

# Pisa™ & RomanPisa™



## INSTALLATION GUIDE





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## INTRODUCTION

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## THE PISA™ AND ROMANPISA™ SYSTEM

*For the duration of this book, “Pisa” will be used to refer to both the Pisa and RomanPisa systems unless otherwise specified.*

The Pisa system is a solid, modular concrete retaining wall system that is used to stabilize and contain earth embankments, large or small.

The Pisa system is based on the principles and designs of the PisaStone system developed in 1970. Over the next 15 years, hundreds of successful installations were completed. During this period the requirements of designers, installers and owners were further refined and identified. These needs led to the evolution of the Pisa system. Today, the Pisa system and several other retaining wall systems licensed by Risi Stone Inc. are manufactured and installed across North America and internationally.

In the Pisa system, the majority of the facing is constructed from a single mass-produced modular unit. Because the units are solid, they can easily be modified by scoring and splitting. Specialized units are available to help speed the installation of wall features like coping, curves, corners, lights, and audio speakers.

The Pisa system can be constructed in two basic configurations: a Pisa Conventional SRW or a Pisa Geogrid Reinforced SRW.

There are many applications for Pisa retaining walls. Most examples can be divided into the two aforementioned configurations which, more or less, follow two basic uses: landscape applications and structural applications.

In landscape applications, the primary purpose of retaining walls is aesthetic in nature. Some examples of Pisa landscape uses are planters, driveway edging, steps, tree wells, and smaller garden retaining walls. Most landscape applications call for walls under 1.0 m (3ft) in height, with minimal loads being applied to the wall. Consequently, most landscape walls are built as conventional SRWs.

In structural applications, the primary function of retaining walls is to provide structure and strength to steep slopes or

cuts. Some common structural uses for Pisa retaining walls are high walls, some in excess of 7.5 m (25 ft); walls required to support parking, roads, or highways; and erosion protection along streams or lakes. In all of these cases, geosynthetic reinforcement is used.

The Pisa system is supported by the local manufacturers and Risi Stone Inc. Local manufacturers will make every attempt to answer your general questions and they will gladly provide customers with answers for site-specific applications. Each manufacturer has access to prepared information on the Pisa system and has plenty of experience installing it. The Vespa.RS design software also helps to provide solutions for specific site designs. Unique applications often necessitate the assistance of a professional engineer. Risi Stone Inc. can provide these solutions through its Engineering Design Assistance program.

### FEATURES AND ADVANTAGES

The Pisa system has a number of features that make the system unique. Each of these features has been developed to give a Pisa retaining wall the advantages of increased beauty, simplified installation, and greater strength.

These features benefit the owner by lowering the entire cost of the retaining wall, both during installation and well into the future.

#### Modular Retaining Wall System

Wall is flexible, yet retains its structural characteristics.

- The wall can absorb minor movements due to frost or settlement.
- Requires minimal embedment below grade.
- A compacted granular base is all that is required.
- Reduces the cost by not requiring an expensive structural footing.

#### Solid Unit Manufactured From 35 MPA (5000 PSI) Concrete

Provides wall with greater durability.

- Ensures the maximum weight of each unit because there are no voids or cores to be filled.
  - Less susceptible to freeze-thaw deterioration.
  - Less likely to be broken by handling or in transit.
- Solid units are easy to split and modify.
- Can easily create site-specific features using the modular units.

No hollows to be filled with gravel and compacted.

- Ensures maximum resistance to overturning forces.
- Saves time and money.



## THE PISA™ AND ROMANPISA™ SYSTEM

### Tongue and Groove Interlock

Interlocking mechanism moulded into the units so there are no separate pins or clips.

- No need to fiddle with multiple pieces: installation rates increase.
- Ensures maximum shear connection between units.

Units are dry-stacked.

- Lower costs because no mortar is used in the construction.
- Minimal training is required to achieve excellent installation results.

Units are self-aligning and self-battering.

- Once the first course is laid flat and levelled, there is no need for continual measuring and adjusting.

