We reserve the right to improve our products and make changes in the specifications and design without notice. The information contained herein has been compiled by KEYSTONE and is to the best of our knowledge accurately represents the KEYSTONE product used in the applications which appear herein. KEYSTONE does not warrant the suitability of this product for the use contemplated and its manner of use are the sole responsibility of the user.
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Definitions

AASHTO – American Association of State Highway Transportation Officials
ASTM – American Society for Testing and Materials
Backfill – Soils used to replace a zone of excavated soils.
Backslope – The angle of soil for finished grade located behind the top of the wall, usually expressed in a ratio such as 3:1 (3 feet horizontal to 1 foot vertical) or 18.4° (33%).
Base Course – First row of Keystone units placed on top of the leveling pad.
CIP – Cast in place concrete
Compaction – Mechanical effort used in densifying soil to a defined minimum percentage of the maximum compacted weight of the soil. See ASTM D698 and D1557 for reference.
Core Fill – See Unit Drainage Fill
Course – A horizontal layer or row of Keystone units.
Drainage Composite – Three dimensional geosynthetic drainage medium encapsulated in a geotextile filter, used to transport water.
Drainage Pipe – A perforated or slotted PVC pipe manufactured in accordance with ASTM D3034 or corrugated HDPE pipe manufactured in accordance with AASHTO M 252 used to transport water away from the drainage zone or reinforced backfill.
Drainage Zone – A predetermined depth of clean crushed angular stone located behind a Keystone unit to prevent the development of hydrostatic forces on the Keystone unit. Also see Unit Drainage Fill.
Efflorescence – A whitish substance that can naturally occur on all concrete products. It comes from salts within the concrete unit being transported by water or from external chlorides.
Embedment – Depth of retaining wall below existing or proposed ground line.
Exposed Wall Face – The exposed visible portion of the retaining wall when installed.
Foundation Soil – Either in-situ soil or compacted backfill, located beneath wall leveling pad and reinforced fill volume.
Geogrid – A structural soil reinforcement element formed by 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.
Geosynthetics – A range of generally polymeric (plastic) products used to solve civil engineering problems. Generally regarded to encompass eight main categories: geotextiles, geogrids, geonets, geomembranes, geosynthetic clay liners, geofoam, geocells and geocomposites.
Geotextile Filter Fabric – Material used for separation and filtration of dissimilar soil types, typically consists in two forms, woven or nonwoven synthetic fibers (polymer based).
Global Stability – The general mass movement analysis of a soil reinforced segmental retaining wall structure(s) and adjacent soil masses and slopes.
HDPE – High-density polyethylene; a polyethylene thermoplastic made from petroleum.
Impermeable or Low Permeable Soil – Clay soil used to prevent water percolation into the drainage zone and reinforced backfill behind the retaining wall.
Keystone unit – A concrete retaining wall element, machine made from Portland cement, water, and aggregates.
Definitions

Leveling Pad – Material used to support the Keystone unit, typically compacted crushed stone material or unreinforced CIP concrete.

Modular Block – See Keystone unit

MSE – Mechanically Stabilized Earth

NCMA – National Concrete Masonry Association

Parapet – Keystone units or CIP concrete installed above finished grade to create a free standing wall that does not retain soil.

PPE – Personal Protective Equipment, i.e.: hard hat, gloves, eye protection, etc.

PVC – Polyvinyl Chloride; a thermoplastic polymer.

Reinforced Soil (Reinforced Backfill) – Compacted soil that is placed within the reinforced soil volume as outlined on the plans.

Reinforcement – See Geogrid.

Retained Soil – In-situ soil or compacted backfill located directly behind the reinforced soil volume or gravity wall system.

Segmental Wall unit – See Keystone unit

SRW – Segmental Retaining Wall; i.e.: multiple Keystone units installed to create a retaining wall

Surcharge – Any loading imposed on the soil behind the wall that exerts an additional force on a wall structure. All surcharge loadings are assumed to be uniform live or dead loads. Usually expressed in pounds per square foot (psf) or kilo-newton per meter squared (kN/m²)

Surcharge Sloping – Any additional loading imposed on the wall structure due to backslope conditions behind the wall.

Swale – A ditch or depression in the soil at the top of the retaining wall used to divert water to another location away from the wall.

Toe Slope – The angle of soil for finished grade located in front of the wall base, usually expressed in a ratio such 3:1 (3 feet horizontal and 1 foot vertical)

Unit Drainage Fill – Crushed stone that is placed within and immediately behind the Keystone concrete units, measuring 2 feet in total depth from the proposed wall face. Also see drainage zone.

Wall Batter – The setback angle measured in degrees created from the fiberglass pin placement location within the Keystone units. The angle is measured using a plumb line from the toe to the top of the wall along the face of the wall.
**Introduction**

The Keystone retaining wall system was created to provide an economical, easy-to-install, aesthetically appealing, and structurally sound system as an alternate to boulder, timber tie, concrete panel, or cast-in-place retaining walls. The Keystone system was initially conceived as a gravity wall system that could be constructed to heights of up to 6.5 feet (2 m). The original Keystone Standard unit was 2 feet (600 mm) from face to tail, providing weight and stability to resist the applied earth pressures. Later, the Keystone Compac unit, a smaller 1-foot (300 mm) deep unit, was introduced. The Keystone units have the stability of a large mass, but are easier to handle, lighter to place, and quicker to install than boulders, crib structures or thin-shelled panel structures. Both units were designed with a structural pin connection and granular interlock, eliminating the need for grouting or mortar. As a result of the structural strength created by the fiberglass pins and unit drainage fill, the interlocked assembly is more stable than most other structures.

Concurrent with the development of the Keystone system, geosynthetic soil reinforcement was gaining approval and acceptance as a viable soil reinforcement material. With the structural pin and crushed stone fill for interlock, the combination of geogrids and Keystone units provide an integrated wall system that can be constructed to heights far exceeding the limits of simple gravity walls. Since 1986, millions of square feet of Keystone retaining walls have been successfully constructed, both as gravity and reinforced systems. Applications vary from residential landscaping walls to structural highway walls, some exceeding 50 feet (15 m) in height.

**KEYSTONE RETAINING WALL UNITS**

Keystone retaining wall units are a zero-slump concrete masonry product developed specifically for use in earth retaining wall structures. Keystone has developed a wide variety of shapes and designs to accommodate most architectural and structural requirements. Local producers of the Keystone products have a variety of colors available, complementing most landscaping and structural retaining wall applications.

Keystone structural products currently discussed in this manual include:
- Standard I/Standard II/Standard III
- Compac I/Compac II/Compac III

Other Keystone structural products that utilize Keystone's patented fiberglass pin system:
- Keystone Century Wall®
- 133Elite®
- Keystone® Country Manor®

(Please contact your local Keystone representative for availability.)

The Keystone units listed above are designed for use as structural retaining walls, i.e., those exceeding 6.5 feet (2m) in height and/or supporting structures or highway loading.

In addition to the above units, Keystone has a complete line of landscape products that are marketed and sold through retail distribution and landscape supply outlets. The concepts in this manual apply to all wall construction, but these landscape products are generally not considered for structural applications and are not discussed in further detail in this manual. For more information on these products, contact your local Keystone representative or visit www.keystonewalls.com.

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KEYSTONE MATERIALS

Keystone units are typically manufactured of concrete with a minimum compressive strength of 3000 psi (21MPa) at 28 days and a maximum absorption of 8% (6% in northern climates). All dimensions are plus or minus 1/8 inch (3mm) except for the unit depth, which varies due to the split rock finish. The manufacturing process is automated, so the mixing, compaction, and curing are performed under controlled conditions and provide consistent quality. The units have various face textures available, depending on your local manufacturer. Some of our most popular textures are molded or split-rock finish in various natural colors. Face shapes can be tri-plane, straight, Victorian, or Sculpterra™ molded face such as Hewnstone.

Standard, Compac, Keystone Century Wall, Keystone Country Manor and 133E lite are vertically interconnected using high-strength pultruded fiberglass pins. The Keystone units have cores that are filled with clean crushed stone to provide additional mechanical interlock and internal drainage. The pins assure a running bond configuration of the units and provide significant lateral connection strength between units. The pins improve the connection between the units and the structural soil reinforcement while assuring proper placement of the reinforcement materials.

The connection pins are available in straight and shouldered designs. Straight pins are 5 1/4 inches (133mm) long and 1/2 inch (12.7mm) in diameter. The Standard and Compac units use straight pins. Shouldered pins are 3 1/4 inches (95mm) long and 1/2 inch (12.7mm) in diameter. The shouldered length portion is 1 1/4 inch (32mm) and the shouldered diameter is 1/2 inch (12mm). The Keystone Century Wall, Country Manor and 133E lite units use shouldered pins. The minimum pin strength is 6,400 psi (44MPa) short beam shear strength and 110,000 psi (750MPa) tensile strength. The pins are manufactured of pultruded fiberglass and will not corrode or deteriorate. In addition, the fiberglass pin does not change properties (soften or become brittle) due to the temperature changes typical in retaining wall applications.

STANDARD UNIT SERIES

The Standard unit varies due to manufacturing considerations from 18 to 21 inches (457 to 534mm) in depth, with a typical face width of 18 inches (457mm) and height of 8 inches (203mm). The geometry yields exactly 1 square foot (0.09 m²) of face area per unit. Units weigh from 95 to 125 pounds (43 to 56kg) each, varying with local manufacturing and aggregates. The centroid of the unit is slightly forward of center toward the face, but for design purposes, it is taken at the center. For design purposes, the in-place density of the aggregate filled unit is 120 pcf (18.85 kN/m³).

Standard units are manufactured with a dual pin hole configuration. The front pin setting allows the units to be placed at a minimum setback of approximately 1/2 inch (28.6mm) per 8 inch (203mm) unit height (1° batter, for design purposes use 0°). The rear pin setting allows placement of the units at a minimum 1 1/2 inch (38.1mm) setback per 8 inch (203mm) unit height (8° batter). An alternate placement of front/back pin hole allows a setback of 5/8 inch (15.9mm) per 8 inch (203mm) unit height (4° batter).

COMPAC UNIT SERIES

The Keystone Compac unit is a 12 inch (305mm) deep unit with a typical face width of 18 inches (457mm) by 8 inches (203mm) high. The geometry yields exactly 1 square foot (0.09 m²) of face area per unit. Depth may vary from 11.5 to 12.5 inches (280 to 317mm) depending upon local manufacturing and splitting requirements. Units weigh from 70 to 95 pounds (32 to 43kg) each, varying with local manufacturing and aggregates. For design purposes, the in-place density of the aggregate filled unit is 120 pcf (18.85 kN/m³).

The dual pin hole configuration allows the same 1° (0° for design purposes), 4°, and 8° setback as the Standard unit.

The information contained herein has been compiled by Keystone® Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.
KEYSTONE CENTURY WALL® UNITS

Keystone Century Wall® is a three piece system that consists of a small, medium, and large unit. The width of the units is the varying dimension that dictates the size. The small unit is 7 inches (178mm) wide, the medium unit is 11 inches (279mm) wide, and the large unit is 18 inches (457mm) wide. The three Century Wall units are 12 inches (305mm) deep and 8 inches (203mm) high. The small unit weighs 37-45 pounds (17-20kg), the medium unit weighs 53-61 pounds (24-28kg), and the large unit weighs 85-93 pounds (39-42kg). Weights may vary with local manufacturing and aggregates.

Century Wall® Units

Similar to the Compac and Standard units, a dual pin hole configuration allows 1° (0° for design purposes), 4°, and 8° setback.

