

SECTION E

SPECIALTY WALL CONSTRUCTION DETAILS

Since its inception in 1986, Keystone has been the segmental retaining wall design leader. This section covers a variety of the most common wall details 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 performance issues. 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 the figure below, notes 1 and 4. This will allow proper drainage under most circumstances. Drain tiles should be routed to a storm drainage system or daylighted below or through the wall at every low point and at 50 to 75 feet (15.2 - 22.9m) on center.

2. Surface run-off

Divert surface drainage at the top of the retaining wall by placing a 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

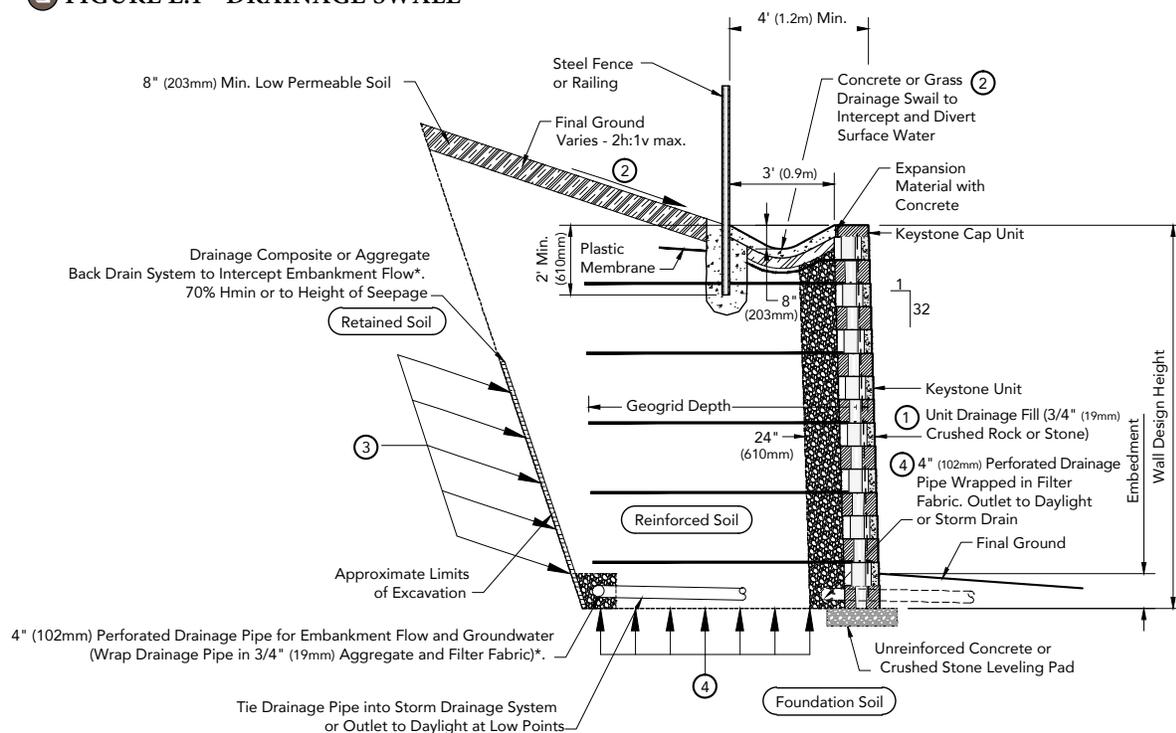
The effects of seasonally fluctuating ground water, at the base of the retaining wall, can be offset by placing an outflow pipe (i.e. drain tile) behind the lowest unit, along with a drain behind the reinforced fill.

GENERAL NOTES:

Rear drainage pipe should be included when:

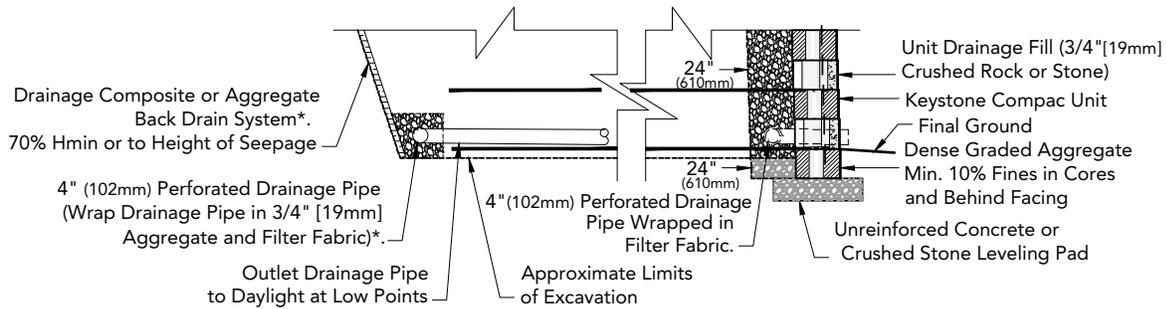
- » Groundwater or seepage is present in retained soils.
- » Springs or seasonal seepage potential is noted in geotechnical report.
- » Reinforced soil of lower permeability than retained soils.
- » Generally, additional drainage material such as aggregate drains and fabrics and/or drainage composite 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.

FIGURE E:1 - DRAINAGE SWALE



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FIGURE E:2 - ALTERNATE RAISED DRAINAGE PIPE LOCATIONS



NOTE:

Alternate raised drain pipe locations may only be used when:

- » The grade in front of the wall is flat and does not allow for gravity outlet of a pipe below the wall or through the base course of block.
- » 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. 62) for drainage requirements.



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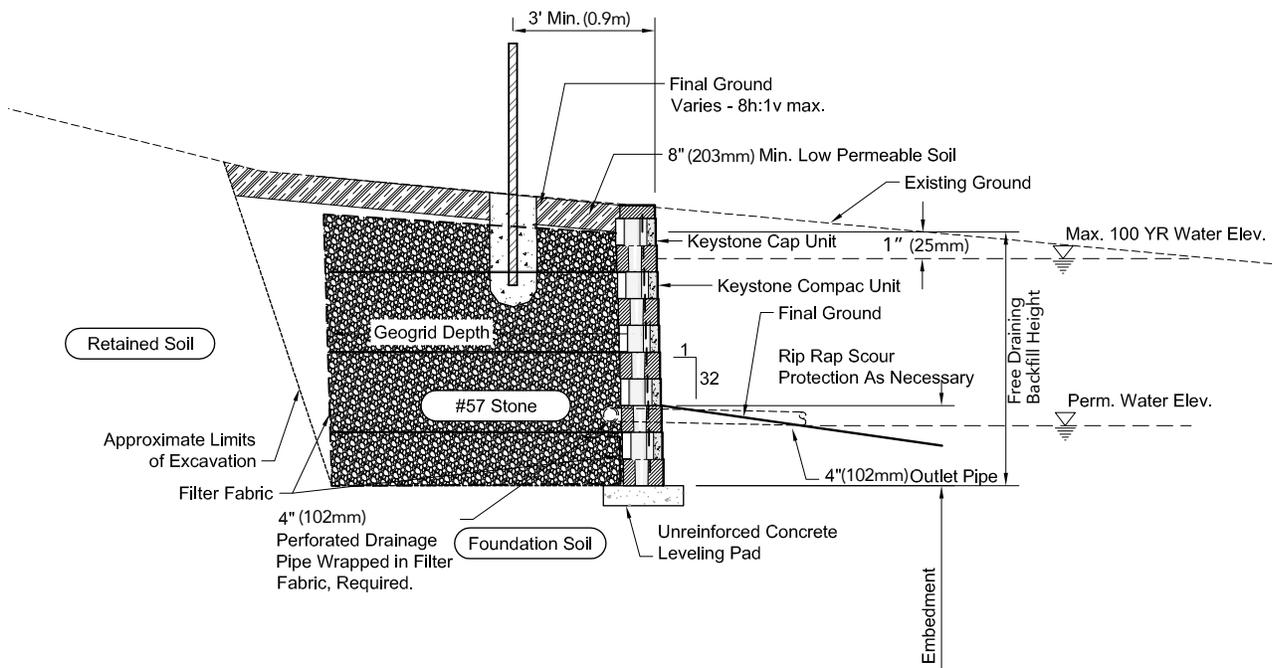
Water Applications

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.
- » The above conditions should be taken into account in the design of the wall.

Always contact a professional engineer to assist you in your water application design. At minimum, the wall reinforced zone soils, to 1'(305mm) above the high water elevation, should be a free draining sand or gravel, wrapped in an appropriate filter fabric.

FIGURE E:3 - WATER APPLICATION

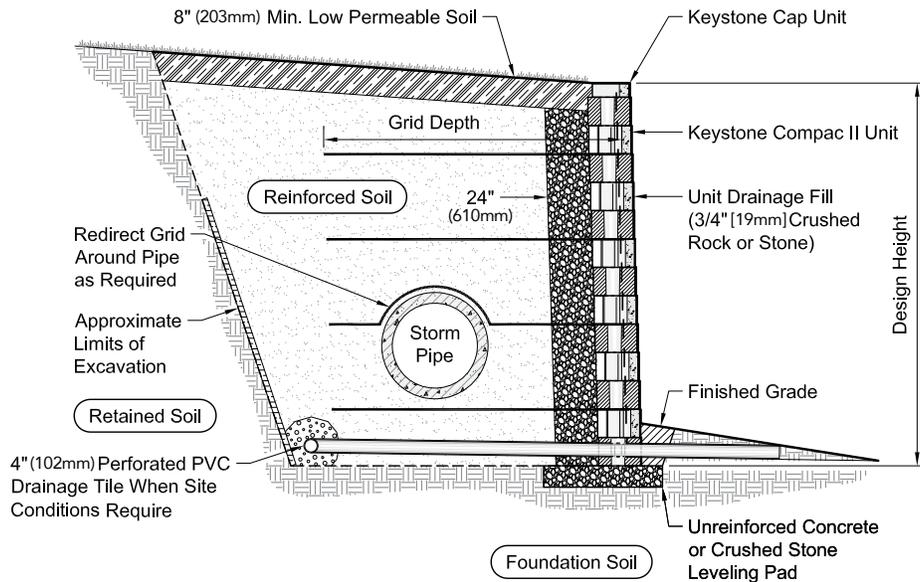


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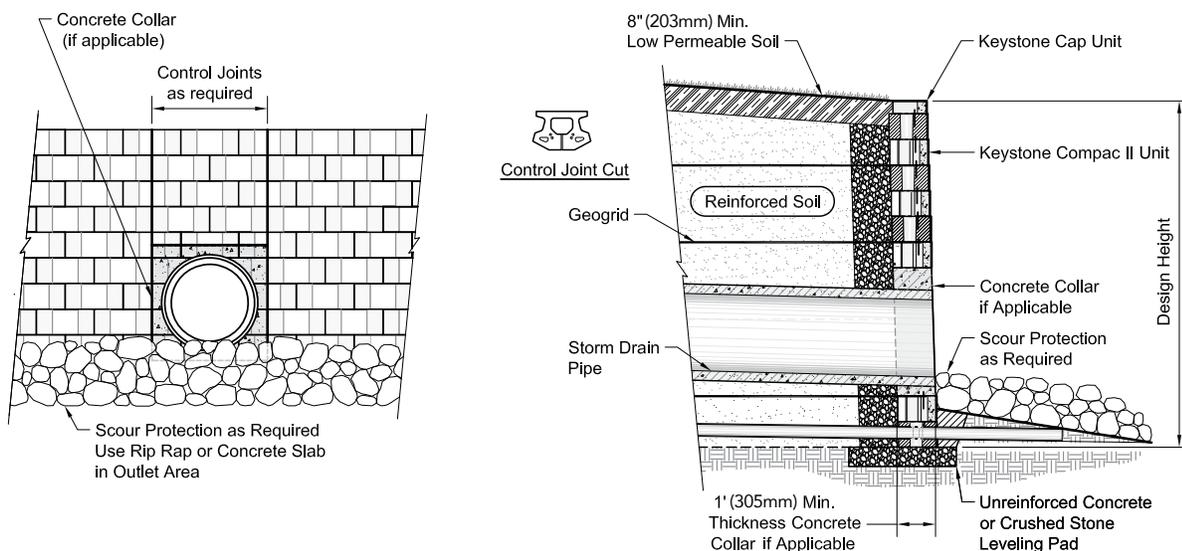
In general the placement of storm drains, parallel to the wall, within the reinforced soil zone, should be avoided. Any maintenance to the storm system, other than a reline, will require deconstruction of the wall down to the pipe elevation so fully intact geogrid can be re-installed during backfilling. Also, coordination of the utility and wall contractors will be necessary during initial construction of the wall to avoid excavation through the geogrid, after wall construction, to place the storm drain.