Creates a continuous interlock throughout the wall face.

- Makes a stronger, more damage-resistant wall.

### Size and Weight

The 21 kg (46 lb) units are well-balanced, easy to handle, and have a moulded finger hold.

- Units can be held by a single person for quicker installation.

Manufacturing method ensures a uniform

height for each unit.

- Courses remain at fixed elevations and should not require shimming.

### Pisa with Geogrid Reinforcement

Ability to construct higher walls.

- Can utilize site soil to infill the geogrids, consequently lowering disposal and extra material charges.
- Can use the same facia throughout a site on lower conventional SRWs and higher geogrid reinforced SRWs.

### Choice of Coping Units

Provides a choice of coping stones for various wall arrangements.

- Coping can be selected to meet site requirements (based on availability).

### 90° Corner Units

Manufactured to speed construction.

- Offers a finished appearance to the wall.
- Initiates the correct running bond pattern.
- Increases the strength of corners.
- Saves time during installation.

### Complementing Accessories

All the standard features for retaining walls can be supplied by the manufacturer.

- Saves time during installation.
- Creates a uniform, finished look for the wall.

### Technical Support and Engineering Design Assistance

Technical expertise developed over thirty years through experience and testing is available to customers.

- Ensures that retaining walls are correctly designed and constructed.
- Advanced software is available to help designers generate stable retaining wall structures.

### System Variations

Due to local conditions and preferences, the licensed manufacturer may produce either the Pisa or the RomanPisa system, or both. The Pisa units are manufactured in pairs, face-to-face.

The rough surface is achieved by splitting the units apart using a simple hammer and chisel. RomanPisa is manufactured by putting a typical Pisa unit through a specialized process that rounds off the edges and corners, and gouges the face.

This gives the wall a worn, cobble appearance that looks like real stone, not concrete. RomanPisa can be substituted for any Pisa system application. The licensed manufacturer may produce the Pisa or RomanPisa systems with one or more minor variances. These differences in no way affect the performance of the wall.

### RomanPisa



## BLOCK DETAILS

### Colours

Each manufacturer of Pisa or RomanPisa has selected a set of standard colours that they make and keep in stock. These colours vary from manufacturer to manufacturer. Some have the ability to mix the base colours and create marbled colour blends.

### Closed-End Coping

Some manufacturers of Pisa or RomanPisa produce closed-end coping units that can be used to hide the groove in the bottom of the coping unit at locations where the retaining wall steps up or down. If closed-end units are not available, cutting can be done to hide the groove.

### Pre-Split Units

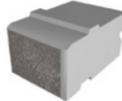
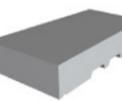
Some manufacturers have opted to split the Pisa units before delivery to the installation site. This is not an option for the customer to choose. The units are either split by the manufacturer or they must be split by the installer.

### Chamfered Face

The face of the Pisa stone may be chamfered on the top and bottom only (standard unit is chamfered on all sides of the face).

### PisaStone

All manufacturers produce ReversaCap coping units to finish off the Pisa or RomanPisa retaining wall. Some also produce the PisaStone retaining wall system, which will allow customers a choice of coping units: Reversa-Cap or PisaStone. If available, PisaStone standard units can be used as a quick and effective way to level the first course of units for straight sections of wall.

Pisa / RomanPisa System Units	Face Width	Back Width	Height	Depth	Weight
 Standard Unit	8 in 200 mm	8 in 200 mm	6 in 150 mm	12 in 300 mm	46 lbs 21 kg
 Tapered Unit	8 in 200 mm	6 in 150 mm	6 in 150 mm	12 in 300 mm	40 lbs 18 kg
 Jumbo Unit	12 in 300 mm	12 in 300 mm	6 in 150 mm	9 in 225 mm	65 lbs 29 kg
 Half Unit	4 in 100 mm	4 in 100 mm	6 in 150 mm	12 in 300 mm	24 lbs 11 kg
 Corner Unit (left and right)	12 in (20 in)* 300 mm (500 mm)*	12 in (20 in)* 300 mm (500 mm)*	6 in 150 mm	8 in 200 mm	47 lbs (78 lbs)* 21 kg (35 kg)*
 ReversaCap® Coping Unit	8 in 200 mm	7 in 175 mm	3 in 75 mm	14 in 356 mm	22 lbs 10 kg
 PisaStone® Coping Unit	24 in 600 mm	24 in 600 mm	3 in 75 mm	12 in 300 mm	72 lbs 33 kg