KEYSTONE COUNTRY MANOR®

Keystone Country Manor® comes in a variety of sizes, most commonly sold as a six piece system, a five piece system, or a three piece system. The units are textured on three sides, allowing for both 1 and 2-sided applications to be built. The width of the units are the varying dimension that dictates the size, each unit has 2 unit width dimensions, because both sides of the unit can be incorporated in the wall face. The various unit widths are 6/4 inches (152/101mm), 8/6 inches (203/152mm), 10/8 inches (254/203mm), 12/12 inches (304/304mm), 12/10 inches (304/254mm), and 16/14 inches (406/355mm). The Country Manor units are 10 inches (254mm) deep and 6 inches (152mm) high. The unit weights from small to large are 25 pounds (11kg), 35 pounds (15kg), 45 pounds (20kg), 45 pounds (20kg), 40 pounds (18kg), and the largest unit weighs 60 pounds (27kg). Weights may vary with local manufacturing and aggregates.

Country Manor® Units

Unique to Country Manor, the three pin hole configurations allow for a near vertical wall, 1 inch setback, or allow random units to protrude from the wall face at a 1 inch increment. (The design batter is 0° or 9.5° for the setback alignment.)

KEYSTONE 133ELITE® UNIT

133Elite® units are 8 inches (203mm) high and 24 inches (610mm) wide to create a face area of 1.33 square feet (0.124m²), hence the name 133Elite®. The depth of the unit is 11.5 inches (292mm). Depending on face treatment, the weight of the 133Elite® unit is approximately 93-100 pounds (42-45kg).

133Elite® Unit

133Elite units are manufactured with one pin position that creates a near vertical setback equal to 1 inch (9.6mm) per 8 inches (203mm) of unit height (2.5° batter).

Note:
Not all units types, face treatments and colors are available at all manufacturing locations. Please check with your local manufacturer or Keystone supplier for availability.

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THE KEYSTONE STANDARD UNIT IS AN AMERICAN ORIGINAL.

The product that started the industry is still the industry leader for tall walls and critical structures. The height-to-depth ratio of the Keystone Standard unit delivers a structurally sound, engineered wall system with superior construction stability, durability, and strength. Architects, engineers, and contractors rely on the Keystone Standard unit to stand strong when the safety and security of their wall designs matter.

<table>
<thead>
<tr>
<th>Standard Unit Series</th>
<th>Standard I</th>
<th>Standard II</th>
<th>Standard III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Height</td>
<td>8&quot; (200mm)</td>
<td>8&quot; (200mm)</td>
<td>8&quot; (200mm)</td>
</tr>
<tr>
<td>Unit Width</td>
<td>18&quot; (455mm)</td>
<td>18&quot; (455mm)</td>
<td>18&quot; (455mm)</td>
</tr>
<tr>
<td>Unit Depth</td>
<td>18&quot; (455mm)</td>
<td>21&quot; (533mm)</td>
<td>18&quot; (455mm)</td>
</tr>
<tr>
<td>Face Area per Unit</td>
<td>1SF (.093m²)</td>
<td>1SF (.093m²)</td>
<td>1SF (.093m²)</td>
</tr>
<tr>
<td>Unit Weight</td>
<td>95-125lbs (43-56kg)</td>
<td>93-115lbs (42-53kg)</td>
<td>90-100 lbs (41-45kg)</td>
</tr>
<tr>
<td>Volume of Voids to Tail</td>
<td>0.70 ft³/ft² (0.21m³/m²)</td>
<td>0.90 ft³/ft² (0.27m³/m²)</td>
<td>0.70 ft³/ft² (0.21m³/m²)</td>
</tr>
<tr>
<td>Volume of Voids to 24&quot; depth</td>
<td>1.20 ft³/ft² (0.37m³/m²)</td>
<td>1.16 ft³/ft² (0.36m³/m²)</td>
<td>1.20 ft³/ft² (0.37m³/m²)</td>
</tr>
<tr>
<td>Fiberglass Pin</td>
<td>Straight Pin</td>
<td>Straight Pin</td>
<td>Straight Pin</td>
</tr>
</tbody>
</table>

NOTE: UNIT WEIGHS, DIMENSIONS AND AVAILABILITY VARY BY MANUFACTURER. PLEASE CONTACT YOUR LOCAL REPRESENTATIVE.
**DESIGN AND BUILD WITH CONFIDENCE.** The Keystone Compac is the perfect choice when the deep embedment length of the Keystone Standard unit is not required. An installer’s favorite, its lighter weight and shorter tail design make it easy to handle.

### Compac Unit Series

<table>
<thead>
<tr>
<th></th>
<th>Compac I</th>
<th>Compac II</th>
<th>Compac III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Height</td>
<td>8” (200mm)</td>
<td>8” (200mm)</td>
<td>8” (200mm)</td>
</tr>
<tr>
<td>Unit Width</td>
<td>18” (455mm)</td>
<td>18” (455mm)</td>
<td>18” (455mm)</td>
</tr>
<tr>
<td>Unit Depth</td>
<td>12” (300mm)</td>
<td>12” (300mm)</td>
<td>12” (300mm)</td>
</tr>
<tr>
<td>Face Area per Unit</td>
<td>1SF (.093m²)</td>
<td>1SF (.093m²)</td>
<td>1SF (.093m²)</td>
</tr>
<tr>
<td>Unit Weight</td>
<td>81-95lbs (37-43kg)</td>
<td>78-91lbs (35-41kg)</td>
<td>69-77lbs (31-35kg)</td>
</tr>
<tr>
<td>Volume of Voids to Tail</td>
<td>0.30 ft³/ft² (0.09 m³/m²)</td>
<td>0.35 ft³/ft² (0.11 m³/m²)</td>
<td>0.41 ft³/ft² (0.13 m³/m²)</td>
</tr>
<tr>
<td>Volume of Voids to 12” depth</td>
<td>1.30 ft³/ft² (0.40 m³/m²)</td>
<td>1.35 ft³/ft² (0.41 m³/m²)</td>
<td>1.41 ft³/ft² (0.43 m³/m²)</td>
</tr>
<tr>
<td>Fiberglass Pin</td>
<td>Straight Pin</td>
<td>Straight Pin</td>
<td>Straight Pin</td>
</tr>
</tbody>
</table>

**NOTE:** UNIT WEIGHTS, DIMENSIONS AND AVAILABILITY VARY BY MANUFACTURER. PLEASE CONTACT YOUR LOCAL REPRESENTATIVE.

### Alternate Face Textures

- **Hewnstone**
- **Victorian**

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BASIC INSTALLATION

You have chosen your preferred Keystone unit for installation, so now it is time to begin installation of your retaining wall. This section will take you through the step-by-step process of installing your retaining wall. Covered in this section is a basic gravity wall installation and also installation procedures for geogrid reinforced walls. While this section may not cover every construction issue you may encounter on your project, it gives a basic overview and helpful hints for the installation of a Keystone retaining wall.

Tools and materials that will be required:

- 12 inch and 48 inch levels
- Tape measure
- Shovel
- Excavating equipment
- Personal protective equipment
- 5 lb dead blow hammer
- Keystone structural units, caps and fiberglass pins
- Structural geogrid, if required
- Unit drainage fill (¾ inch clean crushed stone)
- Backfill material
- Leveling pad material
- Keystone KapSeal™ concrete adhesive
Installation: Step-by-Step

1. Site Examination / Permitting

Select the location and length for the retaining wall. Call before you dig! Calling 811 before every digging job gets your underground utility lines marked for free and helps prevent undesired consequences. Digging without calling can disrupt service to an entire neighborhood, harm you and those around you and potentially result in fines and repair costs. Take the necessary measurements, prepare plans, research zoning requirements for your area and obtain proper building permits for your project. Local permitting may require a soils investigation and/or engineered documentation and drawings.

2. Excavation / Embedment

Verify that the layout dimensions are correct and excavate to the lines and grades shown on the construction drawings or to field dimensions. Remove all surface vegetation, organic soils and debris; verify that the foundation subgrade is in proper condition prior to leveling pad installation. Do not proceed with installation until unsatisfactory conditions have been corrected.

Embedment Recommendations

For small Keystone gravity walls, a minimum 1 inch (25mm) of embedment is recommended for every unit of height (i.e., H/8) or 6 inches minimum, whichever is greater. For reinforced soil Keystone walls, the minimum depth of embedment as a ratio to wall may be determined in the following table from the NCMA Design Manual for Segmental Walls (2009):

<table>
<thead>
<tr>
<th>Step 1</th>
<th>FIGURE A:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEVEL GRADE</td>
<td>LEVELING PAD</td>
</tr>
<tr>
<td>SLOPING GRADE</td>
<td>EMBEDMENT DEPTH, MIN ONE BURIED UNIT</td>
</tr>
<tr>
<td>KRW UNITS STEP UP GRADE</td>
<td></td>
</tr>
</tbody>
</table>

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### Sloping Toe

The minimum embedment required with a slope in front of the wall should be based on the establishment of a minimum 4 feet (1.2m) horizontal bench in front of the wall and establishing a minimum embedment from that point. Fill slopes usually have poor compaction near the edge of slope and all slopes are subject to erosion and surficial instability (see figure B:1).

The depth of embedment should be increased when any of the following conditions occur:

- Weak bearing soils
- Potential scour of wall toe
- Submerged wall applications
- Significant shrink/swell/frost properties of foundation soils

#### Note:

Project plans, specifications, and design codes may require minimum embeddings that exceed the minimums recommended by NCMA.

#### Slope in Front of Wall

<table>
<thead>
<tr>
<th>Slope in Front of Wall</th>
<th>Min. Embedment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Requirement</td>
<td>0.5 ft (150mm)</td>
</tr>
<tr>
<td>Horizontal (walls)</td>
<td>H/20</td>
</tr>
<tr>
<td>Horizontal (Abutments)</td>
<td>H/10</td>
</tr>
<tr>
<td>3H:1V</td>
<td>H/10</td>
</tr>
<tr>
<td>2H:1V</td>
<td>H/7</td>
</tr>
</tbody>
</table>

### 3. Prepare the Base Leveling Pad

Start the leveling pad at the lowest elevation along the wall alignment (see Figure A:1). The minimum leveling pad width shall be unit depth + 12 inches. The leveling pad shall consist of 6 inches of well compacted (95% Standard Proctor or greater) angular granular fill (road base or ⅛ inch to ¾ inch [10-20mm] crushed stone). Concrete is also acceptable to use as a leveling pad. Step the leveling pad up in 8 inch increments at the appropriate elevation change in the foundation. Do not use rounded material, i.e. PEA GRAVEL or SAND for leveling pad material.
4. Install the Base Course

Place the first course of Keystone units (Compac II Units shown) end to end (with face of wall corners touching, do not leave gaps between units) on the prepared base. The pin holes should face upward, as shown. Ensure that all units are in full contact with the base and properly seated by gently pounding each block corner, and level as required. At base elevation changes (see Figure C:1) for installation reference. Leveling the first course is critical for accurate and acceptable results. Lay out corners and curves in accordance with the “Corners and Curves” section of this manual (p. 37).
5. Insert the Fiberglass Pins/Drainage Pipe

Keystone units have 3 setback options, near vertical, ½ inch setback and 1 inch setback (see Figure D:1). For the near vertical option, place the pins in the front pin holes, or for the 1 inch minimum setback, place the pins in the rear pin holes (see Figure E:1). Once placed, the pins create an automatic setback and alignment for the additional courses (see Figure F:1). When required, install drainage pipe behind wall unit and outlet drain to storm system or daylight as required.

6. Install Unit Drainage Fill/Backfill and Compaction.

Once the pins have been installed, provide ½-¾ inch (10-20mm) crushed stone unit drainage material to a minimum total distance of 24 inch (610mm) from wall face. Fill all open spaces between units and open cavities/cores with the same unit drainage material. Place the wall backfill behind the unit drainage fill in maximum 8 inch (200mm) lifts and compact to 95% Standard Proctor Density or 92% Modified Proctor Density with the appropriate compaction equipment. Use only hand operated equipment within 3 feet of the retaining wall face.

* If drainage is required due to excess water or the design engineer’s plans call for a drainage pipe to be installed, add the drain tile behind the tails on the base course. Drainage pipe should maintain positive drainage to daylight, outlet the drainpipe at low point or ends of wall.
7. Install Additional Courses.

