Reference Documents

- A. American Society for Testing and Materials (ASTM)
  1. ASTM C140 Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
  2. ASTM C1262 Standard Test Method for Evaluating the Freeze-Thaw Durability
  3. ASTM C1372 Standard Specification for Dry-Cast Segmental Retaining Wall Units
  4. ASTM D422 Standard Test Method for Particle-Size Analysis of Soils
  5. ASTM D698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft<sup>3</sup> (600 kN-m/m<sup>3</sup>))
  6. ASTM D1557 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft<sup>3</sup> (2,700 kN-m/m<sup>3</sup>))
  7. ASTM D3034 Standard Specification for Type PSM Poly Vinyl Chloride (PVC) Sewer Pipe and Fittings
  8. ASTM D4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
  9. ASTM D4475 Horizontal Shear Strength of Pultruded Reinforced Plastic Rods
  10. ASTM D4476 Flexural Properties of Fiber Reinforced Pultruded Plastic Rods
  11. ASTM D4595 Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method
  12. ASTM D5262 Standard Test Method for Evaluating the Unconfined Tension Creep and Creep Rupture Behavior of Geosynthetics
  13. ASTM D5818 Standard Practice for Exposure and Retrieval of Samples to Evaluate Installation Damage of Geosynthetics
  14. ASTM D6637 Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method
  15. ASTM D6638 Standard Test Method for Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks)
  16. ASTM D6706 Standard Test Method for Measuring Geosynthetic Pullout Resistance in Soil
  17. ASTM D6916 Standard Test Method for Determining the Shear Strength Between Segmental Concrete Units (Modular Concrete Blocks)
- B. American Association of State Highway and Transportation Officials (AASHTO)
  1. AASHTO M 252 Corrugated Polyethylene Drainage Pipe
  2. AASHTO M 288 Standard Specification for Geotextile Specification for Highway Applications

#### 1.04 Submittals/Certification

- A. Contractor shall submit a Manufacturer's certification, prior to start of work, that the retaining wall system components meet the requirements of this specification and the structure design.
- B. Contractor shall submit construction drawings and design calculations for the retaining wall system as prepared and stamped by a Professional Engineer registered in the state of the project. The engineering designs, techniques, and material evaluations shall be in accordance with the Keystone Design Manual.

#### 1.05 Quality Assurance

- A. Contractor shall submit a list of five (5) previously constructed projects of similar size and magnitude by the wall installer where the specific retaining wall system has been constructed successfully. Contact names and telephone numbers shall be listed for each project.
- B. Contractor shall provide evidence that the design engineer has a minimum of five years of documented experience in the design for reinforced soil structures. The design engineer shall provide proof of current professional liability insurance with an aggregate coverage limit of not less than \$2,000,000.
- C. Owner shall provide soil testing and quality assurance inspection during earthwork and wall construction operations. Contractor shall provide quality control testing and inspection during construction. Owner's quality assurance program does not relieve the contractor of responsibility for quality control and wall performance.

#### 1.06 Delivery, Storage and Handling

- A. Contractor shall check all materials upon delivery to assure that the proper type, grade, color, and certification have been received.
- B. Contractor shall protect all materials from damage due to job site conditions and in accordance with manufacturer's recommendations. Damaged materials shall not be incorporated into the work.

### PART 2: PRODUCTS

#### 2.01 Definitions

- A. Keystone Unit: a concrete retaining wall element machine made from Portland cement, water, and aggregates.
- B. Structural Geogrid: a structural element formed of high tenacity woven/knitted polyester yarns or high-density polyethylene (HDPE) into a regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock, or earth and function primarily as reinforcement.
- C. Unit Drainage Fill: drainage aggregate that is placed within and immediately behind the Keystone concrete units.
- D. Reinforced Backfill: compacted soil that is placed within the reinforced soil volume as outlined on the plans.

#### 2.02 Keystone Concrete Retaining Wall Units

- A. Keystone concrete units shall conform to the following architectural requirements:
  1. Face color: concrete gray, unless otherwise specified. The Owner may specify standard manufacturers' color.
  2. Face finish: sculptured rock face in angular tri-plane or straight-face configuration. Other face finishes will not be allowed without written approval of Owner.
  3. Bond configuration: running with bonds nominally located at midpoint of vertically adjacent units, in both straight and curved alignments.
  4. Exposed surfaces of units shall be free of chips, cracks or other imperfections when viewed from a distance of 10 feet (3 m) under diffused lighting.