FIGURE E:4 - PIPE IN REINFORCED ZONE



The placement of storm drains perpendicular to the wall and outletting through the wall face are common. Since it is not possible to cut the block in a curve to fit tightly around the pipe, it is recommended that a cast in place collar be built around the pipe. The wall units can then be cut to the appropriate length and butted closely to the sides of the collar. Care should be taken to position the top of the collar within 1/2" to 1" (13mm to 25mm) below the horizontal joint of the block above. This action will allow placement of the next course of units onto a wet set mortar bed to achieve horizontal wall alignment.

FIGURE E:5 - TYPICAL PIPE OUTLET



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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" (152 x 102 x 8mm) 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 (19mm) 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 (10 - 19mm) crushed stone.
2. Geotextile filter fabric should be placed along the arch and then extend behind the units. See Figure E:7.

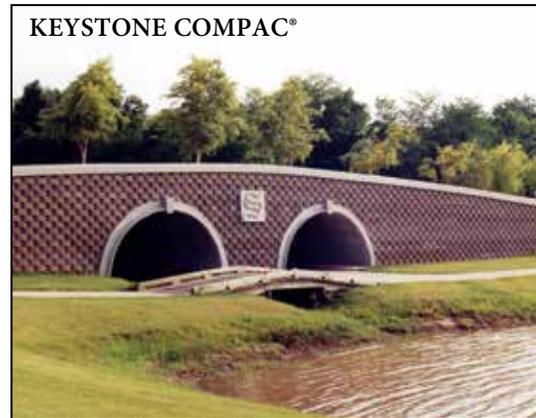
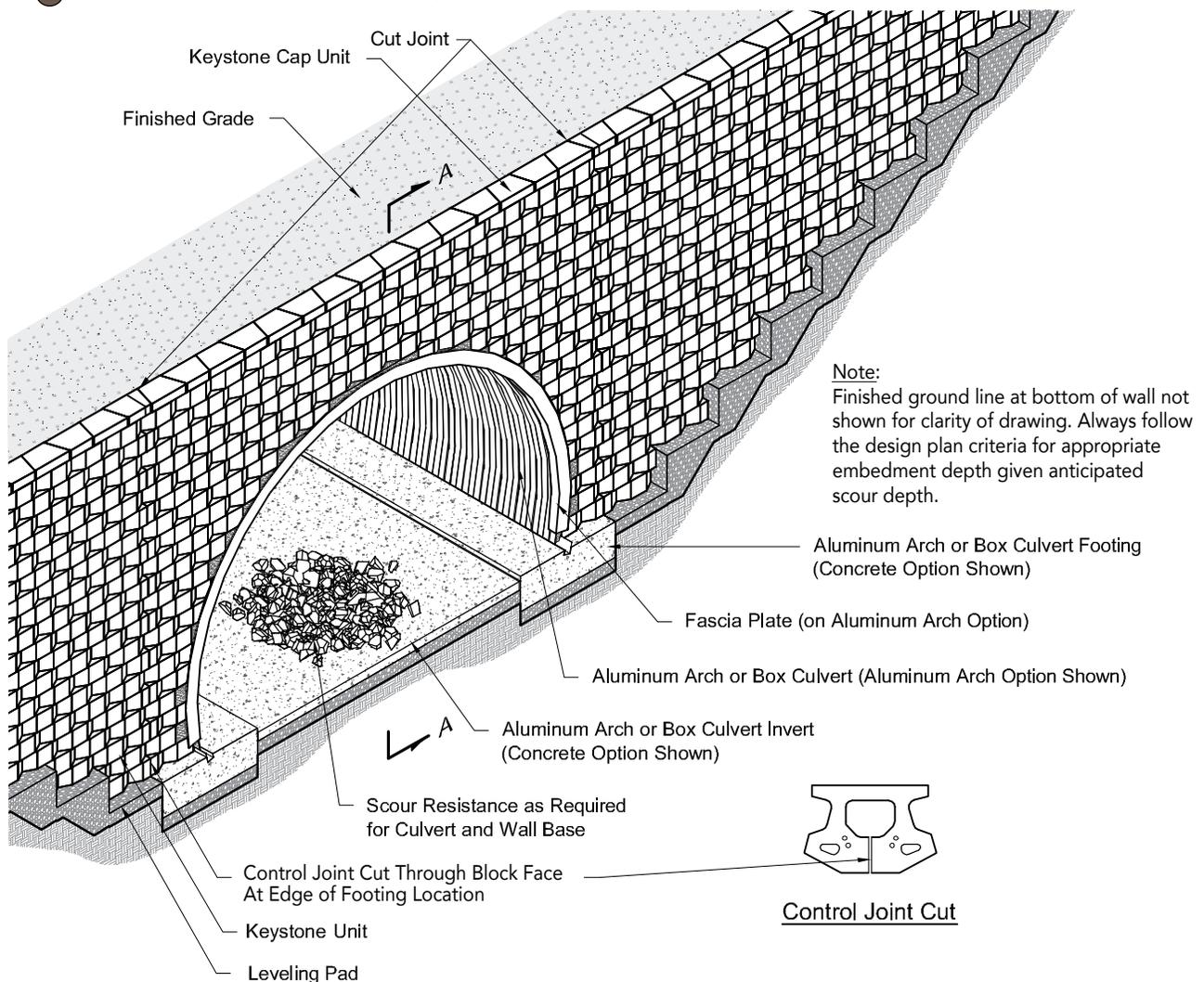
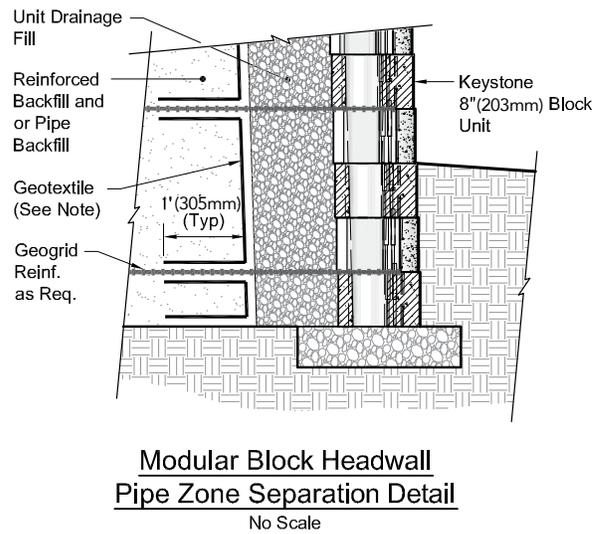
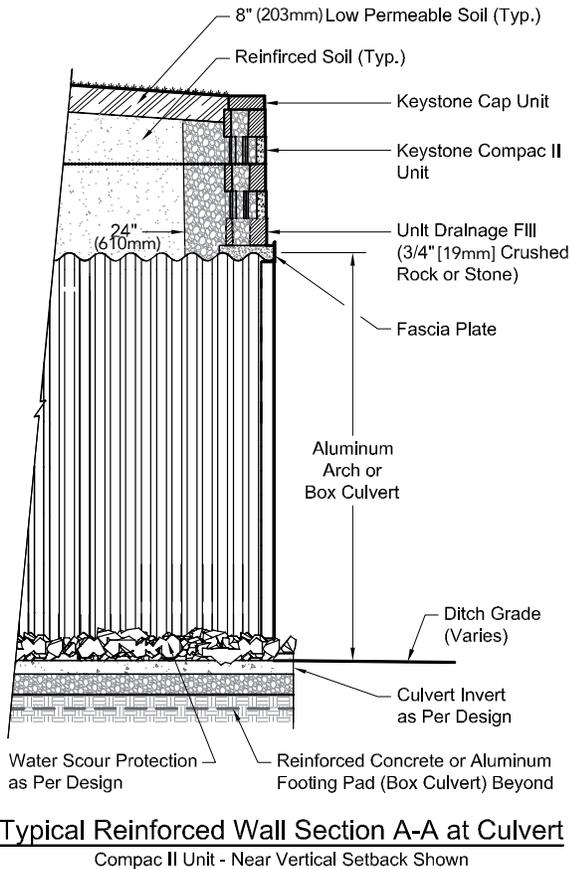
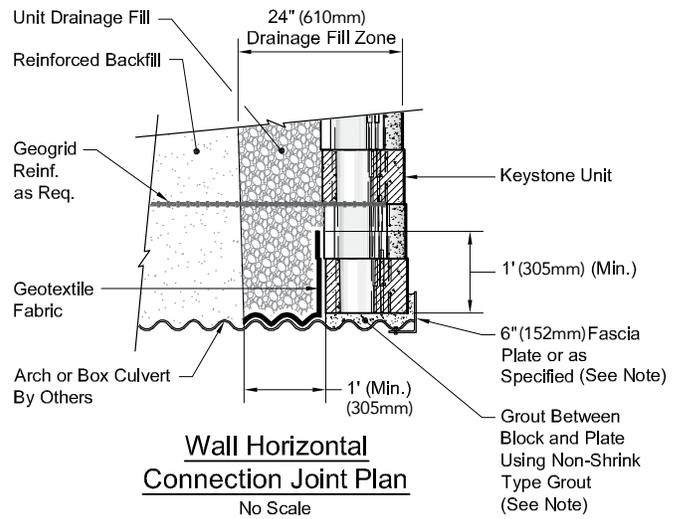
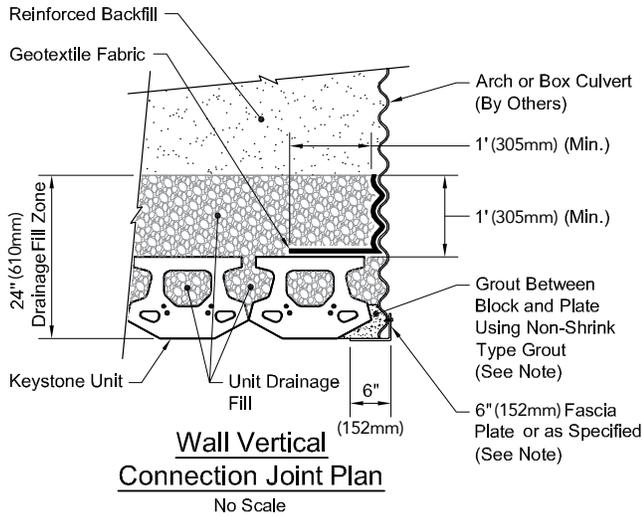


FIGURE E:6 - TYPICAL DRAINAGE STRUCTURE



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FIGURE E:7 - TYPICAL DRAINAGE STRUCTURE DETAILS



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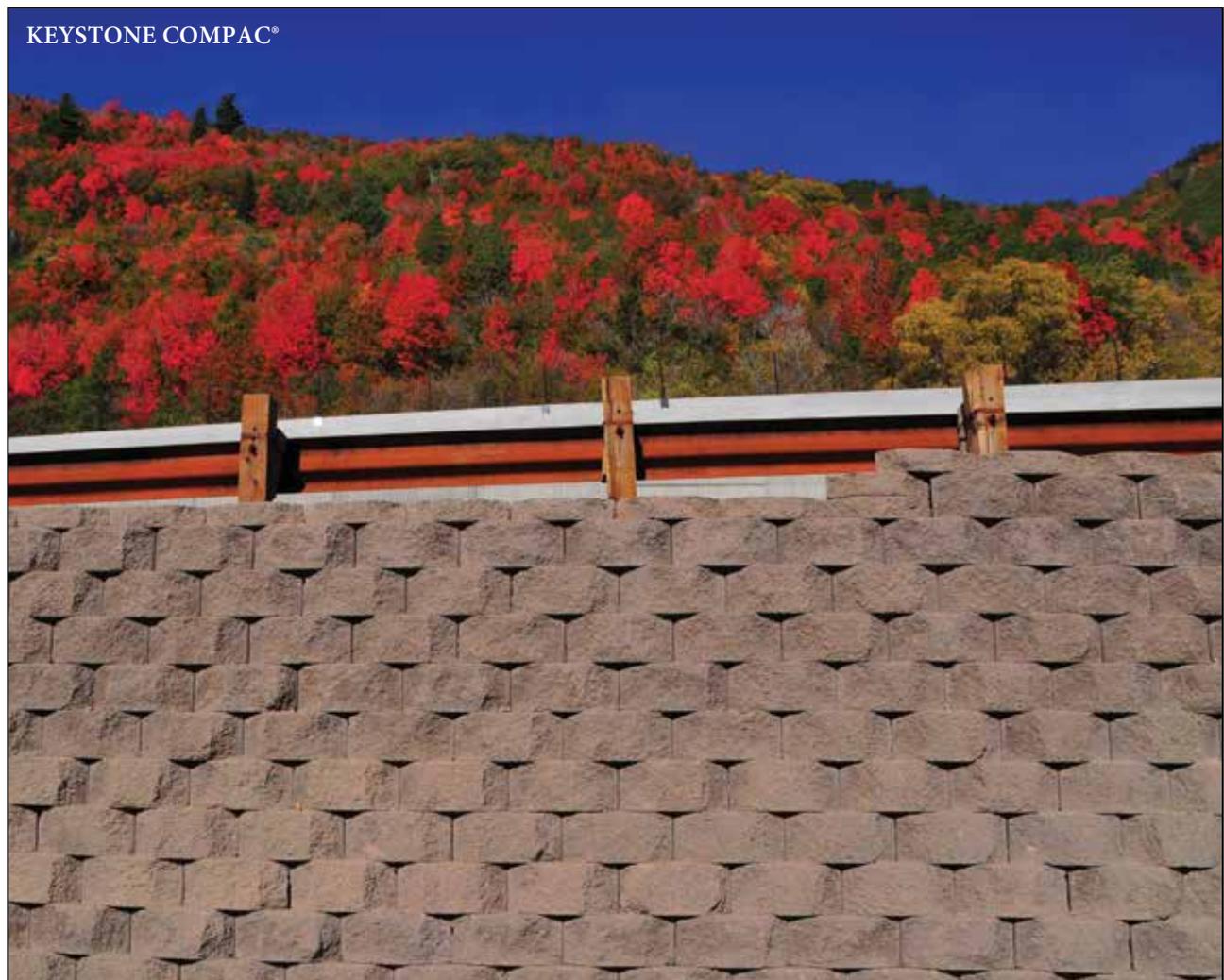
Barriers: Introduction

Keystone walls can readily be installed with many types of barrier systems. There are two main types of barriers: pedestrian fall protection devices and vehicular impact barriers.