Remove all excess unit drainage material from the top surface of the all units. Center the next unit in front of the point where the two units below meet, fitting the pins into the pin connecting core of the above unit. Push the unit toward the face of the wall until they make full contact with the pins (see Figure F:1). Check level front to back and side to side, shim the units or grind as necessary. It is important to check level front to back and side to side on every course to maintain proper wall batter and alignment. Proper shimming materials can be any non-degradable material including but not limited to, asphalt shingles, scrap pieces of geogrid, polyester rope, etc...

Continue backfilling, installing additional units and checking level to the desired top elevation (see Figure G:1). Follow wall unit and unit drainage fill installation closely with backfill. Maximum stacked vertical height of wall units prior to unit drainage fill and backfill placement and compaction shall not exceed 2 courses, unless special construction techniques are employed to insure complete filling of all units with unit drainage fill. For gravity walls continue this construction sequence to complete the wall, and proceed to Step 10. For geogrid reinforced walls, continue with Step 8 and Step 9.
8. Structural Geogrid Installation

Start at the lowest wall elevation where a geogrid layer will be placed. The geogrid elevations, depths, and strength will be specified in the engineered design for the wall. Measure and cut the geogrid material to the specified length. Orient geogrid with highest strength axis perpendicular to the wall alignment. Lay geogrid horizontally on compacted backfill and hook over the pins of the units (see Figure H:1). In general, geogrid will be placed in pieces side-by-side with no gapping, and in a continuous layer along the length of design geogrid elevation, unless a change in elevation is specified in the design. Tension the geogrid by pulling it towards the embankment. Place a stake through the end of the geogrid into the ground to hold it taut and in place. Do not excessively tension geogrid: this may pull units out of proper alignment. Install an additional course of units over the geogrid and insert pins.

9. Reinforced Backfill Placement

Proceed with placement of the unit drainage fill and the backfill in the reinforced zone. Specifications for the material to be used as backfill in the reinforced zone should be defined in the engineered plans. Place this material nearest to the units, moving progressively toward the staked end of the geogrid. This procedure will keep the geogrid under tension. Compact the reinforced fill material to 95% Standard Proctor Density (ASTM D698), or 92% Modified Proctor Density (ASTM D1557) or to the compaction requirements in the engineered plans. Install additional courses as described in step 7, until the next reinforcement elevation. Repeat Step 8 and Step 9 (see Figure G:1.1, page 18). Only hand operated compaction equipment shall be allowed within 3 feet of the back surface of the units. At the end of each day’s operation, grade the backfill away from the wall and direct runoff away from the wall face.

* For assistance in obtaining engineered drawings for your project, please contact your local Keystone representative.
The information contained herein has been compiled by Keystone® Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.
10. Capping the Wall

Follow the same procedures described in Step 6 for proper placement and positioning of the cap units. Complete your wall with the appropriate Keystone capping units. These units are available in a variety of sizes and shapes, including 4 inch (100mm) and 8 inch (200mm) high units. Availability of these units will vary by region. For cap unit descriptions and placement variations see the section, “Wall Finishing”, page 65 of this manual. Sweep the lower units clean and make sure they are dry. Use construction adhesive (Keystone KapSeal™) on the top surface of the last course before applying cap units (see Figure I:1).

11. Finished Grade and Landscaping

The Keystone Retaining wall is now complete. Final grading, planting or other surface material can now be put into place. Typically an 8 inch thick layer of low permeable soil is installed as the final layer of material. This is to help prevent water infiltration to the retained or reinforced zone of the retaining wall. Remember that finished grade conditions affect the wall’s performance. Such conditions should not be altered from the original design. Loading with slopes, parking lots and buildings should be maintained as designed. Any changes to the top of wall finished grade must be evaluated prior to wall completion (see Figures J:1-L:1 for typical cross section details).*

*Note:
See Additional Construction Details “Planting Guidelines” for details on proper planting installations for a Keystone retaining wall. Also See Additional Construction Details for other types of top of wall treatment details.

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Completed Reinforced Wall Sections

**FIGURE K:1 - (REINFORCED WALL) NEAR VERTICAL SETBACK**

- **8" Min. Low Permeable Soil**
- **Keystone Cap Unit**
- **Keystone Compac II Unit**
- **Unit Drainage Fill (3/4" Crushed Rock or Stone)**
- **24"**
- **1/8"**
- **8"**
- **Finished Grade**
- **Unreinforced Concrete or Crushed Stone Leveling Pad**
- **Foundation Soil**
- **Approximate Limits of Excavation**
- **Retained Soil**
- **4" Perforated PVC Drainage Tile**

**Note:**
When site conditions require, wrap drainage tile in 3/4" aggregate and filter fabric with drainage composite or aggregate back drain system, as directed by geotechnical engineer.

**FIGURE L:1 - (REINFORCED WALL) 1" SETBACK**

- **8" Min. Low Permeable Soil**
- **Keystone Cap Unit**
- **Keystone Compac II Unit**
- **Unit Drainage Fill (3/4" Crushed Rock or Stone)**
- **24"**
- **1"**
- **8"**
- **Finished Grade**
- **Unreinforced Concrete or Crushed Stone Leveling Pad**
- **Foundation Soil**
- **Approximate Limits of Excavation**
- **Retained Soil**
- **4" Perforated PVC Drainage Tile**

**Note:**
When site conditions require, wrap drainage tile in 3/4" aggregate and filter fabric with drainage composite or aggregate back drain system, as directed by geotechnical engineer.
This section contains Keystone's design/estimating charts for Compac and Standard unit series gravity walls or geogrid reinforced walls.

The gravity wall charts help determine the maximum possible gravity wall height for a Compac or Standard unit. First, select which unit will be used for the wall. Second, determine which soil type most closely represents the soil conditions on the project site. Finally, select the backslope condition that most closely represents the final constructed wall condition.

The reinforced wall charts consider multiple factors for determining the necessary geogrid length. First, select the appropriate unit type and wall batter. Next, determine the wall load condition that most closely resembles the final project conditions. Then select the soil condition that most closely matches the project site soils. Finally, select the wall height (including embedment) that will best fit the project wall profile.

The design/estimating charts in this section are to be used for reference and preliminary design use only. These charts are not to be considered as a standardized engineering document. A qualified professional should be consulted for final design assistance. Keystone accepts no liability for the improper use of these charts.
The information contained herein has been compiled by Keystone® Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.

**Gravity Wall Schematic**

**STANDARD UNIT - BETHESDA, MD**

**Gravity Wall Schematic**

**NOTES:**
- Wall Height (H) is the total height from top to bottom.
- Minimum wall embedment is 6 inches (150mm) or Height/8, whichever is greater for level toe.
- Subsurface soils must be capable of supporting wall system.
- Unit drainage fill is ¾ inch (20mm) clean crushed stone.
- Leveling pad is crushed stone base material.
- All backfill materials are compacted to 95% Standard Proctor Density or 92% Modified Proctor Density.
- Finished grade must provide positive drainage.
### Maximum Height Gravity Wall Charts

#### NEAR VERTICAL - STANDARD UNITS (18”)

<table>
<thead>
<tr>
<th>MAX. HGT.</th>
<th>BACKSLOPE</th>
</tr>
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<tbody>
<tr>
<td>Soil Type</td>
<td>Level</td>
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<tr>
<td>Sand/Gravel</td>
<td>4.33’ (1.30m)</td>
</tr>
<tr>
<td>Silty Sand</td>
<td>3.67’ (1.10m)</td>
</tr>
<tr>
<td>Silt/Lean Clay</td>
<td>3.67’ (1.19m)</td>
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#### SETBACK OPTION - STANDARD UNITS (18”)

<table>
<thead>
<tr>
<th>MAX. HGT.</th>
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<td>Soil Type</td>
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<td>Sand/Gravel</td>
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<td>Silty Sand</td>
<td>5.00’ (1.50m)</td>
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<tr>
<td>Silt/Lean Clay</td>
<td>4.33’ (1.30m)</td>
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#### NEAR VERTICAL - STANDARD UNITS (21”)

<table>
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<tr>
<td>Silt/Lean Clay</td>
<td>3.67’ (1.10m)</td>
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#### SETBACK OPTION - STANDARD UNITS (21”)

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<td>Soil Type</td>
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<td>Silty Sand</td>
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</tr>
<tr>
<td>Silt/Lean Clay</td>
<td>5.00’ (1.50m)</td>
</tr>
</tbody>
</table>

**NOTES:** CALCULATIONS ASSUME A UNIT WEIGHT OF 120 PCT (19 KN/M²) 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 FS>1.5. CHARTS ARE PERFORMED USING COULOMB EARTH PRESSURE ANALYSIS. (NCMA 3RD EDITION) NEAR VERTICAL WALLS UTILIZE 1° BATTER AND 1” SETBACK WALL UTILIZE 8° BATTER. NO SURCHARGES WERE USED IN THE ANALYSIS. SURCHARGES OR SPECIAL LOADING CONDITIONS WILL REDUCE MAXIMUM WALL HEIGHTS. SLIDING CALCULATIONS ASSUME A 6” (150MM) CRUSHED STONE LEVELING PAD AS COMPACTED FOUNDATION MATERIAL. THE INFORMATION PROVIDED IS FOR PRELIMINARY DESIGN USE ONLY. A QUALIFIED PROFESSIONAL SHOULD BE CONSULTED. KEYSTONE ACCEPTS NO LIABILITY FOR THE IMPROPER USE OF THESE TABLES.
The information contained herein has been compiled by Keystone Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.

Gravty Wall Schematic

GRAVITY WALL SCHEMATIC

Wall Height (H) is the total height from top to bottom. Minimum wall embedment is 6 inches (150mm) or Height/8, whichever is greater for level toe. Subsurface soils must be capable of supporting wall system. Unit drainage fill is ¾ inch (20mm) clean crushed stone. Leveling pad is crushed stone base material. All backfill materials are compacted to 95% Standard Proctor Density or 92% Modified Proctor Density. Finished grade must provide positive drainage.
### Maximum Height Gravity Wall Charts

**NEAR VERTICAL WALL**

(Minimum setback per unit)

**ONE INCH SETBACK WALL**

(1" min. setback per unit) (25mm)

#### MAX. HGT. - COMPAC UNITS

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Level</th>
<th>4H:1V</th>
<th>3H:1V</th>
<th>2H:1V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand/Gravel</td>
<td>3.0'</td>
<td>2.33'</td>
<td>2.33'</td>
<td>2.33'</td>
</tr>
<tr>
<td></td>
<td>(0.91m)</td>
<td>(0.71m)</td>
<td>(0.71m)</td>
<td>(0.71m)</td>
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<tr>
<td>Silty Sand</td>
<td>2.33'</td>
<td>2.33'</td>
<td>1.67'</td>
<td>1.67'</td>
</tr>
<tr>
<td></td>
<td>(0.71m)</td>
<td>(0.71m)</td>
<td>(0.51m)</td>
<td>(0.51m)</td>
</tr>
<tr>
<td>Silt/Lean Clay</td>
<td>2.33'</td>
<td>1.67'</td>
<td>1.67'</td>
<td>&lt;1.00'</td>
</tr>
<tr>
<td></td>
<td>(0.71m)</td>
<td>(0.51m)</td>
<td>(0.51m)</td>
<td>(0.30m)</td>
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#### SETBACK OPTION - COMPAC UNITS

<table>
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<th>Soil Type</th>
<th>Level</th>
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<th>3H:1V</th>
<th>2H:1V</th>
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<tr>
<td>Sand/Gravel</td>
<td>3.67'</td>
<td>3.67'</td>
<td>3.00'</td>
<td>3.00'</td>
</tr>
<tr>
<td></td>
<td>(1.20m)</td>
<td>(1.20m)</td>
<td>(0.91m)</td>
<td>(0.91m)</td>
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<tr>
<td>Silty Sand</td>
<td>3.00'</td>
<td>3.00'</td>
<td>2.33'</td>
<td>2.33'</td>
</tr>
<tr>
<td></td>
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<td>(0.91m)</td>
<td>(0.71m)</td>
<td>(0.71m)</td>
<td>(0.30m)</td>
</tr>
</tbody>
</table>

**NOTES:**

- Calculations assume a unit weight of 120 PCT (19 kN/m²) for all soil types.
- Assumed \( \phi \) angles for earth pressure calculations are: Sand/Gravel=34°, Silty Sand=30°, and Sandy Silt/Sandy Clay=26°. Non critical structures with FS>1.5. Charts are performed using Coulomb earth pressure analysis (NCMA 3rd Edition). Near vertical walls utilize 1° batter and 1" setback wall utilize 8° batter. No surcharges were used in the analysis. Surcharges or special loading conditions will reduce maximum wall heights.
- Sliding calculations assume a 6" (150mm) crushed stone leveling pad as compacted foundation material. The information provided is for preliminary design use only. A qualified professional should be consulted. Keystone accepts no liability for the improper use of these tables.