\* Manufacturer may provide the larger corner unit.

• Consult manufacturer's product information to confirm details of the various units. Imperial measurements are approximate.

## OVERVIEW OF A SUCCESSFUL PROJECT

The following procedure is recommended for the construction of segmental retaining walls over 1.0m (3.0 ft) in height, or as required by local building codes.

### Clear Plan

- Aboveground Site Assessment: existing grades, structures, utilities, property lines, visible water features, etc., established.
- Contact all utility companies to confirm location of underground utilities that may not be visible in aboveground assessment.
- Proposed site modifications defined by designer (landscape architect, engineer, architect) based on owner's requirements and site limitations. Includes proposed grades, retaining wall geometry, slopes, proposed use of land (parking areas, water detention, landscape), relocation of existing structures/utilities, new structures/utilities, location of trees, etc.
- Project drawings generated and submitted to appropriate agencies for approval.
- Investigate local building codes and apply for all permits required.

### Assessment of Subsurface Conditions

- Geotechnical Investigation conducted to evaluate subsurface conditions of site, including soil types, characteristic properties, in-situ state, groundwater conditions, overall slope stability, bearing capacity.
- Recommended design parameters, construction/ excavation techniques, effects of proposed and existing structures, ground improvements, erosion protection, drainage considerations, anticipated settlement, etc., should be identified.

### Site-Specific Retaining Wall Design

- Information provided in plan and geotechnical investigation provided to the wall design engineer.
- The design may be provided by Risi Stone Inc. through the Design Assistance Program (contact local manufacturer for details), or a third-party engineer qualified in this field. The design must synthesize all available information and include cross-section and/or elevation-view drawings, specifications, calculations, quantities, and related construction details.

### Pre-construction meeting

- We recommend that all involved parties (designers, owner's representative, general contractor, installer, inspecting engineer, supplier, etc.) attend a pre-construction meeting to define schedule and clearly state responsibilities.

- Parties not directly involved with the design and construction of the wall, but who may do future work that could influence the wall (e.g. paving, installing fences) should attend the meeting to understand the limitations of the wall and address precautions.
- Experience has shown that this simple step prevents a multitude of potential problems!

### Qualified Professional Engineer Hired for Inspection/ General Review

Inspection and General Review of the proposed SRW must be conducted by a qualified third-party engineer. Inspection is more than soil and compaction testing, but includes all aspects of the installation. The scope of the GRE's responsibilities include, but are not limited to:

- Inspection of all materials used in construction (SRW units, backfill, drainage material, reinforcement, other structures);
- Verification that the design is compatible with the site in all respects;
- Identification of discrepancies between the plan and/or SRW design and actual site conditions, and subsequent notification of designer;
- Continuous evaluation of site conditions, surface water and groundwater, compaction testing, foundation bearing capacity, excavation procedures, construction practices for safety and compliance with design;
- Ensuring wall is constructed according to design; and provide a letter to the owner that the wall has been constructed in general conformance with the design.

### Proper Installation

- Adherence to design, specifications, details, guides, and good construction practice is necessary.
- Conducted under supervision of the GRE.

### Final Grading

- Final grading should be conducted as soon as possible following construction to divert water away from the wall and create the optimum condition for great performance.