- B. Keystone concrete materials shall conform to the requirements of ASTM C1372 - Standard Specifications for Segmental Retaining Wall Units.
- C. Keystone concrete units shall conform to the following structural and geometric requirements measured in accordance with ASTM C140 Sampling and Testing Concrete Masonry Units, ASTM D6916 Determining the Shear Strength Between Segmental Concrete Units and ASTM D6638 Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units:
  1. Compressive strength:  $\geq 3000$  psi (21 MPa)
  2. Absorption:  $\leq 8$  % for standard weight aggregates. *Note to Specifier: Select appropriate unit(s) below and delete others.*
  3. Keystone Standard Units:
    - a. Width: 18" (457 mm).
    - b. Depth: 18" - 21" (457 - 533 mm), not including rough split face.
    - c. Height: 8" (203 mm).
    - d. Weight: 82 - 114 pounds (37 - 52 kg) per unit minimum using standard weight aggregates.
  4. Keystone Compac Units:
    - a. Width: 18" (457 mm).
    - b. Depth: 12" (305 mm), not including rough split face.
    - c. Height: 8" (203 mm).
    - d. Weight: 67 - 89 pounds (30 - 40 kg) per unit minimum using standard weight aggregates.
  5. Keystone Century Wall Units:
    - a. Width: Varies – 7 - 18" (178 - 457 mm).
    - b. Depth: 12" (305 mm) minimum, not including rough split face.
    - c. Height: 8" (203 mm) and 4" (101 mm).
    - d. Weight: 20 - 90 pounds (9 - 41 kg) per unit minimum using standard weight aggregates.
  6. Keystone Country Manor Units:
    - a. Width: 4" - 16" (101 - 406 mm).
    - b. Depth: 10" (254 mm) minimum, not including rough split face.
    - c. Height: 6" (152 mm).
    - d. Weight: 21 - 65 pounds (10 - 29 kg) per unit minimum using standard weight aggregates.
  7. Keystone 133Elite Units:
    - a. Width: 24" (610 mm).
    - b. Depth: 11.5 - 12" (292 - 305 mm).
    - c. Height: 8" (203 mm).
    - d. Weight: 92 - 97 pounds (42 - 44 kg) per unit minimum using standard weight aggregates.
- 8. Accessory Units: Provide matching units.
  - a. Corners: Provide 90 degree corners, finished two sides, where indicated.
  - b. Cap units: Provide solid cap units.
- D. Keystone concrete units shall conform to the following construction requirements:
  1. Vertical setback: 1/8" (3 mm)  $\pm$  per course (near vertical) or 1" (25 mm) + per course per the design (3/8" 133Elite);
  2. Alignment and grid positioning mechanism fiberglass pins, two per unit minimum (one pin for small units).
  3. Maximum horizontal gap between erected units shall be  $\leq 1/2$ " (13 mm).

**2.03 Shear Connectors**

- A. Shear connectors shall be 1/2" (12 mm) diameter thermoset isophthalic polyester resin pultruded fiberglass reinforcement rods to provide connection between vertically and horizontally adjacent units with the following requirements:
  1. Flexural Strength in accordance with ASTM D4476: 128,000 psi (882 MPa) minimum;
  2. Short Beam Shear in accordance with ASTM D4475: 6,400 psi (44 MPa) minimum.
- B. Shear connectors shall be capable of holding the geogrid in the proper design position during grid pre tensioning and backfilling.

**2.04 Base Leveling Pad Material**

- A. Material shall consist of a compacted crushed stone base or non-reinforced concrete as shown on the construction drawings.

**2.05 Unit Drainage Fill**

- A. Unit drainage fill shall consist of clean 1" (25 mm) minus crushed stone or crushed gravel meeting the following gradation tested in accordance with ASTM D-422:

Sieve Size	Percent Passing
1" (25 mm)	100
3/4" (19 mm)	75 - 100
No. 4 (4.75mm)	0 - 10
No. 50 (300um)	0 - 5

- B. Drainage fill shall be placed within the cores of, between, and behind the units as indicated on the design drawings. Not less than one cubic foot (0.028 m<sup>3</sup>), of drainage fill shall be used for each square foot (0.093 m<sup>2</sup>) of wall face unless otherwise specified.

**2.06 Reinforced Backfill**

- A. Reinforced backfill shall be free of debris and organic material; meeting the following gradation tested in accordance with ASTM D-422:

Sieve Size	Percent Passing
3/4" (19 mm)	100 - 75
No. 40 (425um)	0 - 60
No. 200 (75um)	0 - 35

Plasticity Index (PI) <15 and Liquid Limit (LL) <40 per ASTM D-4318.

- B. The maximum aggregate size shall be limited to 3/4" (19 mm) unless field tests have been performed to evaluate potential strength reductions to the geogrid design due to damage during construction.
- C. Material can be site-excavated soils where the above requirements can be met. Unsuitable soils for backfill (high plastic clays or organic soils) shall not be used in the backfill or in the reinforced soil mass.
- D. Contractor shall submit reinforced fill sample and laboratory test results to the Architect/Engineer for approval prior to the use of any proposed reinforced fill material.