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The information contained herein has been compiled by Keystone Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.
The Keystone® Reinforced wall charts are graphically presented to show the proper location and lengths of geogrids used with Standard units at the near vertical and 1 inch (25mm) setback batter (8º). Design heights were set in two block increments beginning at 4.3 feet (1.3m) and ending 11 feet (3.4m). Engineering judgement should be used when interpolating between heights. In general, geogrid should be placed at the design elevation for the entire wall length or until a wall step is reached. Minimum reinforcement lengths were set for 5 feet (1.5m) and a 70% reinforcement length to wall height ratio. Always use the same vertical spacing of geogrid throughout the wall. If your maximum height of wall requires 3 units vertical spacing, then use that spacing even though lower wall heights in the charts may indicate 4 units. Top layers of geogrid shall never be more than 3 units from the top of the wall. Bottom layers of geogrid shall never be more than 3 units from the top of the leveling pad. Insert geogrid layer at these locations where 3 unit courses are exceeded. 250 psf surcharge is applied 6 inches behind the tail of the units. Soil ranges were selected to approximate good, medium and poor soil conditions to concisely cover the typical design range. Wall height is the total height of the wall from the top of the leveling pad to the top of the wall.

The charts use Rankine earth pressure for calculations. The following charts assume the use of a coated polyester geogrid with a minimum allowable design strength of: LTDS=1800 plf (26.3 kN/m) Tal=1200 plf (17.5 kN/m). The following geogrid types are suitable with these design charts:
- Synteen SF35 by Synteen
- Miragrid 3XT by TC Mirafi
- Stratagrid 200 by Strata Systems
- 55/30-20 by Huesker Inc.

All geogrid lengths shown are the actual lengths of geogrid required as measured from the connection pins to the end of the geogrid. The charts assume that the walls are constructed in accordance with Keystone specifications and good construction practice. All soil zones (reinforced, retained, and foundation) must be compacted in 8 inch (200mm) lifts to 95% Standard Proctor density or 92% Modified Proctor density as determined by laboratory testing. The information contained in the design/estimating charts are for preliminary design use only. A qualified professional should be consulted for final design assistance. Keystone accepts no liability for the improper use of these charts.

### NOTES:
- Wall Height (H) is the total height from top to bottom.
- Minimum wall embedment is 6 inches (150mm) or Height/20, whichever is greater for level toe.
- Subsurface soils must be capable of supporting wall system.
- Unit drainage fill is ¾ inch (20mm) clean crushed stone.
- Leveling pad is crushed stone base material.
- All backfill materials are compacted to 95% Standard Proctor density or 92% Modified Proctor density.
- Geogrids must be of appropriate type and length per the design.
- Finished grade must provide positive drainage.
- The symbol \( 5' \) indicates location and length of geogrid measured from the pins to the end of the geogrid.
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### STANDARD UNITS - 1" (25mm) SET BACK

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Height</th>
<th>4.3' (1.3m)</th>
<th>5.7' (1.7m)</th>
<th>7.0' (2.1m)</th>
<th>8.3' (2.5m)</th>
<th>9.7' (3.0m)</th>
<th>11.0' (3.4m)</th>
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<tbody>
<tr>
<td>GEOGRID PLACEMENT</td>
<td>5' (1.5m)</td>
<td>6' (1.8m)</td>
<td>1.9m</td>
<td>2.1m</td>
<td>2.3m</td>
<td>2.4m</td>
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### SAND/GRAVEL: $\phi=34^\circ$, $\gamma=120$ pcf (19kN/m$^3$)

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### STANDARD UNITS - 1" (25mm) SET BACK

<table>
<thead>
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<td>2.3m</td>
<td>2.4m</td>
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### SILTY SAND: $\phi=30^\circ$, $\gamma=120$ pcf (19kN/m$^3$)

<table>
<thead>
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<th>Case 1</th>
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Design/Estimating Charts: Reinforced Wall Charts

STANDARD UNITS - 1" (25mm) SET BACK

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SILT/LEAN CLAY: $\phi=26^\circ$, $\gamma=120$ pcf (19kN/m$^3$)

GEOGRID PLACEMENT

ENGINEER SHOULD EVALUATE DESIGN FOR POOR SOILS AND SURCHARGES.

ENGINEER SHOULD EVALUATE DESIGN FOR POOR SOILS AND BACKSLOPES.

SAND/GRAVEL: $\phi=34^\circ$, $\gamma=120$ pcf (19kN/m$^3$)

GEOGRID PLACEMENT

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## Design/Estimating Charts: Reinforced Wall Charts

### STANDARD UNITS - NEAR VERTICAL

#### SILTY SAND: $\phi = 30^\circ$, $\gamma = 120$ pcf (19kN/m$^3$)

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The Keystone reinforced wall charts are graphically presented to show the proper location and lengths of geogrids used with Compac units at the near vertical and 1 inch (25mm) setback batter (8º). Design heights were set in two block increments beginning at 4.3 feet (1.3m) and ending 11 feet (3.4m). Engineering judgement should be used when interpolating between heights. In general, geogrid should be placed at the design elevation for the entire wall length or until a wall step is reached. Minimum reinforcement lengths were set for 4 feet (1.23m) minimum and a 70% reinforcement length to wall height ratio. Always use the same vertical spacing of geogrid throughout the wall. Top layers of geogrid shall never be more than 2 units from the top of the wall. Bottom layers of geogrid shall never be more than 2 units from the top of the leveling pad. Insert a geogrid layer at these locations where 2 unit courses are exceeded. 250 psf surcharge is applied 6 inches behind the tail of the units. Soil ranges were selected to approximate good, medium and poor soil conditions to concisely cover the typical design range. Wall height is the total height of the wall from the top of the leveling pad to top of wall.

The charts use Rankine earth pressure for calculations. The following charts assume the use of a coated polyester geogrid with a minimum allowable design strength of: LTDS=1875 plf (27.4 kN/m) Tal=1250 plf (18.3 kN/m). The following geogrid types are suitable with these design charts:
- Synteen SF35 by Synteen
- Miragrid 3XT by TCMirafi
- Stratagrid 200 by Strata Systems
- 55/30-20 by Huesker Inc.

All geogrid lengths shown are the actual lengths of geogrid required as measured from the connection pins to the end of the geogrid. The design/estimating charts assume that the walls are constructed in accordance with Keystone specifications and good construction practice. All soil zones (reinforced, retained, and foundation) must be compacted in 8 inch (200mm) lifts to 95% Standard Proctor density or 92% Modified Proctor density as determined by laboratory testing. The information contained in the design/estimating charts are for preliminary design use only. A qualified professional should be consulted for final design assistance. Keystone accepts no liability for the improper use of these charts.

**REINFORCED WALL SCHEMATIC**

Wall Height (H) is the total height from top to bottom.

Minimum wall embedment is 6 inches (150mm) or Height/20, whichever is greater for level toe.

Subsurface soils must be capable of supporting wall system.

Unit drainage fill is ¾ inch (20mm) clean crushed stone.

Leveling pad is crushed stone base material.

All backfill materials are compacted to 95% Standard Proctor density or 92% Modified Proctor density.

Geogrids must be of appropriate type and length per the design.

Finished grade must provide positive drainage.

The symbol ‘5’ indicates location and length of geogrid measured from the pins to the end of the geogrid.
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### Design/Estimating Charts: Reinforced Wall Charts

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<th>GEOGRID PLACEMENT</th>
</tr>
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<tbody>
<tr>
<td>CASE 1</td>
<td>4.3</td>
<td>1.3</td>
<td><img src="image1.png" alt="Diagram" /></td>
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<tr>
<td>CASE 2</td>
<td>4.3</td>
<td>1.3</td>
<td><img src="image2.png" alt="Diagram" /></td>
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<tr>
<td>CASE 3</td>
<td>4.3</td>
<td>1.3</td>
<td><img src="image3.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

**COMPAC UNITS - 1" (25mm) SET BACK**

- **NO SURCHARGE**
  - GEOGRID PLACEMENT
    - (1.5M) (1.5M) (1.5M) (1.7M) (1.8M) (2.1M)

**SAND/GRAVEL: \( \phi = 34^\circ, \gamma = 120 \text{pcf} \) (19kN/m^3)**

**COMPAC UNITS - 1" (25mm) SET BACK**

- **NO SURCHARGE**
  - GEOGRID PLACEMENT
    - (1.5M) (1.5M) (1.5M) (1.7M) (1.8M) (2.1M)

- **250 PSF SURCHARGE**
  - GEOGRID PLACEMENT
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- **SURCHARGE**
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| **CASE 2**                           | **GEOGRID PLACEMENT**                                           |
| **HEIGHT**                           | **GEOGRID PLACEMENT**                                           |
| **4.3' (1.3m) No Surcharge**         | **ENGINEER SHOULD EVALUATE DESIGN FOR POOR SOILS AND BACKSLOPES.** |
| **5.7' (1.7m)**                       |                                                                  |
| **7.0' (2.1m)**                       |                                                                  |
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| **CASE 3**                           | **GEOGRID PLACEMENT**                                           |
| **HEIGHT**                           | **GEOGRID PLACEMENT**                                           |
| **4.3' (1.3m) No Surcharge**         | **ENGINEER SHOULD EVALUATE DESIGN FOR POOR SOILS AND BACKSLOPES.** |
| **5.7' (1.7m)**                       |                                                                  |
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### COMPAC UNITS - NEAR VERTICAL

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| **CASE 2**                              | **GEOGRID PLACEMENT**                                           |
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#### COMPAC UNITS - NEAR VERTICAL

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<thead>
<tr>
<th>CASE 1</th>
<th>HEIGHT</th>
<th>4.3' (1.3m)</th>
<th>5.7' (1.7m)</th>
<th>7.0' (2.1m)</th>
<th>8.3' (2.5m)</th>
<th>9.7' (3.0m)</th>
<th>11.0' (3.4m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(1.3m)</td>
<td>(1.7m)</td>
<td>(2.1m)</td>
<td>(2.5m)</td>
<td>(3.0m)</td>
<td>(3.4m)</td>
</tr>
</tbody>
</table>
So far the discussion regarding the installation of a Keystone retaining wall has centered on the installation of units through the straight line sections of the wall. Equally important and one of the finer aspects for an aesthetically pleasing yet structurally sound wall is the construction of corners and curves.

A corner is typically constructed as either an outside 90° corner, inside 90° corner or acute outside corner (between 75° to 90°). When a wall needs to make a turn greater than 90° it is recommended to install a radius curve for the wall. For curves in the wall, Keystone units typically have a minimum radius depending on the face style, which is outlined later in this section by unit type. The flexibility of the Keystone units allows for the construction of multiple corners or curves within the same wall. The following information will provide a general explanation of construction techniques for building retaining walls with corner and curve conditions.