### Safety Notes

- Ensure all workers are well-versed in the proper use of all equipment and vehicles
- Prior to each use, inspect all machinery to ensure that it is in good condition
- Do not exceed the recommended load/speed/capacity specified by the equipment manufacturer
- Ensure overall maintenance of all machinery is kept up
- Follow all occupational health & safety guidelines set forth by your local government

## FOLLOWING THE DESIGN

### UNDERSTANDING THE DESIGN

Depending on the stage in the design process, there are generally three potential types of design:

#### Typical Design – Not for Construction

Non-site-specific design(s) selected from Risi Stone Inc.' library of pre-engineered cross-section drawings (all available at risistone.com).

Selected based on preliminary information regarding proposed maximum wall height, use of structure, grading, etc. Suitable for preliminary cost estimates, feasibility studies, and conceptual approvals. Not for Construction.

#### Preliminary Design – Not for Construction

A site-specific design produced for preliminary purposes when some component of the required design information is not yet available. Includes all elements needed to construct the wall, but is not considered ready for construction as it remains contingent on verification of some site-specific detail(s).

Includes site-specific cross-section drawings, elevation views, specifications, quantity calculations, details, statement of limitations, etc. Not sealed by the designer.

#### Final Design

All necessary information has been established and the design has been deemed ready for construction. This type of design is sealed by the designer.

### COMPONENTS OF THE DESIGN

The design should clearly provide all information necessary to construct the proposed SRW structure. The basic components are as follows:

#### Design Notes / Limitations

The design should include information regarding the

### TYPICAL CROSS-SECTION DRAWING

#### TYPICAL SECTION - NOT FOR CONSTRUCTION

Design Specific Geometric Information			
Retaining Wall System	Pisa w/ Geogrid	Geogrid Type and Manufacturer	See Notes
Maximum Height mm (in)	2060 (81)	Minimum Geogrid LTDS kN/m (lb/ft)	See Notes
Maximum Slope Above Wall	Horizontal	Maximum Slope Below Wall	None
Max. Surcharge Above Wall kPa (lb/sq.ft)	Traffic Surcharge 12 kPa (250 lb/sq.ft)	Depth of Embedment mm (in)	206 (8)
Batter of Wall	7.12 °	Compacted Base Dimension mm (in)	610 x 153 (24 x 6)

Description (by USCS)	Soil Region				see Infill
	Infill	Retained	Foundation	Base	
Effective Internal Friction Angle	35 °	28 °	28 °	30 °	NR
Moist Unit Weight kN/cu.m (lb/cu.ft)	22 (140)	20 (127)	20 (127)	22 (140)	NR
Effective Cohesion kPa (lb/sq.ft)	NR	NR	NR	NR	NR
Soil Notes	Placed in 150mm (6") lifts and compacted to 95% SPD.	Undisturbed dense soil or well compacted Eng. fill.	Allowable bearing cap must exceed 100kPa (2100 psf)	Crushed Gravel (free draining) compacted to 98% EPD.	Gravel in fill must be well graded, angular, free drain w/max. 8% fines

NR - Not Required Note.

- This design meets or exceeds the minimum factors of safety required by Risi Stone Systems based on the design parameters listed above. The analysis was performed as outlined in the National Concrete Masonry Association Design Manual for Segmental Retaining Walls, Second Edition. This is a typical, non site-specific design.
- No analysis of global stability, total or differential settlement, or seismic effects has been performed.
- This design is only provided to illustrate the general arrangement of the SRW structure for preliminary costing and feasibility purposes only. This drawing is not for construction. A qualified Engineer must be retained to provide the Final Design prior to construction.
- Structures such as handrails, guardrails, fences, terraces, and site conditions such as water applications, drainage and soil conditions, additional live and dead loads, etc., have significant effects on the wall design and have not been taken into account in this typical section. When accounted for in the Final Design, other conditions and elements may result in additional design measures (geogrid, drainage, etc) and cost.
- For geogrid reinforced structures, a minimum Long Term Allowable Design Strength of 14 kN/m was assumed. Contact your manufacturer or Risi Stone Systems for a list of approved geogrid reinforcements.