## 2.07 Geogrid Soil Reinforcement

- A. Geosynthetic reinforcement shall consist of geogrids manufactured specifically for soil reinforcement applications and shall be manufactured from high tenacity polyester yarn or high density polyethylene. Polyester geogrid shall be knitted from high tenacity polyester filament yarn with a molecular weight exceeding 25,000 g/m and a carboxyl end group values less than 30. Polyester geogrid shall be coated with an impregnated PVC coating that resists peeling, cracking, and stripping.
- B.  $T_a$ , Long Term Allowable Tensile Design Load, of the geogrid material shall be determined as follows:
- $$T_a = T_{ult} / (R_{fcr} * R_{fd} * R_{fid} * F_s)$$
- $T_a$  shall be evaluated based on a 75-year design life.
1.  $T_{ult}$ , Short Term Ultimate Tensile Strength shall be determined in accordance with ASTM D4595 or ASTM D6637.  
 $T_{ult}$  is based on the minimum average roll values (MARV).
  2.  $R_{fcr}$ , Reduction Factor for Long Term Tension Creep  
 $R_{fcr}$  shall be determined from 10,000-hour creep testing performed in accordance with ASTM D5262 -  $R_{fcr}$  can typically vary from 1.50 to 5.0.
  3.  $R_{fd}$ , Reduction Factor for Durability  
 $R_{fd}$  shall be determined from polymer specific durability testing covering the range of expected soil environments.  $R_{fd}$  can typically vary from 1.10 to 2.0.
  4.  $R_{fid}$ , Reduction Factor for Installation Damage  
 $R_{fid}$  shall be determined from product specific construction damage testing performed in accordance with ASTM D5818. Test results shall be provided for each product to be used with project specific or more severe soil type.  $R_{fid}$  can typically vary from 1.05 to 2.0.
  5.  $F_s$ , Overall Design Factor of Safety  
 $F_s$  shall be 1.5 unless otherwise noted for the maximum allowable working stress calculation.
- C. The maximum design tensile load of the geogrid shall not exceed the laboratory tested ultimate strength of the geogrid/facing unit connection divided by a factor of safety of 1.5. The connection strength testing and computation procedures shall be in accordance with ASTM D6638 Connection Strength between Geosynthetic Reinforcement and Segmental Concrete Units.
- D. Soil Interaction Coefficient,  $C_i$   
 $C_i$  values shall be determined per ASTM D6706 at a maximum 3/4" (19 mm) displacement.
- E. Manufacturing Quality Control  
The geogrid manufacturer shall have a manufacturing quality control program that includes QC testing by an independent laboratory.  
The QC testing shall include:
- Tensile Strength Testing
  - Melt Flow Index (HDPE)
  - Molecular Weight (Polyester)

## 2.08 Drainage Pipe

- A. If required, the drainage pipe shall be perforated or slotted PVC pipe manufactured in accordance with ASTM D-3034 or corrugated HDPE pipe manufactured in accordance with AASHTO M252.

## 2.09 Geotextile Filter Fabric

- A. When required, Geotextile filter fabric shall be 4.0 oz/sy, polypropylene, needle-punched nonwoven fabric in accordance with AASHTO M288.

## PART 3: EXECUTION

### 3.01 Excavation

- A. Contractor shall excavate to the lines and grades shown on the construction drawings. Owner's representative shall inspect the excavation and approve the foundation soils prior to placement of leveling material or fill soils.
- B. Over excavation and replacement of unsuitable foundation soils and replacement with approved compacted fill will be compensated as agreed upon with the Owner.

### 3.02 Base Leveling Pad

- A. Leveling pad material shall be placed to the lines and grades shown on the construction drawings, to a minimum thickness of 6" (150 mm) and extend laterally a minimum of 6" (150 mm) in front and behind the Keystone wall unit.
- B. Soil leveling pad materials shall be compacted to a minimum of 95% Standard Proctor density per ASTM D-698 or 92% Modified Proctor Density per ASTM D1557.
- C. Leveling pad shall be prepared to insure full contact to the base surface of the concrete units.

### 3.03 Keystone Unit Installation

- A. First course of units shall be placed on the leveling pad at the appropriate line and grade. Alignment and level shall be checked in all directions; insuring that all units are in full contact with the base and properly seated.
- B. Place the front of units side-by-side. Do not leave gaps between adjacent units. Layout of corners and curves shall be in accordance with manufacturer's recommendations.
- C. Install shear/connecting devices per manufacturer's recommendations.
- D. Place drainage fill within and behind wall units. Place and compact backfill soil behind drainage fill. Follow wall erection and drainage fill closely with structure backfill.
- E. Maximum stacked vertical height of wall units, prior to unit drainage fill and backfill placement and compaction, shall not exceed two courses.