Tools and materials that will be required:

- 12 inch and 48 inch levels
- Tape measure
- Concrete saw
- Block splitter
- Masonry cold chisel
- 5 lb dead blow hammer
- Hammer drill with 5/8 inch masonry drill bit
- Keystone KapSeal™ concrete adhesive
90° Outside Corner: Standard Unit

For ease of construction of outside 90° corners, Keystone producers typically provide a corner unit specifically designed for this purpose. Corner unit options and product designs may vary by manufacturer, please contact your local manufacturer for availability before you begin your project planning. Details at right show a typical corner unit available in many locations.

If corner units are not available, Keystone recommends transitioning the wall from a corner to a radius curve in the wall and avoiding mitered corners. This will enable the wall to maintain its pin connection integrity and running bond wall configuration for continued wall stability and performance.

If creating a radius is not an option, the last resort is to miter the Keystone units to create the outside 90° corner. Unfortunately mitering a corner can result in undesirable wall performance issues in the corner, including gapping of the units, or an entire separation of the wall corner due to soil movement. Keystone recommends using an integration of the mitered Keystone units with rebar and grout or concrete to prevent the unwanted performance issues. Please contact your local Keystone representative for assistance when attempting to construct mitered outside corners.

Battered walls (8°) present an issue in outside corners, as the wall rises vertically, the wall will get smaller. See details on pages 42-43 for detailed installation and cutting instructions.

Notes:
Follow standard installation instructions for preparation of sub grade and leveling pad.
Tails of units near the corner may have to be trimmed to allow for a battered setback wall.
Place additional unit drainage fill at outside wall corner to extend back from wall face each way a distance equal to the wall height / 2 (H / 2).

The information contained herein has been compiled by Keystone® Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.
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90° Outside Corner: Standard Unit

**FIGURE N:1 - TYPICAL SECOND (EVEN COURSES)**

- **Keystone Standard I Unit**
- **Leveling Pad**
- **Standard I Cut Unit**
- **Keystone Corner Unit**

Unit Drainage Fill Limits (3/4" Crushed Rock or Stone)

Additional Corner Unit Drainage Fill Limits (See Notes)

**Notes:**
- Place additional unit drainage fill at outside wall corner to extend back from wall face each way a distance equal to the wall height / 2 (H / 2).
- Measure, cut and orient the geogrid, as per the engineer’s design and/or the geogrid manufacturer’s specifications in the correct strength direction.
- Place the geogrid over the Keystone unit pins and tension the geogrid by pulling it back away from the wall. Place a stake through the geogrid at the back to tension the geogrid in place.
- Proceed with placement of additional Keystone units, unit drainage fill and backfill material. Start backfilling nearest the Keystone units and then move back away from the wall, placing backfill materials over the geogrid to hold the geogrid in place under tension. After the backfilling process, the tension stakes may be removed for reuse.
- Compact the backfill materials in 8 inch lifts to the next reinforcement elevation, and repeat.

**FIGURE O:1 - TYPICAL GEOGRID INSTALLATION FOR OUTSIDE CORNER**

Unit Drainage Fill Limits

Reinforced Backfill

Additional Wall Corner Unit Drainage Fill Limits (See Notes)

3" of Soil Fill is Required Between Overlapping Geogrid for Proper Anchorage (Typ.)

Notes:

isometric detail
90° Outside Corner: Compac Unit

**FIGURE P:1 - TYPICAL BASE (ODD COURSES)**

- Keystone Compac II Unit
- Leveling Pad
- Compac II Cut Unit (After Base Course)
- Keystone Corner Unit
- Compac II Cut Unit (After Base Course)

Unit Drainage Fill Limits (3/4" Crushed Rock or Stone)

**Notes:**
Place additional unit drainage fill at outside wall corner to extend back from wall face each way a distance equal to the wall height / 2 (H / 2).

**FIGURE Q:1 - TYPICAL SECOND (EVEN COURSES)**

- Keystone Compac II Unit
- Leveling Pad
- Compac II Cut Unit
- Keystone Corner Unit
- Compac II Cut Unit

Unit Drainage Fill Limits (3/4" Crushed Rock or Stone)

Additional Corner Unit Drainage Fill Limits (See Notes)

**Notes:**
Place additional unit drainage fill at outside wall corner to extend back from wall face each way a distance equal to the wall height / 2 (H / 2).
Notes:

Unit drainage fill and backfill materials should be placed compacted to the geogrid elevation and Keystone unit pins should be in place prior to geogrid installation.

Place additional unit drainage fill at outside wall corner to extend back from wall face each way a distance equal to the wall height / 2 (H / 2).

Measure, cut and orient the geogrid, as per the engineer’s design and/or the geogrid manufacturer’s specifications in the correct strength direction.

Place the geogrid over the Keystone unit pins and tension the geogrid by pulling it back away from the wall. Place a stake through the geogrid at the back to tension the geogrid in place.

Proceed with placement of additional Keystone units, unit drainage fill and backfill material. Start backfilling nearest the Keystone units and then move back away from the wall, placing backfill materials over the geogrid to hold the geogrid in place under tension. After the backfilling process, the tension stakes may be removed for reuse.

Compact the backfill materials in 8 inch lifts to the next reinforcement elevation, and repeat.

The information contained herein has been compiled by Keystone Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.
When constructing a battered wall (8°) there are construction issues at the corner as the wall rises vertically. Because the wall is setback 1 inch per course, it creates a need to cut the corner or structural units within 3 feet of either side of the corner to maintain a proper running bond pattern in the straight sections of the wall. Keystone has developed a typical trim pattern to follow. The pattern is repeatable for taller walls beyond the height shown in the illustration shown below (see Figure S:1). This illustration is based on a full running bond pattern on the base course, with no trimmed units. (In the case of two corners near each other, it is best to set each corner unit base first to establish corner location, and then set the base course of structural units running to the corners and trim units as necessary.)

**FIGURE S1: BATTERED SETBACK AT 90° OUTSIDE CORNER**

**Notes:**
- Keystone Compac II units shown in 1 inch setback position.
- Full uncut units to be used for the base course and as indicated in the details vertically up the wall corner.
- Due to corner perpendicular wall setback per course to maintain running bond course alignment cut the corner and or adjoining block units next to the corner unit as roughly labeled for cut length and shaded for cut unit designation in both directions from the wall corner for proper wall joint alignment.
- Secure all cut units and corner units in place with construction adhesive.
- Cut corner units shall not be less than 16 inches wide and 9 inches deep.
- Verify actual cut lengths as wall is constructed.
The information contained herein has been compiled by Keystone Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.
The construction of inside corners is relatively simple, because no additional units are required. All you will need is your tape measure, concrete saw, block splitter blade or chisel and a level. There are two ways you can install an inside corner construction; you can butt one wall into the other wall, or you can use the interlocking method as shown below.

**FIGURE V:1 - TYPICAL BASE (ODD COURSES)**

**FIGURE W:1 - TYPICAL SECOND (EVEN COURSES)**
Unit drainage fill and backfill materials should be placed compacted to the geogrid elevation and Keystone unit pins should be in place prior to geogrid installation.

Measure, cut and orient the geogrid, as per the engineer’s design and/or the geogrid manufacturer’s specifications in correct strength direction.

Place the geogrid over the Keystone unit pins and tension the geogrid by pulling it back away from the wall. Place a stake through the geogrid at the back to tension the geogrid in place.

Proceed with placement of additional Keystone units, unit drainage fill and backfill material. Start backfilling nearest the Keystone units and then move back away from the wall, placing backfill materials over the geogrid to hold the geogrid in place under tension. After the backfilling process, the tension stakes may be removed for reuse.

Compact the backfill materials in 8 inch lifts to the next reinforcement elevation, and repeat.

Extend geogrid the wall height / 4 (H / 4) beyond the adjoining wall face at inside wall corners.
90° Inside Corner: Compac Unit

**FIGURE Y:1 - TYPICAL BASE (ODD COURSES)**

- Compac II Cut Unit, Align Center of Unit Face with Adjoining Wall Face (Base Course Only)
- Keystone Compac II Unit
- Leveling Pad
- Unit Drainage Fill Limits (3/4" Crushed Rock or Stone)

**FIGURE Z:1 - TYPICAL SECOND (EVEN COURSES)**

- Compac II Cut Unit
- Keystone Compac II Unit
- Leveling Pad
- Unit Drainage Fill Limits (3/4" Crushed Rock or Stone)
Notes:

Drainage zone and backfill materials should be placed compacted and up to the geogrid elevation and Keystone unit pins should be in place prior to geogrid installation.

Measure, cut and orient the geogrid, as per the engineer’s design and the geogrid manufacturers specifications on correct strength direction.

Place the geogrid over the Keystone unit pins and tension the geogrid by pulling it back away from the wall. Place a stake through the geogrid at the back to tension the geogrid in place.

Proceed with placement of additional Keystone units then drainage zone and backfill material. Starting at the wall and moving back away from the wall place the drainage zone and backfill materials over the geogrid to hold the geogrid in place under tension. After the backfilling process the tension stakes may be removed for reuse.

The backfill materials up to the next wall elevation where a geogrid is to be placed.

Extend geogrid the wall height / 4 (H / 4) beyond the adjoining wall face at inside wall corners.
Acute Corner: Standard Unit

In special cases, an acute corner construction is needed. No special units are necessary for the construction of acute corners, you will just need to field split or cut the corner units. All you will need is your tape measure, concrete saw, splitter blade or chisel and a level. The following is the recommended installation procedure for acute corners.

**FIGURE B2 - TYPICAL BASE (ODD COURSES)**

Keystone Standard I Unit

Unit Drainage Fill Limits (3/4” Crushed Rock or Stone)

Leveling Pad

Standard I Cut Unit (After Base Course)

Keystone Corner Unit Cut for a Combined 25” Outside Face Length (Each Course)

Drill and Place Pins In Corner Units for Extra Strength

Keystone Corner Unit Outside Face Cut to 16”

Standard I Cut Unit (After Base Course)

Notes:

Cut corner piece units to be used for each odd or even course vertically up the wall corner. Corner units to be cut the same for each alternating odd or even course.

Place additional unit drainage fill at outside wall corner to extend back from wall face each way a distance equal to the wall height / 2 (H / 2).

**FIGURE C2 - TYPICAL SECOND (EVEN COURSES)**

Keystone Standard I Unit

Additional Wall Corner Unit Drainage Fill Limits (See Notes)

Unit Drainage Fill Limits (3/4” Crushed Rock or Stone)

Leveling Pad

Standard I Cut Unit

Keystone Corner Unit Outside Face Cut to 16”

Drill and Place Pins In Corner Units for Extra Strength

Keystone Corner Unit Cut for a Combined 25” Outside Face Length (Each Course)

Notes:

Cut corner piece units to be used for each odd or even course vertically up the wall corner. Corner units to be cut the same for each alternating odd or even course.

Place additional unit drainage fill at outside wall corner to extend back from wall face each way a distance equal to the wall height / 2 (H / 2).
Unit drainage fill and backfill materials should be placed compacted to the geogrid elevation and Keystone unit pins should be in place prior to geogrid installation.

Place additional unit drainage fill at acute wall corner to extend back from wall face each way a distance equal to the wall height / 2 (H / 2).

Measure, cut and orient the geogrid, as per the engineer’s design and/or the geogrid manufacturer’s specifications in the correct strength direction.

Place the geogrid over the Keystone unit pins and tension the geogrid by pulling it back away from the wall. Place a stake through the geogrid at the back to tension the geogrid in place.

Proceed with placement of additional Keystone units, unit drainage fill and backfill material. Start backfilling nearest the Keystone units and then move back away from the wall, placing backfill materials over the geogrid to hold the geogrid in place under tension. After the backfilling process, the tension stakes may be removed for reuse.