**Pisa®**  
Retaining Wall  
Geogrid Section  
2060mm (6.75ft)  
Site: Surcharge - Clays  
Infill: Granular  
P21RBQAI206

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## FOLLOWING THE DESIGN

design standard used, limitations of design, status of design (preliminary or final), design assumptions, purpose of the wall, and potential construction issues.

### Cross-Section Drawing(s)

The cross-section drawing is usually provided to illustrate the general arrangement of the wall, soil zones, assumed parameters, structural elements, water levels, etc. A cross-section drawing is normally provided for the maximum height section through the wall and/or the most critical section. Additional cross-sections may be provided to indicate variable conditions or wall orientation (terraces/location of structures) throughout.

### Elevation-View Drawing(s)

The elevation view or "face" view of the wall depicts the wall as a whole, essentially laying the wall out flat on the page. This drawing details the overall geometry of the proposed wall, steps at the top and bottom of wall, required geogrid length and placement (where applicable), location of other structures, etc. This drawing provides the contractor with an exact model upon which to establish grades and construct the wall.

### Calculations and Quantity Estimates

Risi Stone Inc. conducts analysis using the Vespa.RS design software (available at risistone.com), a branded version of the popular Vespa MSE Design Software. Risi Stone Inc.'s design reports feature the Vespa design output. This output is customizable and depending on the application, may include the design calculations, all design parameters, quantity calculations, etc. The quantity calculations exactly represent the wall layout provided in the elevation view and Calculated Panel Geometry section of the Vespa.RS output. The contractor is responsible for verifying the quantities provided by checking the most recent grading information, and/or site grading, against the elevation view provided.