### 3.04 Structural Geogrid Installation

- A. Geogrid shall be oriented with the highest strength axis perpendicular to the wall alignment.
- B. Geogrid reinforcement shall be placed at the strengths, lengths, and elevations shown on the construction design drawings or as directed by the Engineer.
- C. The geogrid shall be laid horizontally on compacted backfill and attached to the Keystone wall units. Place the next course of Keystone concrete units over the geogrid. The geogrid shall be pulled taut, and anchored prior to backfill placement on the geogrid.
- D. Geogrid reinforcements shall be continuous throughout their embedment lengths and placed side-by-side to provide 100% coverage at each level. Spliced connections between shorter pieces of geogrid or gaps between adjacent pieces of geogrid are not permitted.

**3.05 Reinforced Backfill Placement**

- A. Reinforced backfill shall be placed, spread, and compacted in such a manner that minimizes the development of slack in the geogrid and installation damage.
- B. Reinforced backfill shall be placed and compacted in lifts not to exceed 6" (150 mm) where hand compaction is used, or 8 - 10" (200 to 250 mm) where heavy compaction equipment is used. Lift thickness shall be decreased to achieve the required density, as needed.
- C. Reinforced backfill shall be compacted to a minimum of 95% Standard Proctor density per ASTM D-698 or 92% Modified Proctor Density per ASTM D1557. The moisture content of the backfill material prior to and during compaction shall be uniformly distributed throughout each layer.
- D. Only lightweight hand operated equipment shall be allowed within 3 feet (1 m) from the tail of the Keystone concrete unit.
- E. Tracked construction equipment shall not be operated directly upon the geogrid reinforcement. A minimum fill thickness of 6" (150 mm) is required prior to operation of tracked vehicles over the geogrid. Tracked vehicle turning should be kept to a minimum to prevent tracks from displacing the fill and damaging the geogrid.
- F. At the end of each day's operation, the Contractor shall slope the last lift of reinforced backfill away from the wall units to direct runoff away from wall face. The Contractor shall not allow surface runoff from adjacent areas to enter the wall construction site.

**3.06 Cap Installation**

- A. Cap units shall be glued to underlying units with an all-weather adhesive recommended by the manufacturer such as Keystone Kapseal.

**3.07 As-built Construction Tolerances**

- A. Vertical alignment:  $\pm 1.5"$  (40 mm) over any 10' (3 m) distance.
- B. Wall Batter: within 2 degrees of design batter.
- C. Horizontal alignment:  $\pm 1.5"$  (40 mm) over any 10' (3 m) distance.  
Corners, bends & curves:  $\pm 1$  foot (300 mm) to theoretical location.
- D. Maximum horizontal gap between erected units shall be  $\leq 1/2"$  (13 mm).

**3.08 Field Quality Control**

- A. Wall construction shall be monitored by a qualified Engineer to verify field conditions. If this work is not performed by the site geotechnical engineer, the geotechnical engineer shall be consulted in those matters pertaining to soil conditions and wall performance.
- B. The foundation soils at each wall location shall be inspected by the Engineer and any unsuitable soils or improperly compacted embankment material removed and replaced as directed by the Engineer prior to wall construction to provide adequate bearing capacity and minimize settlement.
- C. All wall excavation and retained soils shall be inspected for groundwater conditions and any additional drainage provisions required in the field shall be incorporated into the wall construction as directed by the Engineer.
- D. Wall backfill material shall be tested and approved by the Engineer for use in the reinforced soil zone meeting the minimum requirements of the approved design plans.
- E. All soil backfill shall be tested by the Engineer for moisture, density, and compaction periodically (every 2' vertically, 100'-200' c/c) meeting the minimum requirements of the approved design plans or project specifications.
- F. Wall construction shall be periodically inspected by the Engineer to ensure the geogrid reinforcement elevations and lengths are installed in accordance with the approved design plans.
- G. All wall elevations, grades, and backslope conditions shall be verified by the Engineer in the field for conformance with the approved design plans. Any revisions to the structure geometry or design criteria shall require design modification prior to proceeding with construction.

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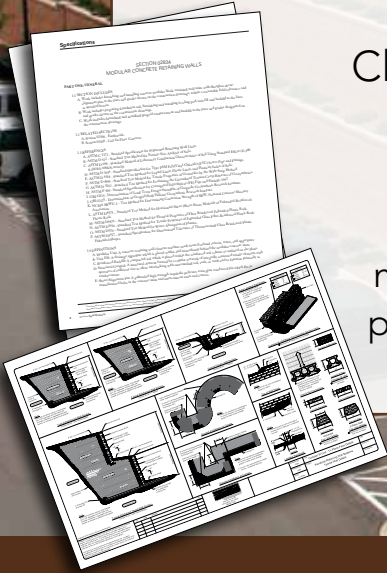
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