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 (0.9m) in height.

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, typically 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 state DOT agencies for specific details related to traffic barriers and MSE walls.



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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).

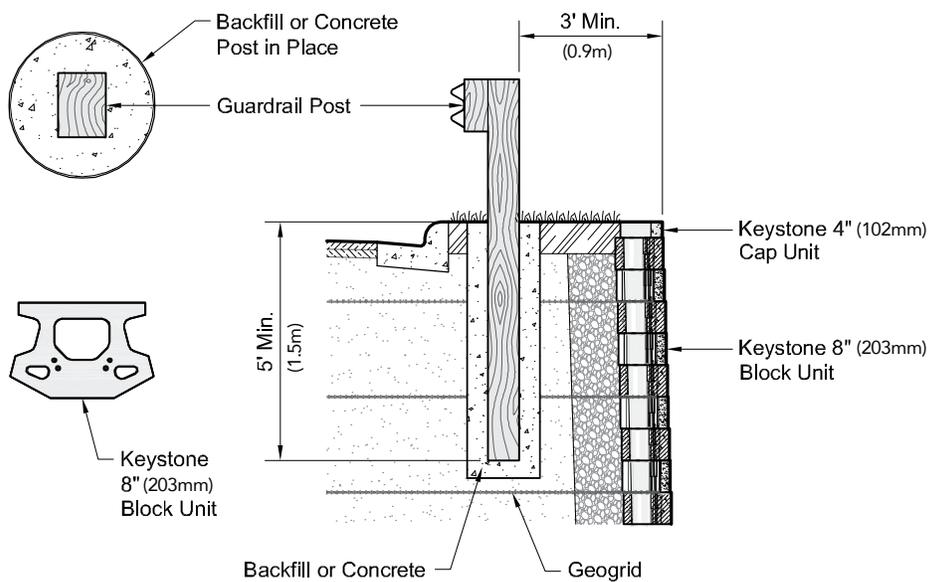
1. The guardrail must be located a minimum of 3 feet (0.9m) from a wall face.
2. The guardrail post shall be placed a minimum 5 feet (1.5m) into the ground.
3. The guardrail shall extend through a minimum of 2 geogrid layers.

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. Sleeves can be installed during wall construction for the guardrail foundation posts.
2. Wooden posts can be augered into the ground after wall construction (installing sleeves during wall construction is the preferred method).
3. Steel posts can be driven into the ground after wall construction.



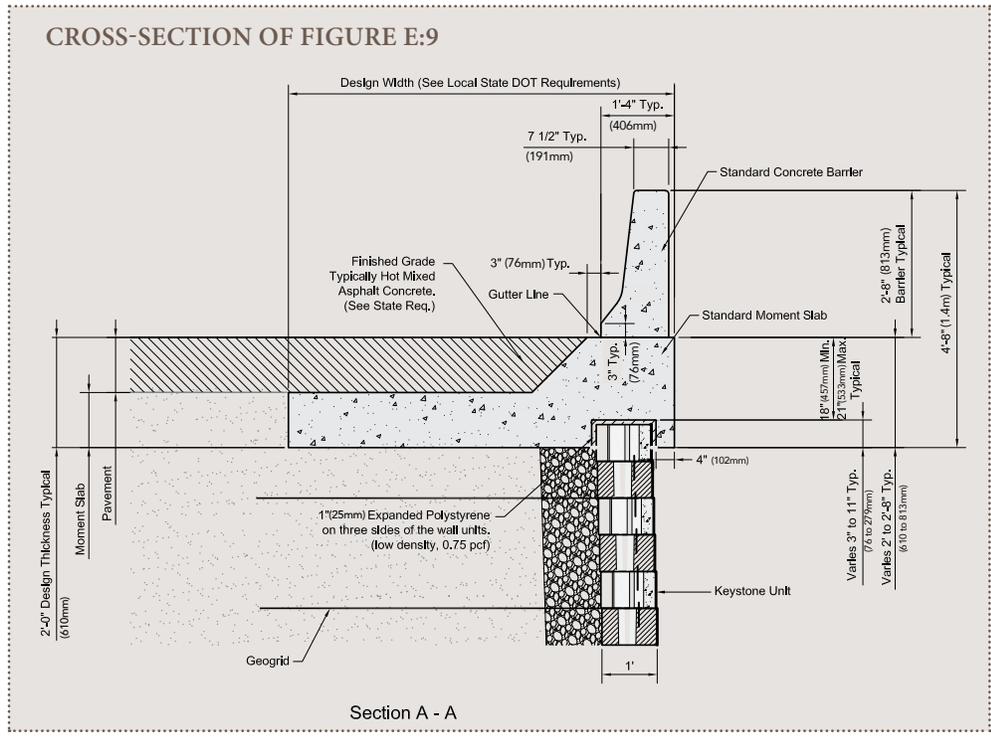
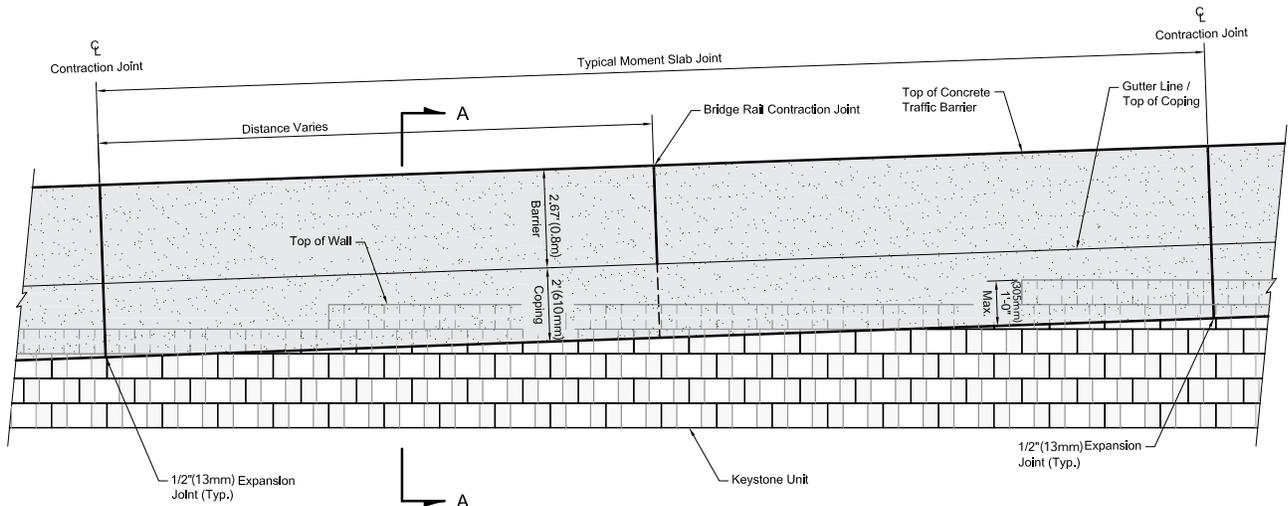
FIGURE E:8 - TYPICAL GUARDRAIL CROSS SECTION



Barriers: Cast in Place Concrete Traffic Barrier

Concrete traffic barrier systems on MSE walls are most commonly used in highway applications. These barrier systems consist of a traffic barrier placed on a continuous footing or structural slab (moment slab). In recent years, the MSE wall industry has seen considerable advances in research and development, better understanding the complex nature of the distribution of loads from the barrier through the wall systems. As a result of these new studies and developments, individual state agencies have begun to develop and design specific barriers and moment slabs to meet their local conditions and design codes. Subsequently, there is no longer a “one size fits all” approach to traffic barrier systems but, instead, more of a general design basis which each state utilizes to develop details. The details found in this section are intended to show the basic concept of an interaction between a Keystone MSE wall and a barrier. For more in-depth details, please visit or contact your state DOT agency.

FIGURE E:9 - PARTIAL CAST IN PLACE TRAFFIC BARRIER

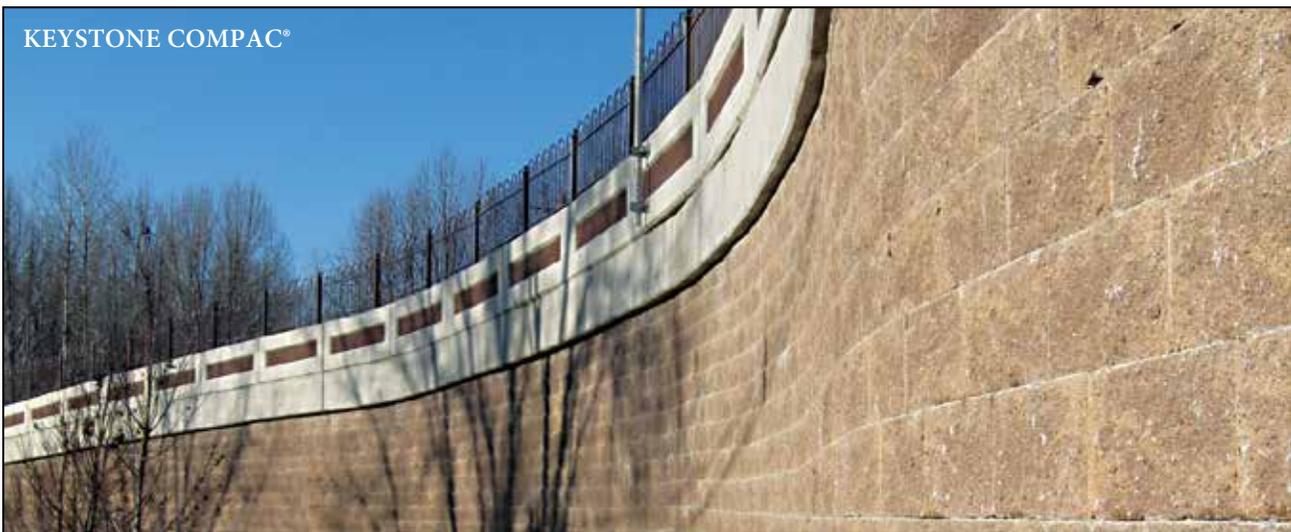


NOTES:

1. Concrete moment slab and barrier are shown for general concept purposes only. Reinforcing steel not included as part of these drawings. Contact your local State DOT for state-specific barrier details.
2. Provide materials and perform all work in accordance with current State Standard Specifications for construction.
3. Dimensions provided for reference only. See State DOT details for specific dimensions.