Compact the backfill materials in 8 inch lifts to the next reinforcement elevation, and repeat.
CORNERS & CURVES

Acute Corner: Compac Unit

**FIGURE E:2- TYPICAL BASE (ODD COURSES)**

- Keystone Compac II Unit
- Unit Drainage Fill Limits (3/4” Crushed Rock or Stone)
- Leveling Pad
- Compac II Cut Unit (After Base Course)
- Keystone Corner Unit Cut for a Combined 25” * Outside Face Length (Each Course)
- Keystone Corner Unit Outside Face Split to 16”
- Drill and Place Pins in Corner Units for Extra Strength

**FIGURE F:2- TYPICAL SECOND (EVEN COURSES)**

- Keystone Compac II Unit
- Additional Wall Corner Unit Drainage Fill Limits (See Notes)
- Unit Drainage Fill Limits (3/4” Crushed Rock or Stone)
- Leveling Pad
- Compac II Cut Unit
- Drill and Place Pins in Corner Units for Extra Strength
- Keystone Corner Unit Cut for a Combined 25” * Outside Face Length (Each Course)

Notes:
- Cut corner piece units to be used for each odd or even course vertically up the wall corner. Corner units to be cut the same for each alternating odd or even course.
- Additional crushed rock or stone drainage fill at outside wall corners to extend back from wall face each way at wall height / 2 (H / 2).
- * Distance varies as angle increases.

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FIGURE G:2 - TYPICAL GEOGRID INSTALLATION FOR OUTSIDE ACUTE CORNERS

Notes:

Unit drainage fill and backfill materials should be placed compacted to the geogrid elevation and Keystone unit pins should be in place prior to geogrid installation.

Place additional unit drainage fill at acute wall corner to extend back from wall face each way a distance equal to the wall height / 2 (H / 2).

Measure, cut and orient the geogrid, as per the engineer’s design and/or the geogrid manufacturer’s specifications in the correct strength direction.

Place the geogrid over the Keystone unit pins and tension the geogrid by pulling it back away from the wall. Place a stake through the geogrid at the back to tension the geogrid in place.

Proceed with placement of additional Keystone units, unit drainage fill and backfill material. Start backfilling nearest the Keystone units and then move back away from the wall, placing backfill materials over the geogrid to hold the geogrid in place under tension.

After the backfilling process, the tension stakes may be removed for reuse.

Compact the backfill materials in 8 inch lifts to the next reinforcement elevation, and repeat.
Concave Curves: Introduction

Concave curves for moderately tall Keystone walls are more difficult to construct than a straight wall due to the complex geometry resulting from a battered wall face in a curve. Inside curves allow good access for compaction and the wall face units tend to support each other like an arch when the soil strain associated with the active earth pressure condition develops.

For concave curves as the wall gets taller, the top of the wall becomes longer than the base. For wall systems that maintain the desired running bond configuration, gaps between units tend to form. In a wall in the near vertical pin position (<1°) the gapping is less significant than it is for a battered wall (8°).

When laying out wall geometry, several measures can be taken to minimize this issue or concentrate it to particular locations, which tend to make the issue easier to work with from a construction perspective. Use the following table to determine the amount of gapping (expansion) that will be tolerated at the design wall batter. The table will then provide the minimum radius through the curve based on the desired gap tolerance.

<table>
<thead>
<tr>
<th>Expansion per block per course in a curve</th>
<th>1/32&quot;</th>
<th>1/16&quot;</th>
<th>1/8&quot;</th>
<th>1/4&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>WALL SETBACK</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1° (1/8&quot;)</td>
<td>6&quot;</td>
<td>3&quot;</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4° (9/16&quot;)</td>
<td>27'</td>
<td>13'</td>
<td>7'</td>
<td>4'</td>
</tr>
<tr>
<td>8° (1&quot;)</td>
<td>54'</td>
<td>27'</td>
<td>13'</td>
<td>7'</td>
</tr>
</tbody>
</table>

Block gapping is expected, it is the amount of gapping that can controlled by increasing the radius of the curve.

As the table indicates the minimum radius increases with an increase to the wall batter. The near vertical position is typically the best solution for tighter radius situations.

Unfortunately, the larger radii may not be achievable for a given wall. Therefore, filling the gaps between the units will be required when the gaps start to exceed 1/8 inch. See the illustration below:

<table>
<thead>
<tr>
<th>Course</th>
<th>Width of Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left block cut (L)</td>
</tr>
<tr>
<td>5th</td>
<td>15 3/16&quot;</td>
</tr>
<tr>
<td>6th</td>
<td>15 5/8&quot;</td>
</tr>
<tr>
<td>7th</td>
<td>15 9/16&quot;</td>
</tr>
<tr>
<td>8th</td>
<td>15 11/16&quot;</td>
</tr>
<tr>
<td>9th</td>
<td>15 7/8&quot;</td>
</tr>
<tr>
<td>10th</td>
<td>16 3/16&quot;</td>
</tr>
<tr>
<td>11th</td>
<td>16 3/4&quot;</td>
</tr>
<tr>
<td>12th</td>
<td>15 5/8&quot;</td>
</tr>
</tbody>
</table>

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Notes:

Keystone Compac II units shown in 1 inch setback position.

Full uncut units to be used in the first three courses and as indicated in the details.

Due to per course perpendicular wall setback at both ends of the curve to maintain running bond course alignment at ends and center of curve, cut the units in the curve per course as roughly labeled for cut width and shaded for unit designation through the curve for proper wall joint alignment at ends and center of curve.

Place full base course units with no gapping between adjacent units. With the placement of each additional course of Keystone units the units batter, move or setback away from the point of radius. The rate of gapping is controlled by the severity of the batter (i.e. a 1 inch setback will gap more quickly than a near vertical setback). The distance between the pin holes on adjacent first course units should not exceed 12 inches on center.

Depending on wall height and radius, connecting pins may fall outside of connecting cores in additional units above, if this occurs re-drill new pin holes as needed using a 5/8 inch masonry bit and realign units and/or use Keystone KapSeal adhesive (or approved equal) to secure units together.

5 feet ± example radius shown, verify actual cut widths for each course as wall is constructed and for other radius sizes.
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Concave Curves: Standard Unit

Notes:

Unit drainage fill and backfill materials should be placed compacted to the geogrid elevation and Keystone unit pins should be in place prior to geogrid installation.

Measure, cut and orient the geogrid, as per the engineer’s design and/or the geogrid manufacturer’s specifications in the correct strength direction.

Place the geogrid over the Keystone unit pins and tension the geogrid by pulling it back away from the wall. Place a stake through the geogrid at the back to tension the geogrid in place.

Proceed with placement of additional Keystone units, unit drainage fill and backfill material. Start backfilling nearest the Keystone units and then move back away from the wall, placing backfill materials over the geogrid to hold the geogrid in place under tension. After the backfilling process, the tension stakes may be removed for reuse.

Compact the backfill materials in 8 inch lifts to the next reinforcement elevation, and repeat.

FIGURE J2 - CONCAVE CURVE GEOGRID INSTALLATION
FIGURE K:2- CONCAVE CURVE INSTALLATION (BASE COURSE)

Unit Drainage Fill Limits
(3/4" Crushed Rock or Stone)

24" Unit Drainage Fill Zone (Typ.)

12" Max. Pin Spacing (See Notes)
Gapping Between Units (See Notes)

Keystone Compac II Unit

Levelling pad

Keystone Construction Manual www.keystonewalls.com
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Notes:

Unit drainage fill and backfill materials should be placed compacted to the geogrid elevation and Keystone unit pins should be in place prior to geogrid installation.

Measure, cut and orient the geogrid, as per the engineer’s design and/or the geogrid manufacturer’s specifications in the correct strength direction.

Place the geogrid over the Keystone unit pins and tension the geogrid by pulling it back away from the wall. Place a stake through the geogrid at the back to tension the geogrid in place.

Proceed with placement of additional Keystone units, unit drainage fill and backfill material. Start backfilling nearest the Keystone units and then move back away from the wall, placing backfill materials over the geogrid to hold the geogrid in place under tension. After the backfilling process, the tension stakes may be removed for reuse.

Compact the backfill materials in 8 inch lifts to the next reinforcement elevation, and repeat.
Convex curves are an aesthetically pleasing accent to any retaining wall. Keystone units can be easily integrated with multiple curves within the same wall. However, convex curves require attention to the small details when constructing these curves. Wall performance issues can result from installing too tight of radii, resulting in difficult compaction and many small cut pieces. Units tend to bind as the wall gets taller, thus using a concrete saw or splitter is required to trim some units as the wall is constructed to maintain the running bond configuration. Use the following table to determine the minimum radius of the curve to help reduce the amount of trimming that will be required at the design wall setback.

### Minimum Radius Table to Reduce Block Trimming

<table>
<thead>
<tr>
<th>WALL SETBACK</th>
<th>Trimming per block per course in a curve</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/32&quot;</td>
</tr>
<tr>
<td>1° (1/8&quot;)</td>
<td>6'</td>
</tr>
<tr>
<td>4° (9/16&quot;)</td>
<td>27'</td>
</tr>
<tr>
<td>8° (1&quot;)</td>
<td>54'</td>
</tr>
</tbody>
</table>

Near Vertical Setback is recommended for walls with multiple curves.

As indicated in the above table, 1 inch setback walls require large radius curves to minimize the binding of the units. A wall in a near vertical setback requires minimal trimming of the units. When constructing an outside curve with a 1 inch setback and tight radius, we recommend performing the following steps to maintain pin integrity and running bond configuration. See the illustration below for additional details.

1. Trim unit corner sides equally using either a masonry chisel or concrete saw. Avoid trimming units in the same vertical location to avoid stack bonding and an aesthetically unpleasing look.
Notes:

Keystone Compac II units shown in 1 inch setback position.

Full uncut units to be used for the base course and as indicated in the details.

Place full base course units, with no gapping, between adjacent units. With the placement of each additional course of Keystone units the units batter, move or setback toward the point of radius. The rate of closure is controlled by the severity of the batter (i.e. a 1 inch setback will gap more quickly than a near vertical setback). The distance between the pin holes on adjacent first course units should not exceed 12 inches on center.

To maintain running bond configuration through the curve, cut the units equally as shown in the shaded units below. Cutting shown is for the example only and will vary by the radius of the curve.

Depending on wall height and radius, connecting pins may fall outside of connecting cores through the cut units. If this occurs, re-drill new pin holes as needed using a 5/8 inch masonry bit and realign units and/or use Keystone Kapseal adhesive (or approved equal) to secure units together.

6 foot ± example radius shown, verify actual cut widths for each course as wall is constructed and for other radius sizes.
The information contained herein has been compiled by Keystone ® Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.

Convex Curves : Standard Unit

**FIGURE N:2 - CONVEX CURVE INSTALLATION (BASE COURSE)**

- **Notes:**
  - For taller walls, as the wall increases in height, the units will tend to bind on successive courses. To avoid this binding issue, follow the instructions noted above. The distance between the pin holes on adjacent course units should not exceed 12 inches on center.
  - Place additional unit drainage fill at outside wall corner to extend back from wall face each way a distance equal to the wall height / 2 (H / 2).
Convex Curves: Standard Unit

**FIGURE O:2 - CONVEX GEOGRID CURVE INSTALLATION**

Unit drainage fill limits and backfill materials should be placed compacted to the geogrid elevation and Keystone unit pins should be in place prior to geogrid installation.

Place additional unit drainage fill at outside wall curve to extend back from wall face each way a distance equal to the wall height / 2 (H / 2).

Measure, cut and orient the geogrid, as per the engineer’s design and/or the geogrid manufacturer’s specifications in the correct strength direction.

Place the geogrid over the Keystone unit pins and tension the geogrid by pulling it back away from the wall. Place a stake through the geogrid at the back to tension the geogrid in place.

Proceed with placement of additional Keystone units, unit drainage fill and backfill material. Start backfilling nearest the Keystone units and then move back away from the wall, placing backfill materials over the geogrid to hold the geogrid in place under tension. After the backfilling process, the tension stakes may be removed for reuse.

Compact the backfill materials in 8 inch lifts to the next reinforcement elevation, and repeat.