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Barriers: Cast in Place Concrete Traffic Barrier



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 with 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 E:10 - TYPICAL FENCE POST OFFSET

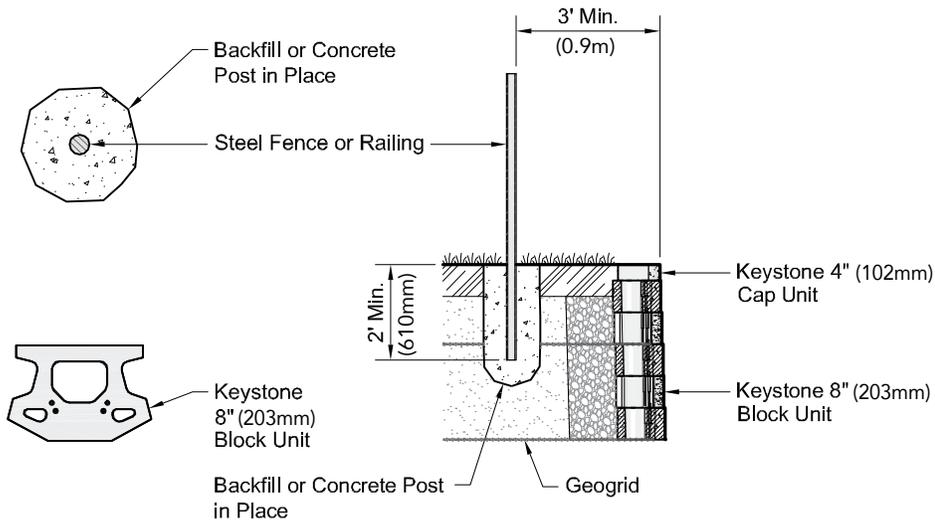
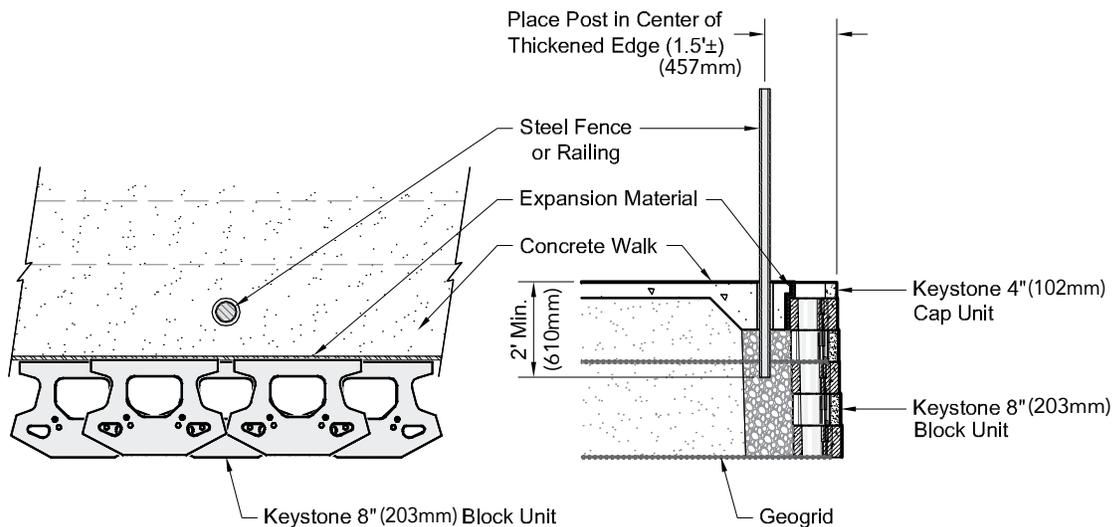
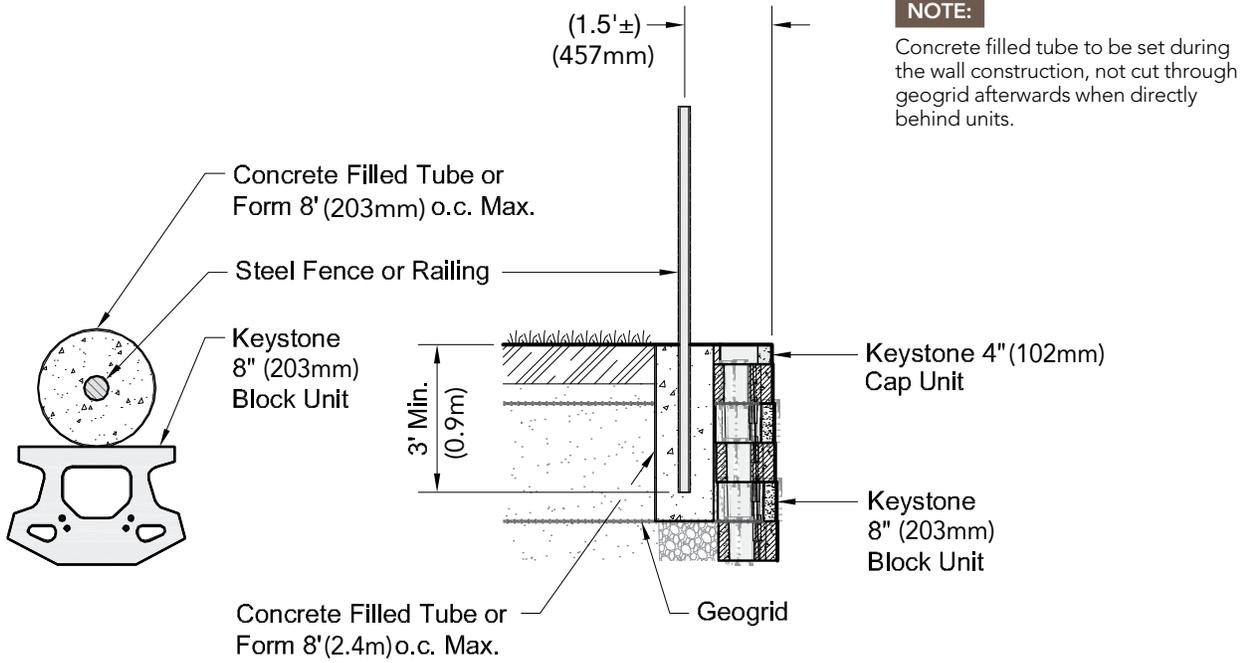


FIGURE E:11 - INTEGRATED SIDEWALK & FENCE



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FIGURE E:12 - MINIMUM FENCE OFFSET



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Barriers: Special Fence Installation - Standard Unit Only

Keystone Standard units are always recommended in situations where railings are considered for direct mounting on the wall system. The Keystone Standard unit is typically large enough to satisfy a 20plf or 200lbs (91kg) 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 a critical evaluation. Railing shall not exceed maximum height of 42 inches (1.1m) above the units.

FIGURE E:13 - DIRECT MOUNT RAILING IN STANDARD UNIT WALL - NEAR VERTICAL

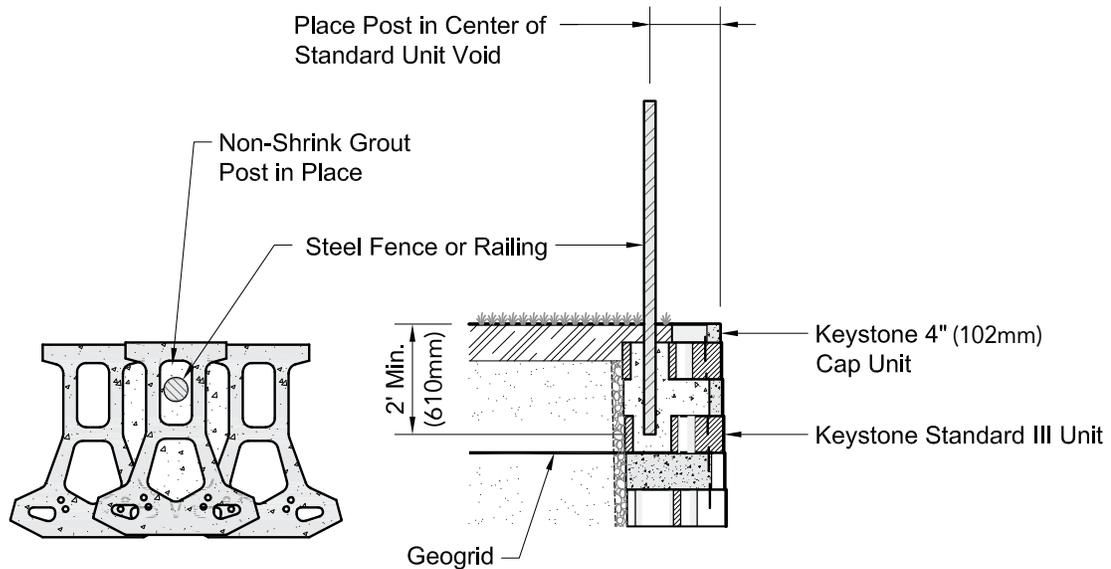
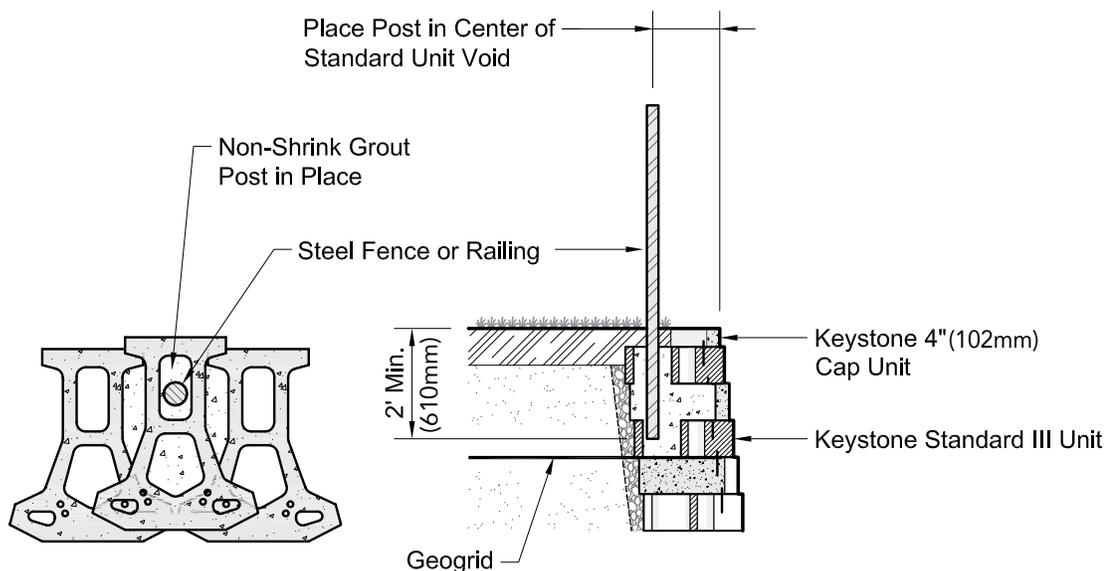


FIGURE E:14 - DIRECT MOUNT RAILING IN STANDARD UNIT WALL - 1" SETBACK



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Barriers: Special Fence Installation - Standard Unit Only

FIGURE E:15 - ROUND POST
(post size shall not exceed 3" [76mm] diameter)

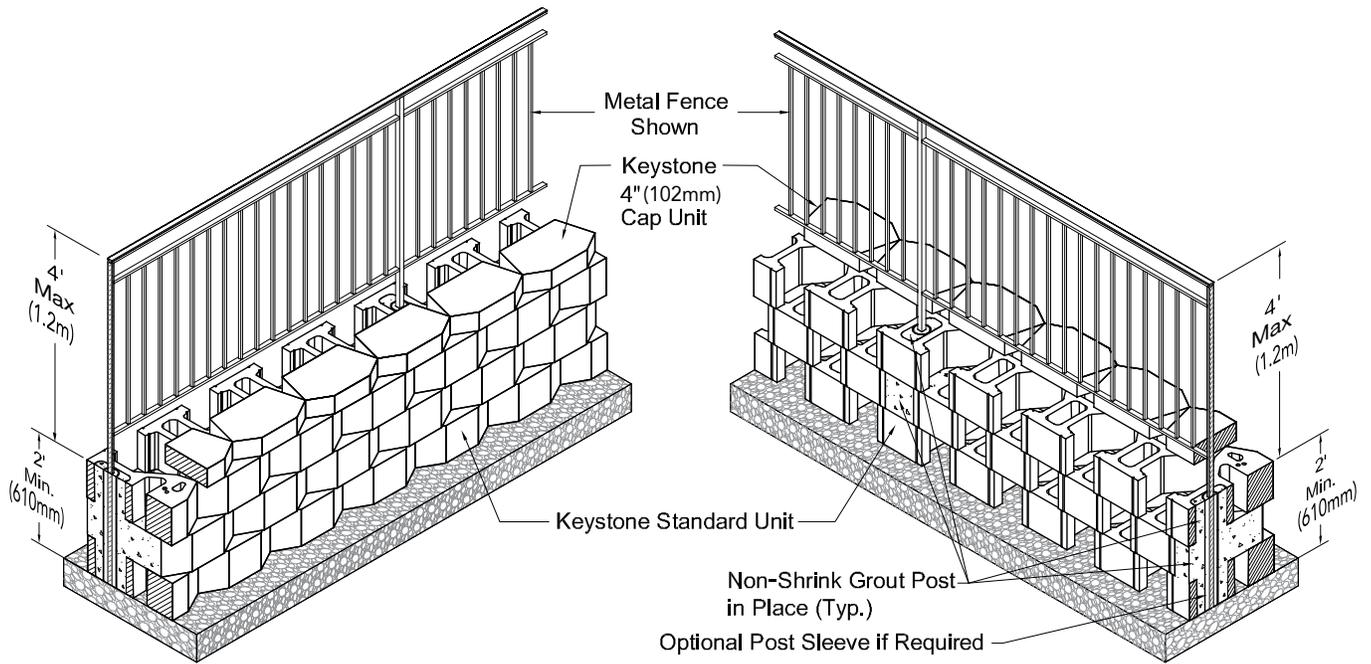
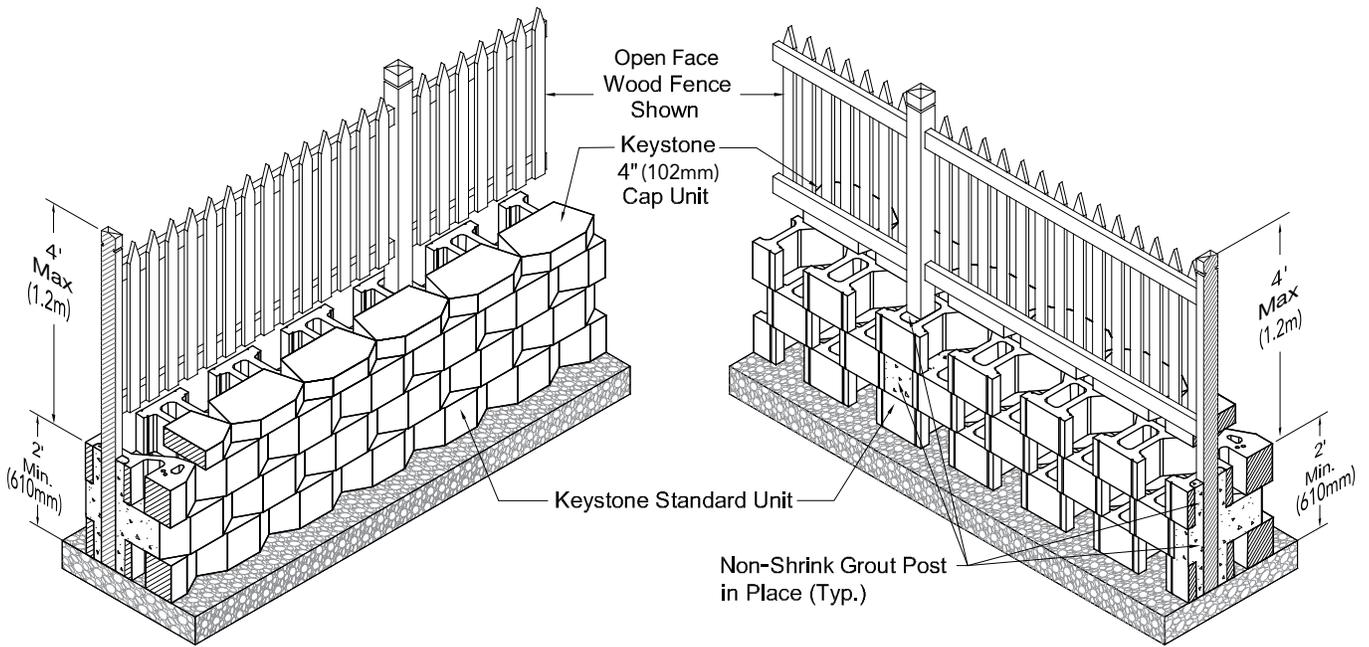


FIGURE E:16 - SQUARE POST
(post size embedded in units shall not exceed 3" x 3" [76mm x 76mm])



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Barriers: Parapet

Back-to-back parapet walls are sometimes placed above a Keystone wall. Figures E:17 to E:20 illustrate the concept of parapet wall layout and design. Care should be taken to properly compact the wall backfill and the 24" (610mm) drainage column behind the wall to minimize settlement and tilting of the parapet.

FIGURE E:17 - TYPICAL PARAPET COURSE PLANS

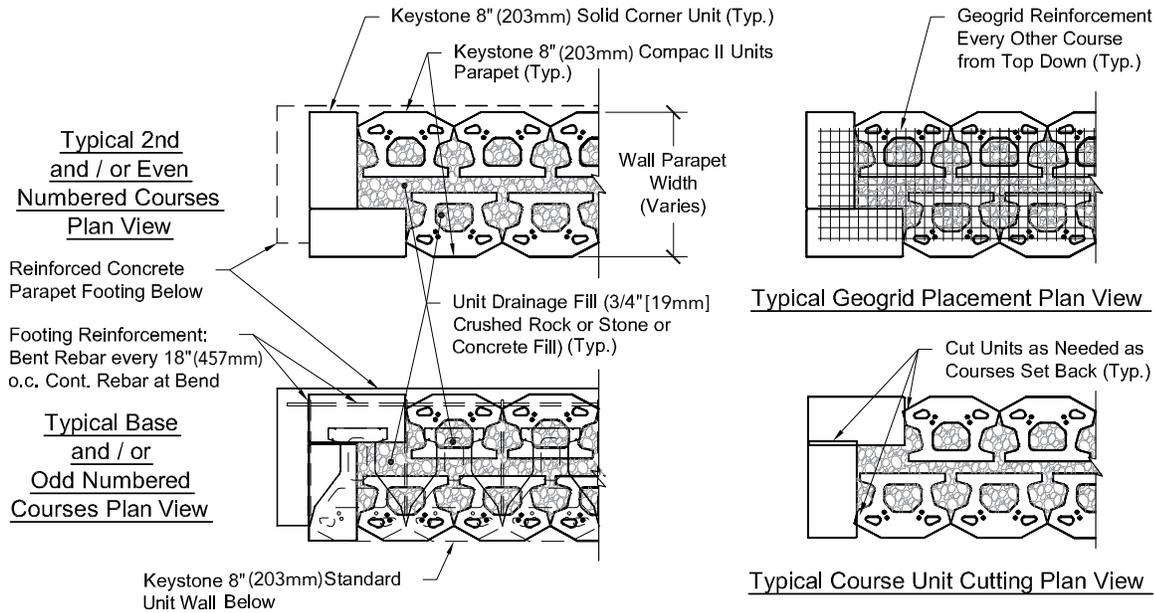
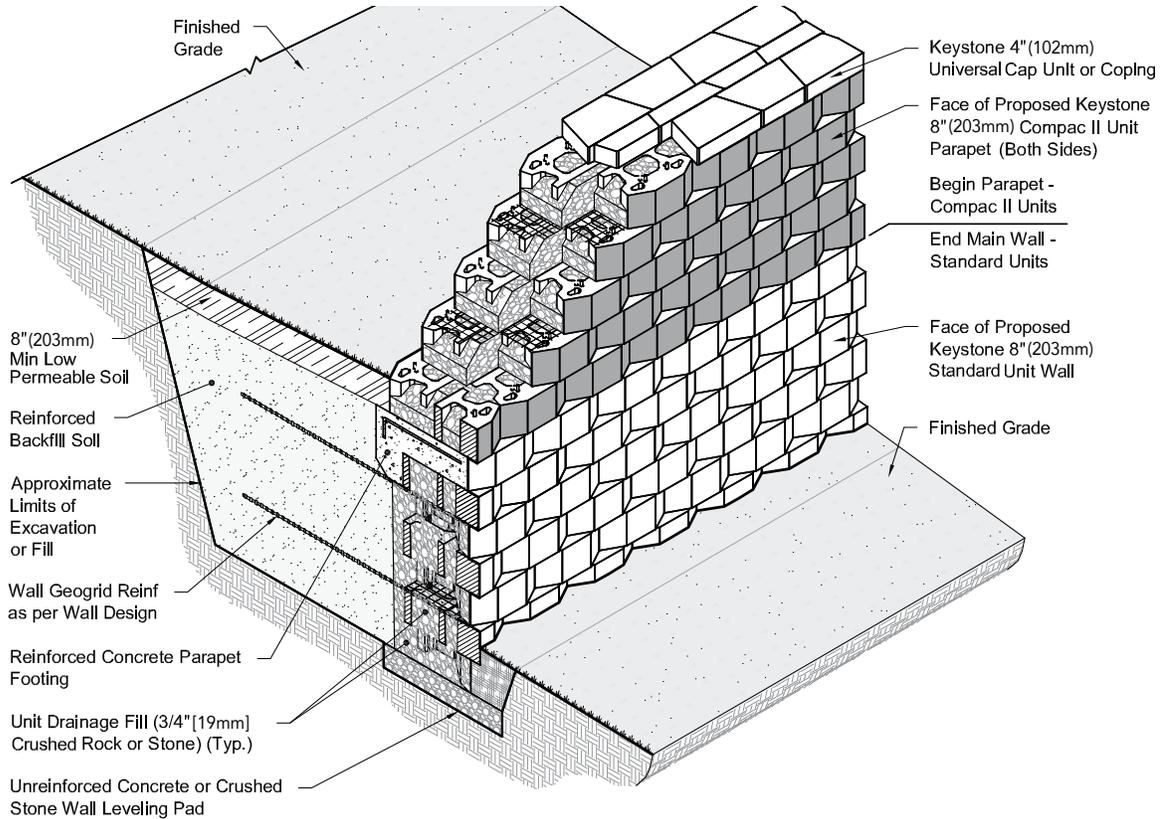


FIGURE E:18 - WALL/PARAPET SECTION VIEW (STANDARD & COMPAC UNITS)



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FIGURE E:19 - WALL/PARAPET CAPPING & END SECTION VIEW (STANDARD & COMPAC UNITS)

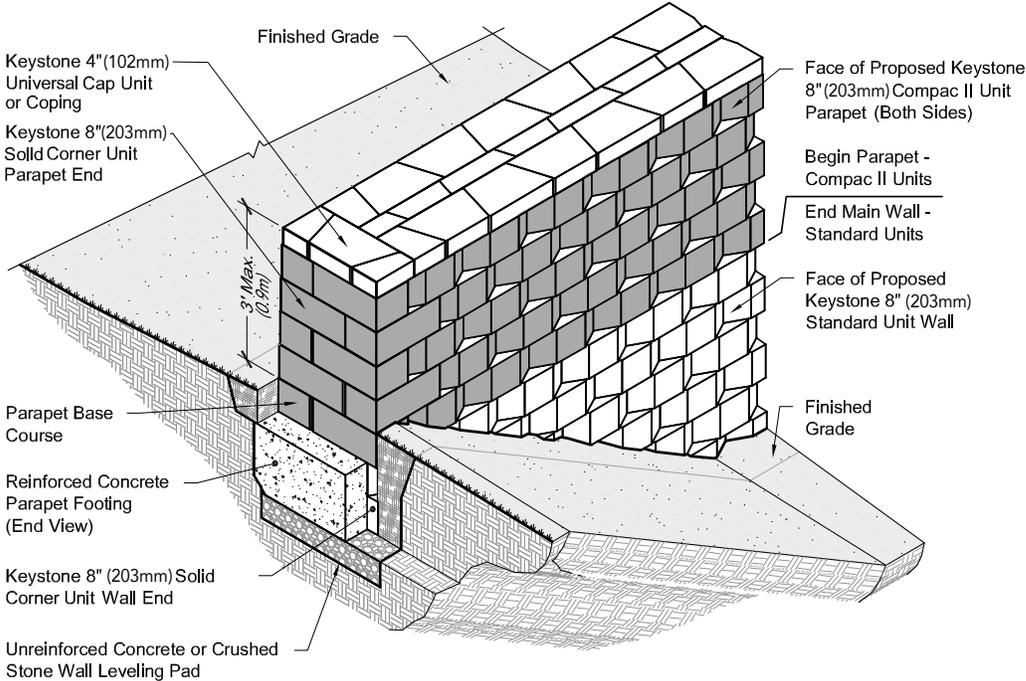
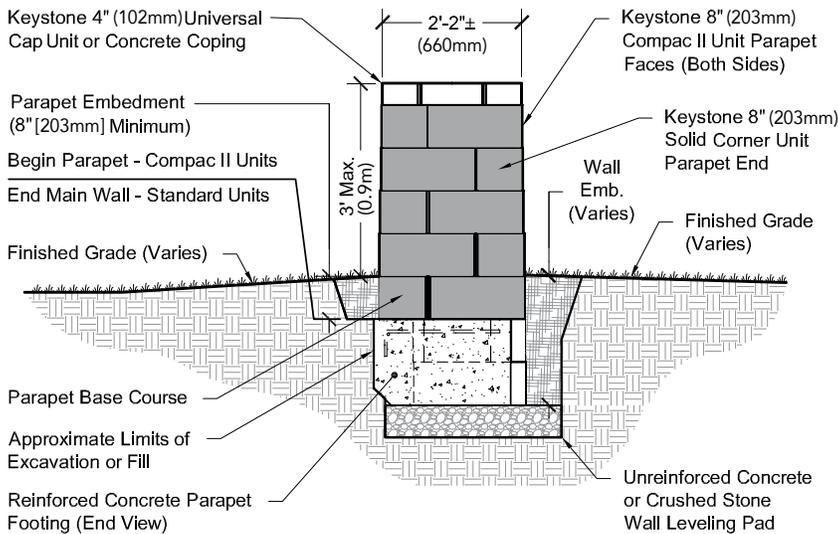