The information contained herein has been compiled by Keystone Retaining Wall Systems, Inc. and to the best of our knowledge, accurately represents the Keystone product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Structural design and analysis shall be performed by a qualified engineer.
Convex Curves: Compac Unit

**FIGURE P2 - CONVEX CURVE INSTALLATION (BASE COURSE)**

- **Notes:**
  - For taller walls, as the wall increases in height, the units will tend to bind on successive courses. To avoid this binding issue, follow the instructions noted above. The distance between the pin holes on adjacent course units should not exceed 12 inches on center.
  - Place additional unit drainage fill at outside wall corner to extend back from wall face each way a distance equal to the wall height / 2 (H / 2).

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Convex Curves: Compac Unit

**FIGURE Q2- CONVEX CURVE GEOGRID INSTALLATION**

Unit Drainage Fill Limits

Reinforced Backfill

Additional Corner Drainage Fill Limits

(See Notes)

Geogrid Reinforcement

(Typ.)

3" of Soil Fill is Required Between Overlapping Geogrid for Proper Anchorage (Typ.)

H/2

H/2

Keystone Compac II Unit

Leveling pad

Notes:

Unit drainage fill and backfill materials should be placed compacted to the geogrid elevation and Keystone unit pins should be in place prior to geogrid installation.

Place additional unit drainage fill at outside wall curve to extend back from wall face each way a distance equal to the wall height / 2 (H / 2).

Measure, cut and orient the geogrid, as per the engineer’s design and/or the geogrid manufacturer’s specifications in the correct strength direction.

Place the geogrid over the Keystone unit pins and tension the geogrid by pulling it back away from the wall. Place a stake through the geogrid at the back to tension the geogrid in place.

Proceed with placement of additional Keystone units, unit drainage fill and backfill material. Start backfilling nearest the Keystone units and then move back away from the wall, placing backfill materials over the geogrid to hold the geogrid in place under tension. After the backfilling process, the tension stakes may be removed for reuse.

Compact the backfill materials in 8 inch lifts to the next reinforcement elevation, and repeat.
A wall is not complete without the perfect finishing touch. The flexibility of the Keystone units create a variety of wall finishing options. The most common wall finish is to cap the wall with a Keystone cap. Cap options vary by region so check with your local Keystone producer for availability in your area. Keystone units can also be capped with a variety of decorative precast concrete products, or even CIP concrete copings. This section outlines the construction techniques and details for these various options.

Tools and materials that will be required:

- 12 inch and 48 inch levels
- Tape measure
- Personal protective equipment
- Keystone caps
- Landscape finishing material
- Keystone KapSeal™ concrete adhesive
WALL FINISHING OPTIONS

Cap Units: Standard & Compac

A Keystone retaining wall is not complete without the “capping touch.” The two primary wall units, the Standard and Compac units, both have open voids, making them an aesthetically undesirable finish for the top of the wall. Keystone offers a selection of cap designs, available in various combinations of facial finish and degrees of angled sides*. The following information will clearly explain the uses of these units and show a variety of finishing techniques. You may also opt to finish your wall with a precast decorative concrete finishing option, see your local manufacturer for details.

CAPPING UNITS

Universal Cap - finished on both front and back

Tri-plane angled-sided

Tri-plane Straight-sided

NOTE: UNIT WEIGHTS, DIMENSIONS AND AVAILABILITY VARY BY MANUFACTURER. PLEASE CONTACT YOUR LOCAL REPRESENTATIVE.

* 8” capping option not shown. Capping options and product designs vary by manufacturer. Contact your local manufacturer for availability. Capping is not required to guarantee structural stability, capping improves the aesthetics of the finished wall.
Like other Keystone units, all cap units can be used interchangeably. Depending on the wall contour, some cap units will work more effectively than others (i.e. angled side units for concave curves). In any given installation, if binding occurs between units, the units can be modified to fit using a concrete saw, chisel or other device. Make sure to wear proper PPE equipment when splitting or cutting.

Installation of the cap units is a simple one step operation. Sweep the lower units clean and make sure the units are dry; use a construction adhesive (ex. Keystone KapSeal™) on the top surface of the last course before applying cap units (see Figure I:1 on page 19 for installation instructions). The following illustrations demonstrate common uses of the Keystone cap units.
**Capping : Standard & Compac**

The size of each Keystone unit makes this system very adaptable to grade changes. The top of a Keystone wall can be constructed with level top of wall grade or up to 1:1 unit step downs from the top of the wall. These grade changes may occur along the length of a wall or at its points of origin. A cap unit up and down grades, an additional installation procedure is required to firmly fix some cap units in position. To prevent showing the unit voids at the stepping of a wall (Standard or Compac), 4 inch cap units can be double stacked or one 8 inch cap unit may be placed at each step down or step up location (see Figure C:1 on page 14). Each additional cap unit is offset 9 inches (23cm) to maintain the running bond wall pattern. The caps should be attached using a bonding material. Keystone KapSeal™ adhesive is designed for this use with a special formulation to withstand temperature and moisture extremes. If this material is unavailable, other flexible epoxy based adhesives designed to bond concrete or masonry may be used. Refer to manufacturer’s instructions for complete details. Apply the adhesive to areas where the units make contact (see Figure I:1 on page 19 for installation instructions).

**FIGURE X:2 - STRAIGHT WALL WITH DOUBLE-STACKED CAP STEP**

Keystone 3 Plane Face Cap Unit
w/Angled Sides
Double Stacked at Block Step

**FIGURE Y:2 - RANDOM STEPS WITH SPLIT DOUBLE-STACKED UNIVERSAL CAPS**

Keystone Universal Cap Units
Double Stacked at Block Step

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If Keystone cap units are not a desired top of wall treatment, or if concrete coping is required in the project plans, the following details are for a typical CIP coping option. These two concrete coping options are installed with proper form work and add an alternate aesthetically pleasing look to the top of the wall that can follow profile grades with the steps.

**FIGURE Z:2 - PARTIAL CAST IN PLACE CONCRETE COPING**

**NOTE:**
1. Maintain 2" minimum cover on all rebar
2. Full expansion joints shall be placed every 3rd joint and at all wall radius and bend points.
3. Ensure that all top of wall steps are completely covered by overhang of concrete coping (3" min.) (cross section C only)

**FIGURE A:3 - PARTIAL CAST IN PLACE TOP CONCRETE COPING DETAIL**

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www.keystonewalls.com  Keystone Construction Manual  69
Keystone has been the segmental retaining wall design leader for over 25 years. This section covers a variety of the most common wall details and/or issues that may be confronted when constructing a Keystone wall. Some of the details presented in the section have been developed specifically based on industry design standards. Other details have been developed through our years of experience in the segmental retaining wall industry.

Items that are covered in this section:

- Retaining wall drainage
- Water applications
- Barriers
- Fencing
- Parapets
- Steps and stairs
- Terraced and wall applications
- Wall repair
- Tree planting guidelines
- Creative options
Retaining Wall Drainage Options

Poor drainage is a leading cause of retaining wall failures. Hydrostatic pressure can accumulate behind a wall and add an increased load on the wall if drainage provisions are not installed or not adequate for the conditions. The Keystone system has superior drainage features. The techniques below should be considered where the specified drainage issues are present.

1. **Basic drainage/Unit drainage fill**
   Keystone’s mortarless, interlocking system, with a free draining gravel drainage zone and corefill (see “Installation: Step-by-Step” section), allow proper drainage under most circumstances. No weep holes are necessary.

2. **Surface run-off**
   Divert surface drainage at the top of the retaining wall by placing an impermeable soil cap (i.e. clay) or formed swale (i.e. soil or concrete) along the back surface of the Keystone units. This will help direct run-off away from the retaining wall.

3. **Embankment flow**
   When embankment ground water flow behind the wall is likely, place a drainage composite or chimney drain over the cut soil (see product suppliers for recommended coverage and installation instructions or drainage composite). The drainage composite or chimney drain should drain to an outflow pipe (i.e. drain tile) to remove water. Numerous cost-effective products are available to serve this purpose.

4. **Ground water flow**
   The effects of seasonally fluctuating ground water, at the base of the retaining wall, can be offset by placing an outflow pipe (i.e. drain tile) behind the lowest unit, along with a drain behind the reinforced fill.

**FIGURE B:3 - DRAINAGE SWALE**

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**GENERAL NOTES:**

* Rear drainage pipe should be included when:
  - Groundwater or seepage is present in retained soils
  - Springs or seasonal seepage potential is noted in geotechnical report
  - Reinforced soil of lower permeability than retained soils
  - Generally, additional drainage material such as aggregate drains & fabrics and/or drainage composite nets are used in conjunction with rear drainage pipe as directed.
  - When above conditions are not present or groundwater conditions are not a factor, the rear drainage pipe may be omitted or alternately located behind units at the base of the drainage fill.

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Alternate raised drain pipe locations may only be used when:

- Grading at base does not allow gravity outlet of pipe.
- There is no storm sewer system to outlet pipe directly into.

Only used when site geometry requires drain pipe to be raised in order to outlet at face.

*See general notes (p. 72) for drainage requirements.
When considering a water application for the Keystone wall system, the following areas need to be analyzed and designed to maintain structural integrity of the wall under normal, high wave and flooding water conditions:

» Start by analyzing the wall under normal design criteria (i.e. WALL HEIGHT, BASE CONDITIONS, SURCHARGE LOADS, SOILS DATA, REINFORCEMENT REQUIREMENTS, DRAINAGE, ETC…)
» Determine the water level on the wall under normal and adverse conditions.
» Determine flow rate for streams, channels, etc.
» Determine degree of wave action; minor, major or boat wake.
» Determine the potential for flooding and inundation of the wall.

Always contact a professional engineer to assist you in your water application design.

FIGURE D:3 - WATER APPLICATION

COMPAC UNIT - ANN ARBOR, MI

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**FIGURE E:3 - PIPE IN REINFORCED ZONE**

8" Min. Low Permeable Soil

Keystone Cap Unit

Grid Depth

Keystone Compac II Unit

Unit Drainage Fill (3/4" Crushed Rock or Stone)

Finished Grade

Unreinforced Concrete or Crushed Stone Leveling Pad

Redirect Grid Around Pipe as Required

Approximate Limits of Excavation

Retained Soil

4" Perforated PVC Drainage Tile When Site Conditions Require

Foundation Soil

**FIGURE F:3 - TYPICAL PIPE OUTLET**

Concrete Collar (if applicable) Saw Cut Units to Fit Within 1/2" of Pipe

Control Joints as required

Scour Protection as Required Use Rip Rap or Concrete Slab in Outlet Area

8" Min. Low Permeable Soil

Keystone Cap Unit

Keystone Compac II Unit

Concrete Collar if Applicable

Scour Protection as Required

Unreinforced Concrete or Crushed Stone Leveling Pad

Control Joint Cut

Geogrid

Storm Drain Pipe

1" Min. Thickness Concrete Collar if Applicable

Note: For pipes larger than 24", a concrete collar may be cast around pipe for ease of construction and appearance.
Headwall Application

Keystone retaining walls are an economical and effective headwall system for many types of multi-plate arches, precast concrete panel arches, and various types of culverts:

NOTE:
Total width of headwall face must be in full or half width unit increments.

Fascia plate shown is 6" x 4" x 5/16" hot rolled steel angle (galvanized finish) or as specified. Use if desired to conceal rough cut Keystone unit edges for an aesthetic appearance.

Cut Keystone units to conform to arch or box culvert. Grout between block and plate using non-shrink type grout conforming to ASTM C1107. Maximum 3/4 inch gap to be grouted with non-shrink grout.

When building the Keystone wall, backfill in equal lifts on each side of culvert. Measure for exact course height and unit running bond pattern on each side of arch or box culvert so they meet correctly at top of culvert.

Pipe Zone Separation Notes:
1. Drainage aggregate fill in the pipe zone is 3/8 inch to 3/4 inch crushed stone.
2. Geotextile must be selected so it is not blinded by the pipe backfill material.