FIGURE E:20 - PARAPET END SECTION VIEW



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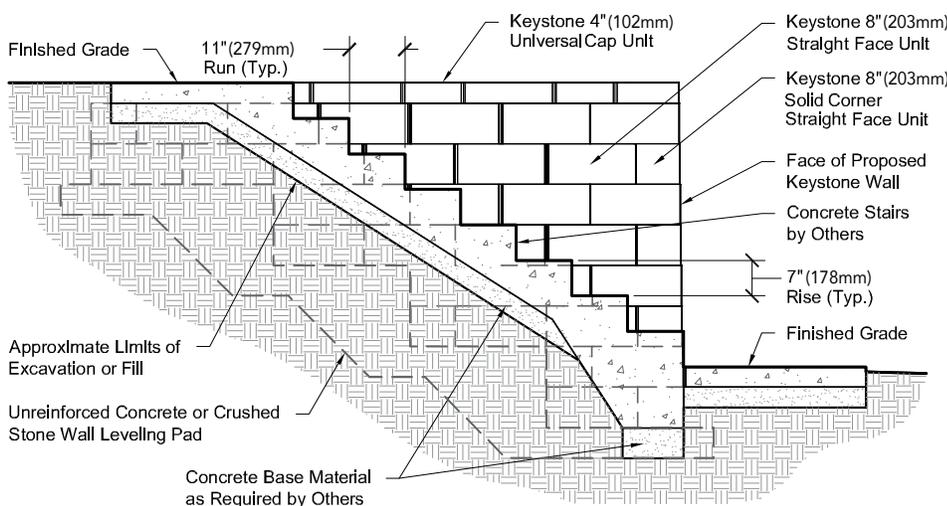
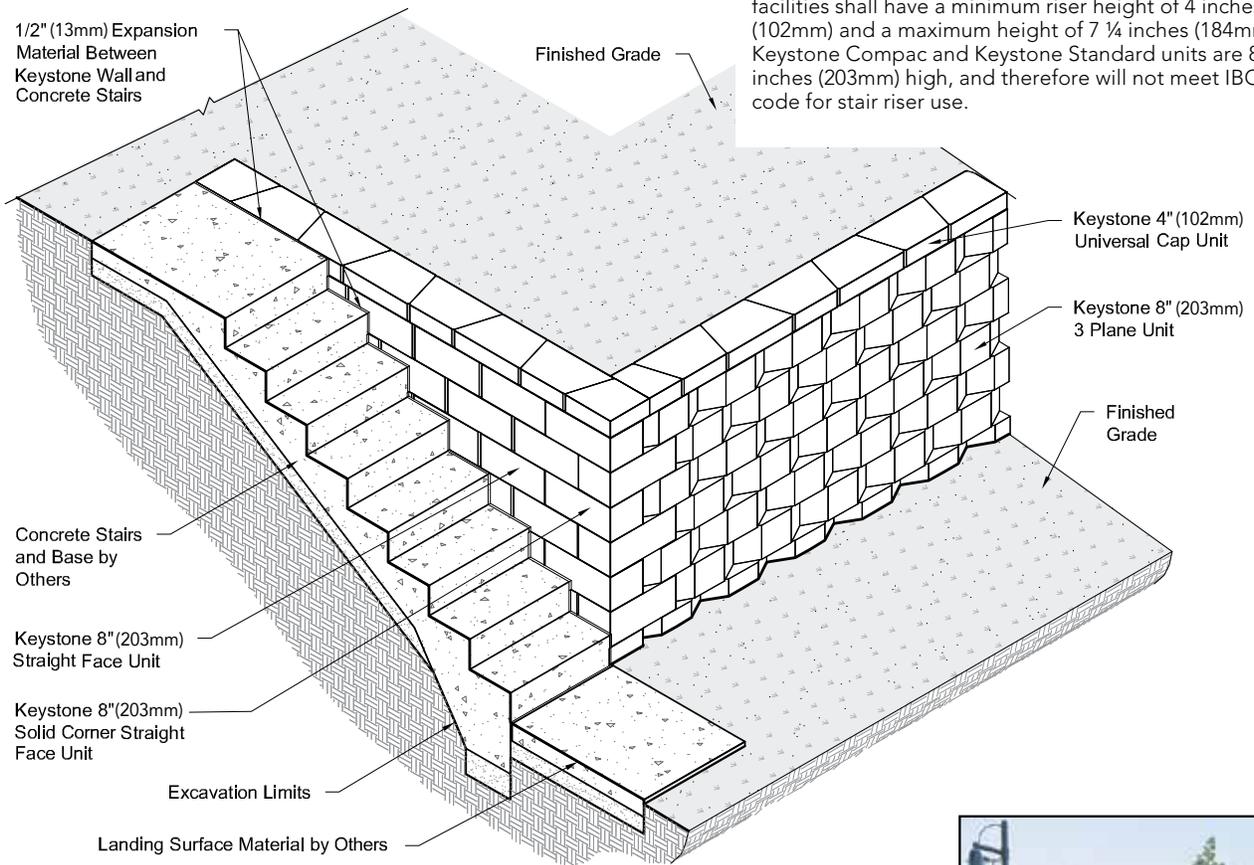
Step & Stair Installation

Keystone walls can easily be constructed to incorporate CIP concrete stairs within the wall systems. The stairways can be designed to be incorporated into a 90 degree wall return (see Figure E:21), or project out from the wall face (see Figure E:24). 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 they include a 1/2 inch (13mm) 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 (102mm) and a maximum height of 7 1/4 inches (184mm). Keystone Compac and Keystone Standard units are 8 inches (203mm) high, and therefore will not meet IBC code for stair riser use.

FIGURE E:21 - INSET STAIRWAY DETAILS



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FIGURE E:22 - STAIR IN WALL DETAIL PLAN VIEWS

NOTE:

Use Keystone 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.

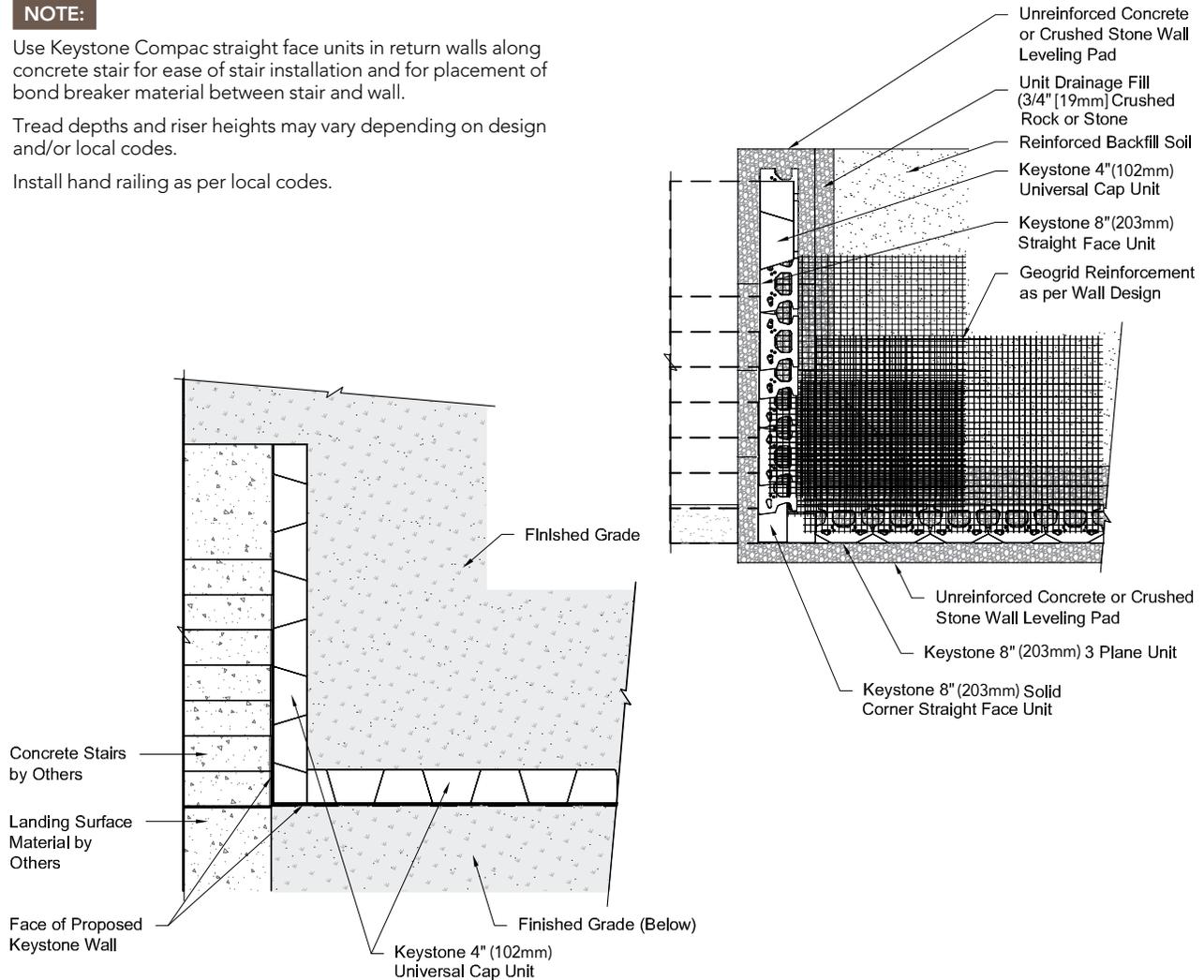
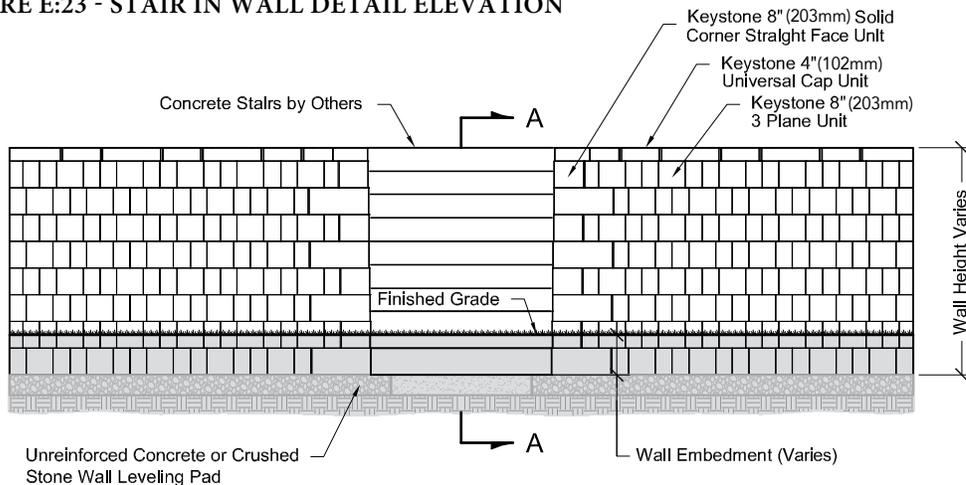