FIGURE 6.3 - TYPICAL DRAINAGE STRUCTURE

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Barriers: Introduction

Keystone walls can readily be installed with many various types of barrier systems. There are two main types of barriers that can be installed at the top of Keystone wall systems: vehicular barrier devices, and pedestrian fall protection devices.

Vehicular barrier devices typically fall into two categories, flexible and rigid. Flexible barriers are the most common traffic impact barrier device due to the simplicity of installation and the fact that they are typically more cost effective than a rigid option.

When a flexible barrier is not an option, due to insufficient room to install a guardrail at the top of a wall, often times a rigid cast in place (CIP) concrete traffic barrier is the next best solution. CIP concrete traffic barriers are most commonly used in DOT applications, but can also be specified in private application roadways with heavy traffic areas. CIP concrete traffic barriers can vary greatly by the application type, location, or design codes. Refer to the engineered design for specific design criteria.

Pedestrian fall protection devices come in various forms such as, railings, fences or parapets. Most public design codes require some form of fall protection when a retaining wall reaches a specified height. Please contact your local building officials for code requirements in your area to determine if and when a fall protection device is required for your retaining wall. Keystone recommends fall protection be installed for all walls over 3 feet in height.
When installing a guardrail with a Keystone wall, there are three important guidelines that must be met as mandated by The American Association of State Highway Transportation Officials (AASHTO).

1. The guardrail must be located a minimum of 3 feet from a wall face.
2. The guardrail post shall be augered or driven a minimum 5 feet into the ground.
3. The guardrail needs to pass through a minimum of 2 geogrid layers.

There are a number of installation methods for a guardrail with a Keystone wall. Always reference the project engineered drawings for the preferred installation method.

1. Sonotubes can be installed during wall construction for the guardrail foundation posts.
2. Wooden posts can be augered into the ground after wall construction.
3. Steel posts can be driven into the ground after wall construction.
Barriers: Cast in Place Concrete Traffic Barrier

Keystone walls can readily be capped with a reinforced CIP concrete traffic barrier. The following details are provided for reference as a typical "Jersey Barrier." Always follow the project plan details for installation details.

1. Install the Keystone wall per project installation instructions or as outlined in this manual.
2. Set and secure forming materials along the top course of the Keystone wall using standard forming procedures. Pour and finish traffic barrier as by the project engineered design. Insert control joints at a maximum 10 feet on center along the length of the barrier, or as specified by engineer.

**FIGURE I:3 - PARTIAL CAST IN PLACE TRAFFIC BARRIER**

**NOTE:**
1. If short CIP barrier sections are to be constructed adjacent to precast barrier sections, then this section's dimensions shall be adjusted to conform to the precast dimensions.
2. Elevations shown are at the labeled gutter point.

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**Figure J:3 - Partial Cast in Place Reinforced Traffic Barrier**

1. All longitudinal bars are #4 as shown.
2. Concrete cover 2 inch (Typ.)

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**Critical Information**

- **Keystone Construction Manual**
- **www.keystonewalls.com**

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**Specialty - Traffic Barriers**
Barriers: Fencing Options

Fences can be placed at the top of a Keystone wall with fence posts placed behind the Keystone units. The choice, location, and compliance to local codes of the appropriate fall protection system, is the responsibility of the owner and site engineer. Follow these procedures for proper installation of fence posts with Keystone walls.

1. Install the Keystone wall per general installation instructions.
2. Fence posts positioned behind the Keystone units may be installed and anchored using a variety of installation methods.
3. These details can also be used for Keystone Standard units.

**FIGURE K.3 - TYPICAL FENCE POST OFFSET**

- Backfill or Concrete Post in Place
- Steel Fence or Railing
- Keystone 8" Block Unit
- Backfill or Concrete Post in Place
- Geogrid
- Keystone 4" Cap Unit
- Keystone 8" Block Unit

**FIGURE L.3 - INTEGRATED SIDEWALK & FENCE**

- Place Post in Center of Thickened Edge (1.5'1)
- Steel Fence or Railing
- Expansion Material
- Concrete Walk
- Keystone 4" Cap Unit
- Keystone 8" Block Unit
- Geogrid
FIGURE M3 - MINIMUM FENCE OFFSET

NOTE:
Concrete filled tube to be set during the wall construction, not cut through geogrid afterwards when directly behind units.

Concrete Filled Tube or Form 8" o.c. Max.
Steel Fence or Railing
Keystone 8" Block Unit
Concrete Filled Tube or Form 8" o.c. Max.

Keystone 4" Cap Unit
Keystone 8" Block Unit
Geogrid

STANDARD UNIT - MINNETRISTA, MN
Keystone Standard units are always recommended in situations where railings are considered for direct mounting on the wall system. It is difficult for a railing design to satisfy structural design requirements when considering the direct mounting on, or into, the Keystone modular wall system. The small unit size and mass provides minimal resistance to overturning by itself so a number of units must be engaged to provide the required resistance. The Keystone Standard unit is typically large enough to satisfy a 20 plf or 200lb post minimum IBC loading, provided that the post is grouted into the upper three courses as shown below. Shear resistance of Standard units (>1000plf) exceeds the driving forces (20plf) by a wide margin in a gravity wall application and is not critical evaluation. Railing shall not exceed maximum height of 42 inches above the units.

**Figure N:3 - Direct Mount Railing in Standard Unit Wall - Near Vertical**

![Diagram](image)

**Figure O:3 - Direct Mount Railing in Standard Unit Wall - 1" Setback**

![Diagram](image)
Special Fence Installation: Standard Unit Only

**FIGURE P.3 - ROUND POST**
(post size shall not exceed 3” diameter)

- Metal Fence Shown
- Keystone 4” Cap Unit
- Keystone Standard Unit
- Non Shrink Grout Post in Place (Typ.)
- Optional Post Sleeve if Required

**FIGURE Q.3 - SQUARE POST**
(post size embedded in units shall not exceed 3” x 3”)

- Open Face Wood Fence Shown
- Keystone 4” Cap Unit
- Keystone Standard Unit
- Non Shrink Grout Post in Place (Typ.)

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Keystone walls can easily be constructed to incorporate CIP concrete stairs within the wall systems. The stairways can be designed to be incorporated into reinforced soil of the wall (see Figure V:3), or project out from the wall face (see Figure Y:3). Construct the Keystone wall as per design. Where a stairway is proposed, create a 90° outside corner with Keystone straight face and corner units. Construct the CIP concrete stairs as the project plans, making sure the include a ½ inch expansion joint between the stairs and the Keystone units.

**NOTE:**
International Building Code (IBC) indicates that stair facilities shall have a minimum riser height of 4 inches and a maximum height of 7 ¼ inches. Keystone Compac and Standard units are 8 inches high, therefore will not meet IBC code for stair riser use.
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### FIGURE W:3 - STAIR IN WALL DETAIL PLAN VIEWS

**NOTE:**

- Use Compac straight face units in return walls along concrete stair for ease of stair installation and for placement of bond breaker material between stair and wall.
- Tread depths and riser heights may vary depending on design and or local codes.
- Install hand railing as per local codes.

### FIGURE X:3 - STAIR IN WALL DETAIL ELEVATION

- Unreinforced Concrete or Crushed Stone Wall Leveling Pad
- Unit Drainage Fill (3/4" Crushed Rock or Stone
- Reinforced Backfill Soil
- Keystone 4" Universal Cap Unit
- Keystone 8" Straight Face Unit
- Geogrid Reinforcement as per Wall Design

Concrete Stairs by Others

Lancing Surface Material by Others

Face of Proposed Keystone Wall

Finished Grade

Keystone 4" Universal Cap Unit

Unreinforced Concrete or Crushed Stone Wall Leveling Pad

Keystone 8" Solid Corner Straight Face Unit

Finished Grade (Below)

Keystone 8" Solid Corner Straight Face Unit

Concrete Stairs by Others

Wall Height (Varies)

Unreinforced Concrete or Crushed Stone Wall Leveling Pad

Wall Embodiment (Varies)

A

A
NOTE:
Place bond breaker material between Keystone units and concrete stair. Stair designs may vary. Tread depths and riser heights may vary depending on design and or local codes. Install hand railing as per local codes.
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A n area of design that affects many site applications is the use of terraced walls. The upper terrace wall can put pressure on the lower terrace if the walls are too close together. Multiple terrace walls in close proximity to each other, can have structural stability issues related to the lower walls not having the capacity to carry the loads developed by the upper walls. Always consult with a qualified professional for assistance with terraced walls.
Terrace Wall Application

COMPAC UNIT - CHILLIWACK, BRITISH COLUMBIA

COMPAC UNIT - BLUFFDALE, UT
**Wall Repair**

**PROBLEM:** Damaged or cracked unit in wall.

**SOLUTION:** For minor cracks, fill opening with construction epoxy and dust lightly with concrete material of similar color. Use a ground up piece from another Keystone unit.

For low height walls, dismantle units down to broken unit(s), replace with new unit(s). Rebuild wall placing corefill and backfill with necessary light compaction until capping of wall as shown in above detail.

For taller walls or where it is not practical to dismantle the wall, follow steps shown in the details below. (see Figure D:4)

**FIGURE C:4 - REPLACE CRACKED UNIT**

Remove Keystone Units Down to Broken Unit and Replace Broken Unit with New Unit Then Reinstall Removed Wall Units

Cracked Unit in Wall Face, Remove and Replace with New Unit

**FIGURE D:4 - REPLACE UNIT FACE ONLY - FOR TALLER WALLS**

Keystone 4" Cap Unit

Keystone 8" Compac II Unit Shown

Remove Face of Damaged Unit and Replace with a Face Section from a New Standard or Compac Unit

**NOTES:**
Solution allows wall to remain intact. Wall structure with geogrid soil reinforcement is not interrupted.

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NOTES:

All planting offsets shall be a minimum of 2 feet + the opening diameter as measured from face of wall.

Lateral spacing between openings shall be a minimum of 3 x opening diameter.

Only top two layers of geogrid may be cut to allow planting of tree ball. Avoid disturbance of adjacent reinforcement.

If trees are spaced closely together and cutting of geogrid becomes excessive, consult with your Keystone representative.

Extreme care shall be taken if installing irrigation systems directly behind the wall so as to not damage the soil reinforcement during installation or have potential leakage into the retaining wall system. Leaking irrigation lines can saturate the backfill and create hydrostatic pressure and wall movement.

Utilize a root control barrier as required to avoid root pressures or growth through the Keystone concrete units.

Numbers in parenthesis are for example only.
Creative Options

A dd distinctive detail to any Keystone retaining wall. For subtle design accents vary the texture of units in geometric patterns while maintaining the Keystone unit color choice. Texture combinations can be sculptured rockface mixed with straight split units, smooth face units or corduroy units. Dramatic accents can occur when combining units of complimentary and or contrasting color schemes. Consult your local manufacturer/distributor for standard colors, custom color availability, pricing and unit texture options available by region.

Addiitional options:
» Mixture of units of different heights. (i.e. 8 inch (200mm) & 4 inch (100mm) combinations)
» Specific graphic emblem. (i.e. State shape logo - Texas, Illinois, etc...)
» Various bonds (Flemish), diagonal bars, geometric repeats, horizontal bands, stair step bands, etc...

Use these features to coordinate the site landscape retaining walls with accents on building architecture (i.e. belt courses, bands and geometric details).
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Creative Options

BANDING

COMPAC UNIT - KELOWNA, BRITISH COLUMBIA

FLEMISH BOND

COMPAC UNIT - LITTLETON, CO

BANDING

COMPAC UNIT - INDIANAPOLIS, IN

GRAPHIC EMBLEM

COMPAC UNIT - EGYPT

GEOMETRIC PATTERN

COMPAC UNIT - EGYPT

GRAPHIC EMBLEM

COMPAC UNIT - HOUSTON, TX
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