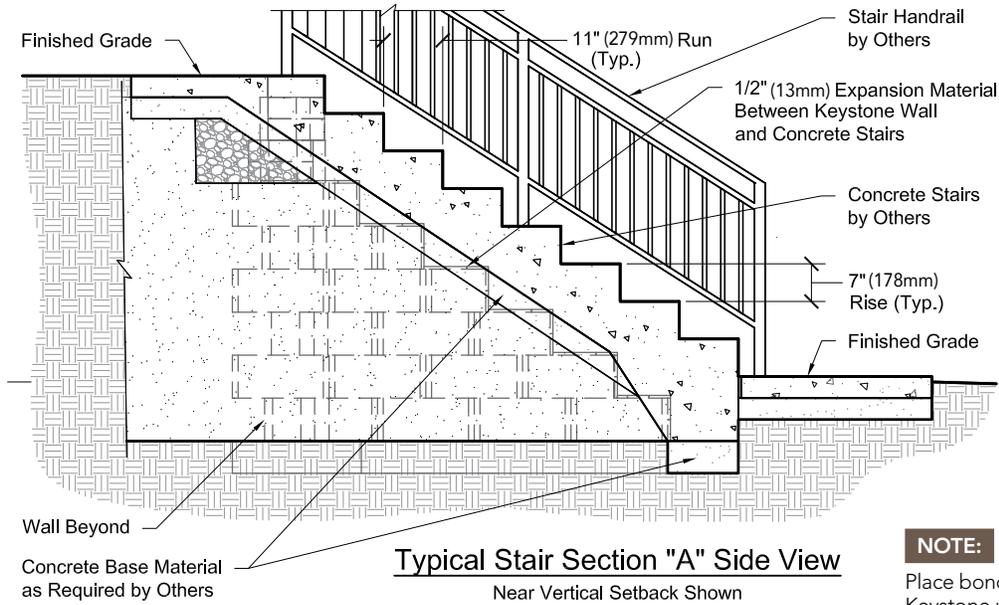
FIGURE E:23 - STAIR IN WALL DETAIL ELEVATION



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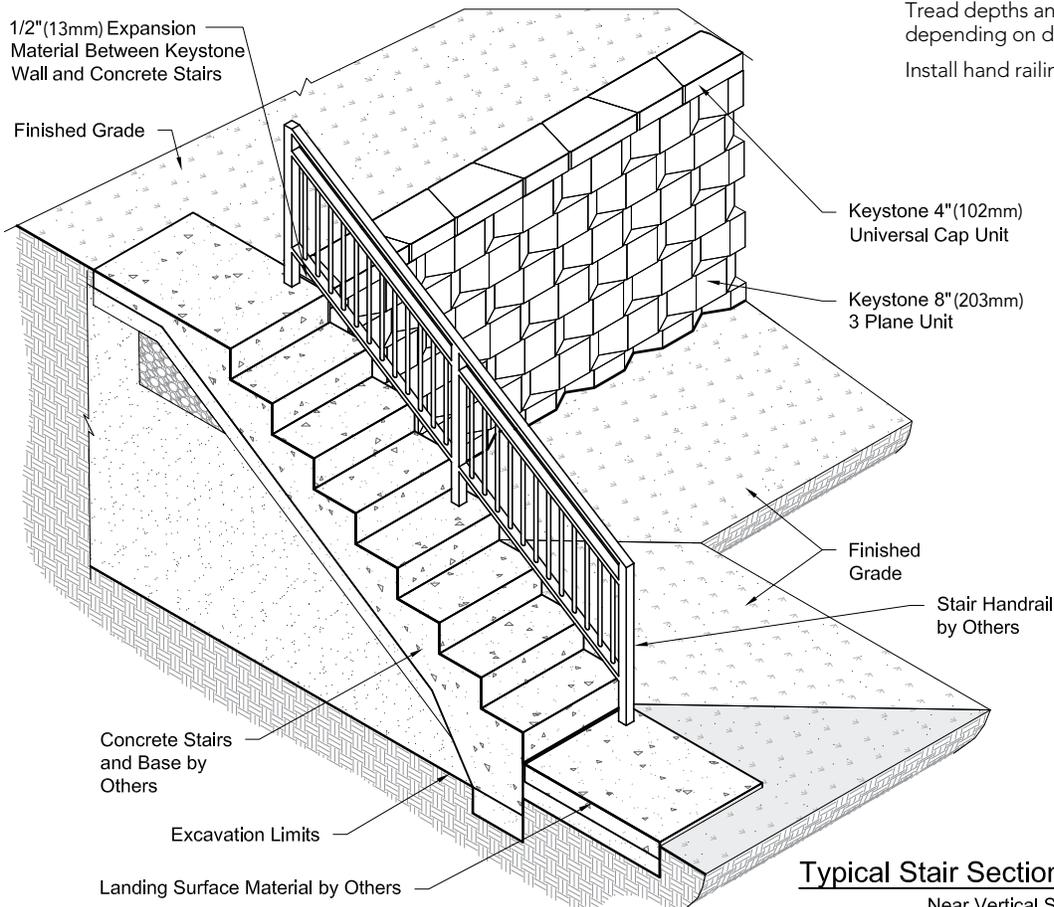
Step & Stair Installation

FIGURE E:24 - PROJECTED STAIRWAY DETAIL



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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FIGURE E:25 - STAIR IN FRONT OF WALL DETAIL PLAN VIEWS

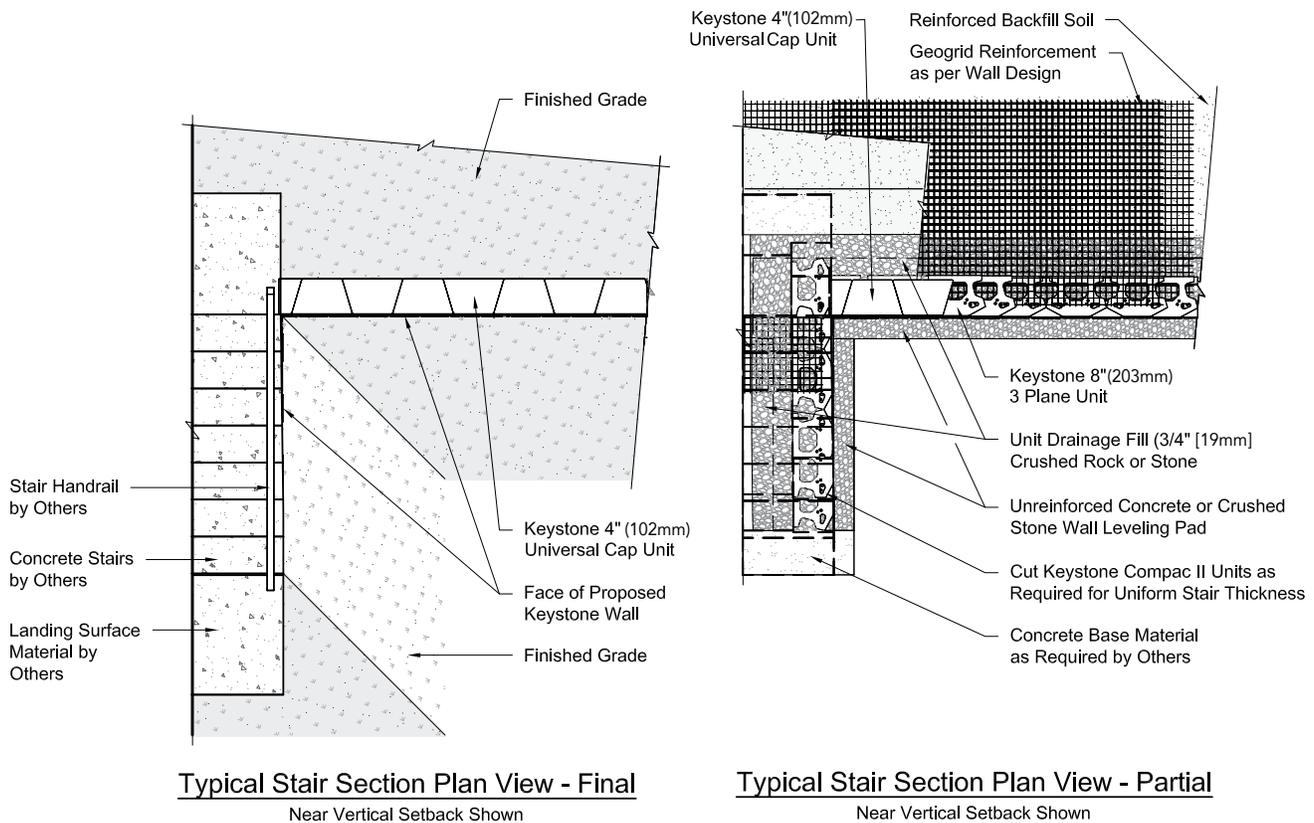
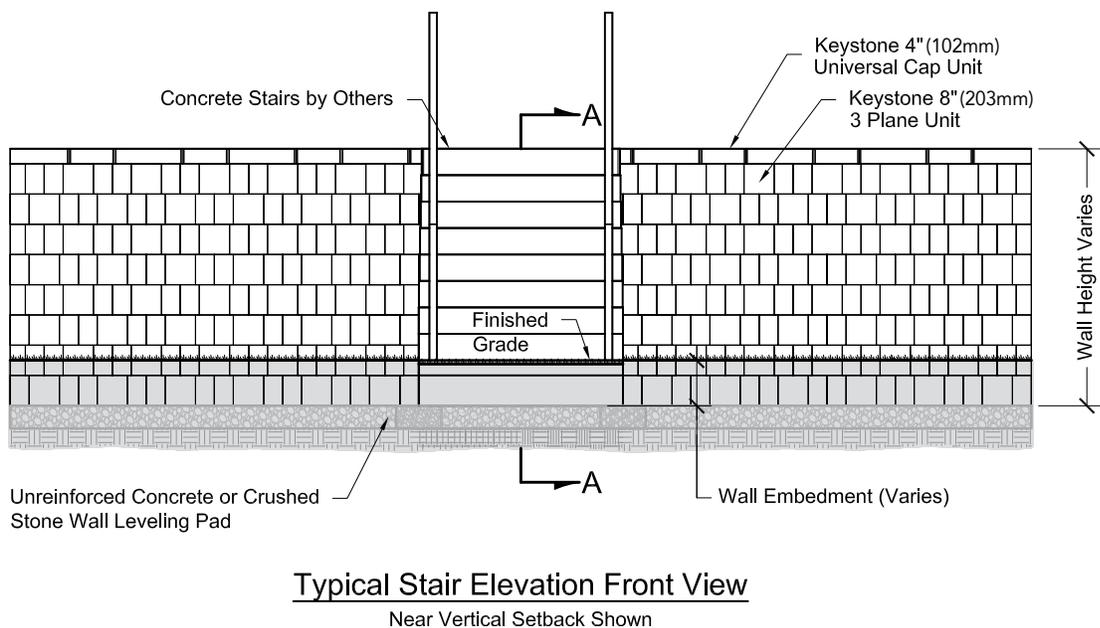


FIGURE E:26 - STAIR IN FRONT OF WALL DETAIL ELEVATION



SECTION E: SPECIALTY - Step & Stair

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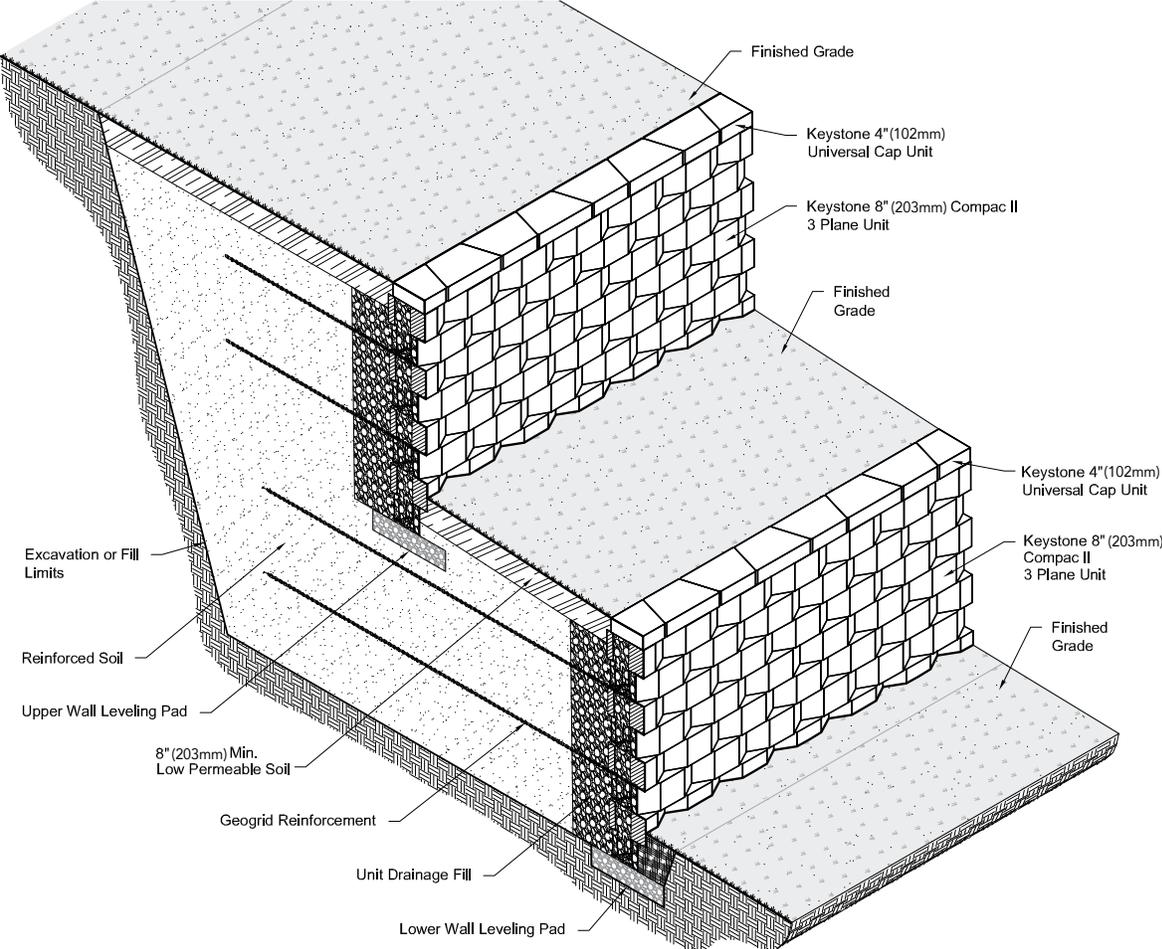
Terraced Wall Application

Terraced Keystone walls can provide a visually appealing solution to grade change. Slope conditions below, between and above the walls, soil conditions and the horizontal distance between the walls will impact terraced wall design. In many cases, the geogrid lengths of the lower wall will be longer than typical to satisfy stability requirements. Always consult a qualified design professional for assistance with terraced walls.



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FIGURE E:27 - TYPICAL TERRACED WALL ISOMETRIC .



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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 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 E:29)

FIGURE E:28 - REPLACE CRACKED UNIT

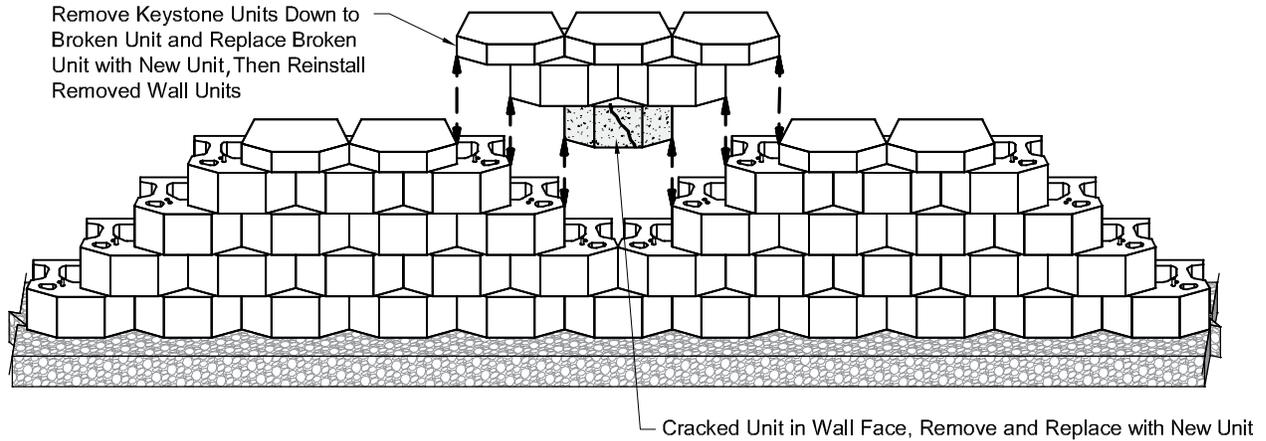
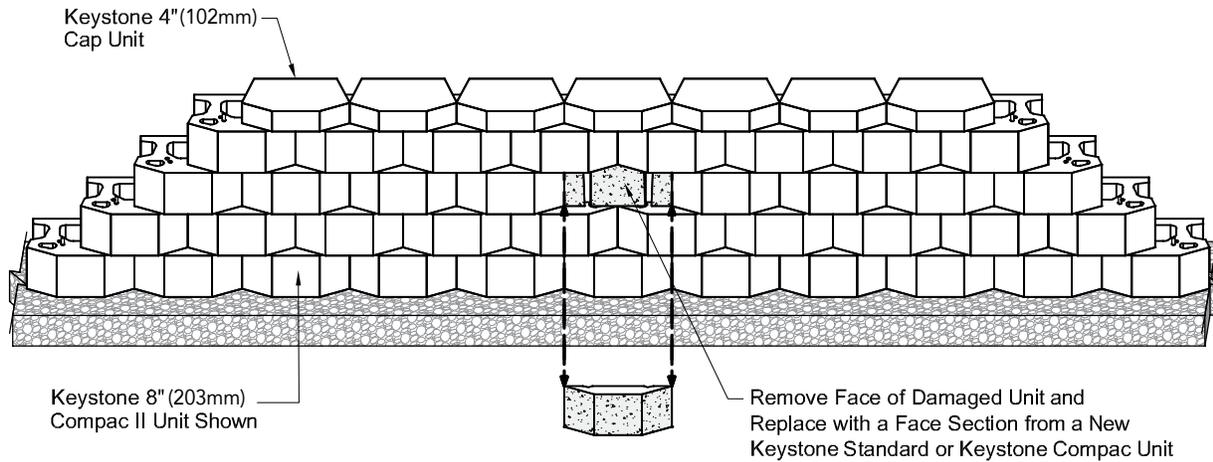
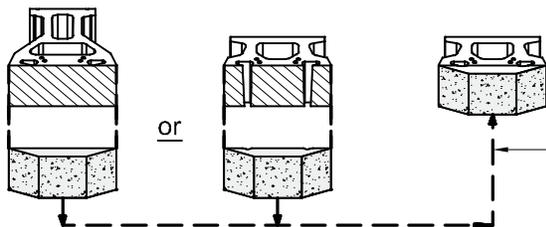


FIGURE E:29- REPLACE UNIT FACE ONLY - FOR TALLER WALLS



Keystone Standard Unit

Keystone Compac Unit



NOTES:

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

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FIGURE E:30 - TYPICAL PLANTING LIMITS

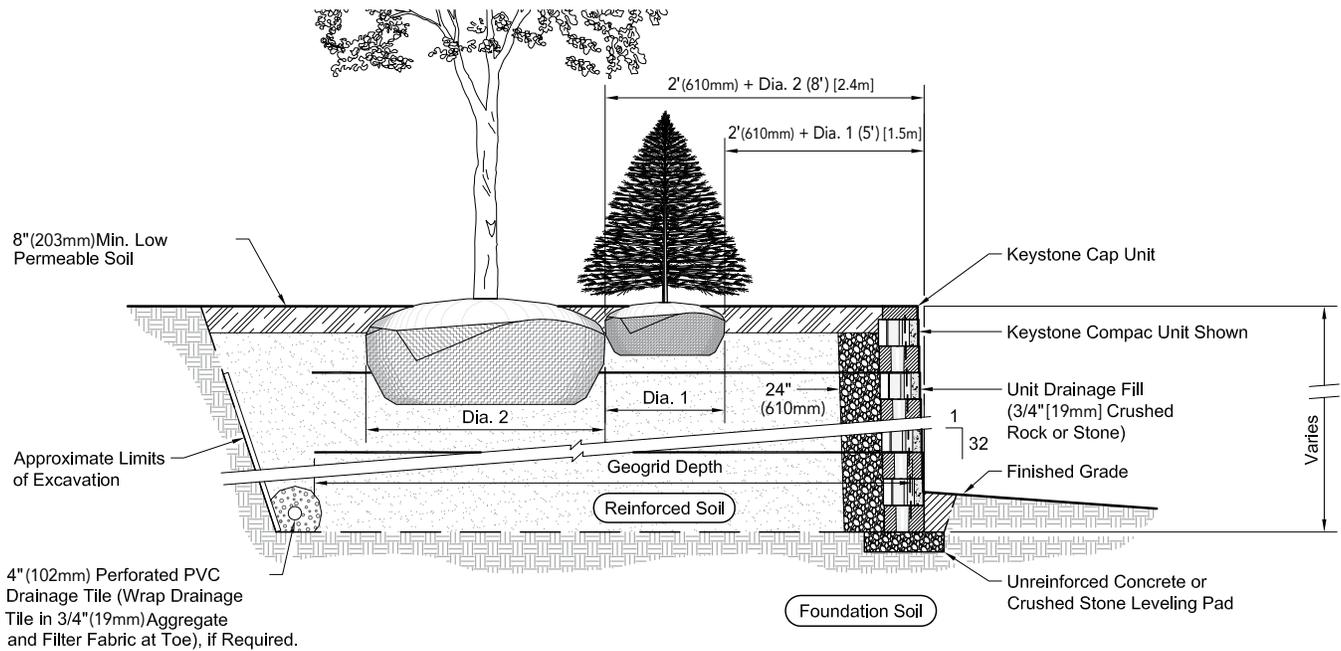
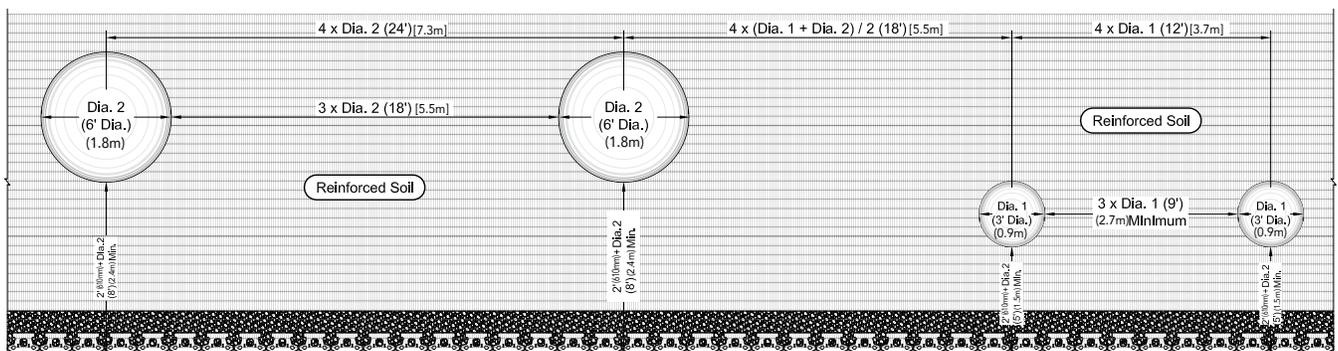


FIGURE E:31 - TYPICAL PLANTING LIMITS



NOTES:

- All planting offsets shall be a minimum of 2 feet (610mm) + the root ball 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.

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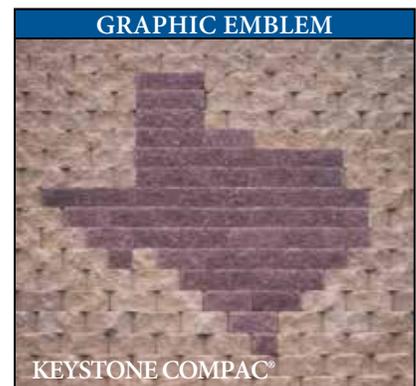
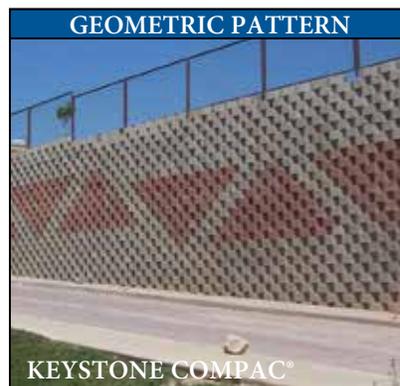
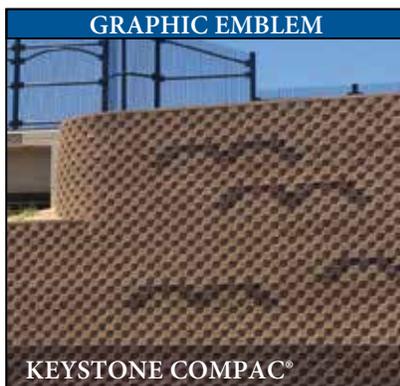
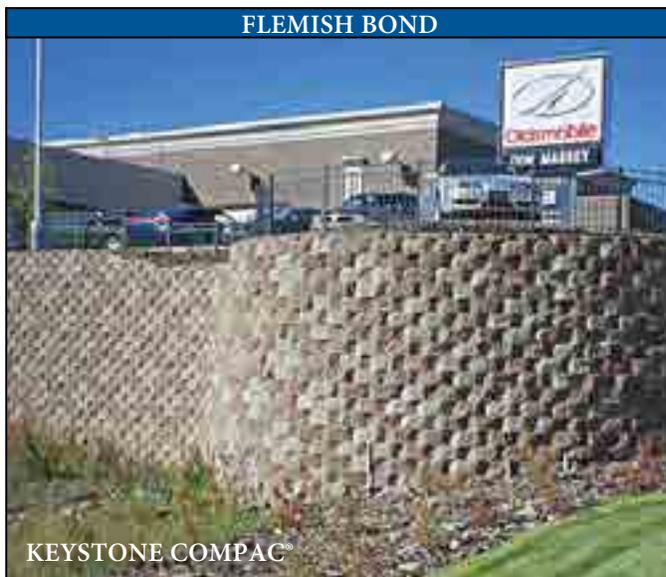
Creative Options

Add 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 tri-plane mixed with straight split units. Dramatic accents can occur when combining units of complementary and/or contrasting color schemes. Consult your local manufacturer/distributor for standard colors, custom color availability, pricing, and unit texture options available by region.

Additional options:

- » Specific graphic emblem (for example, a logo, state shape, image, etc.).
- » Various bonds (for example, 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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