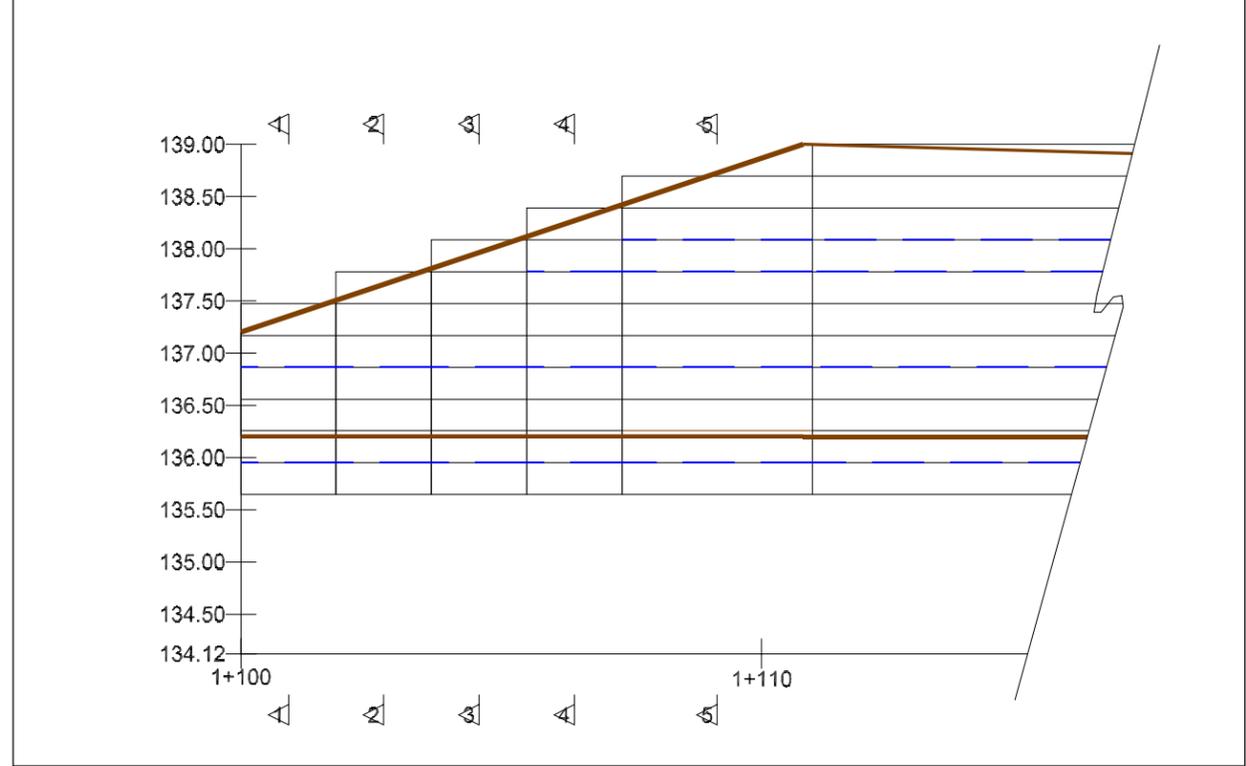
### Details

The cross-section and elevation-view drawings are to be used in conjunction with the related detail drawings. These may include handrails, corners, curves, stepping foundation, steps, etc. Adherence to these details is vital for optimum wall performance.

### Specifications

The Design should include standard specifications that outline specific requirements of the Design, Construction, Materials, Certification, and Finishing.

TYPICAL ELEVATION-VIEW DRAWING





## INSTALLATION

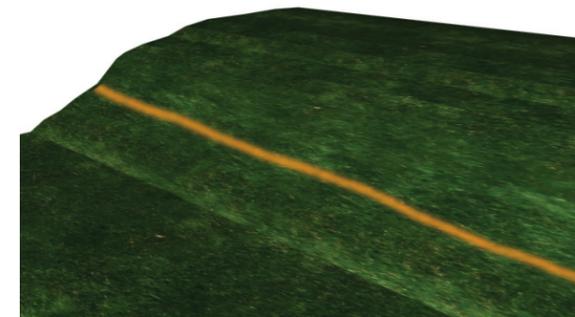
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## CONVENTIONAL SRW INSTALLATION PROCEDURE

The following are the basic steps involved in constructing a conventional (non-geogrid reinforced) Pisa segmental retaining wall. These steps are to be used in conjunction with all relevant details provided in the Details Section. Refer to Overview of a Successful Project before beginning.

### PLAN

With your final design in hand, begin to establish the wall location and proposed grades. Locate all utilities and contact local utility companies before digging. Mark a line where the front of the wall will be placed, keeping in mind the 19mm (¾ in) setback per course.



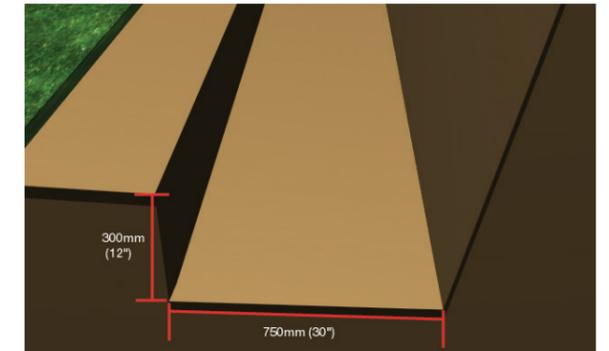
### EXCAVATE

Excavate a trench down to the foundation grades specified in the design. The front of the trench should be 150mm (6 in) from the planned face of the wall. The trench should be a minimum of 750mm (30 in) wide (front to back) and 300mm (12 in) deep. This depth assumes one unit is buried (unit height of 150mm [6 in]) plus the compacted granular base minimum depth of 150mm (6 in). As wall height increases, depth of embedment also increases, normally about 10% of the wall height.

Greater embedment depths may be required to account for slopes more than 3H:1V in front of the wall, scour protection in water applications, global stability, or as specified in the design. The rear 150mm (6 in) of the trench is excavated to account for the drainage layer. Excavations should be conducted in accordance with local codes under direction of the General Review Engineer (GRE).

### VERIFY FOUNDATION SUBGRADE

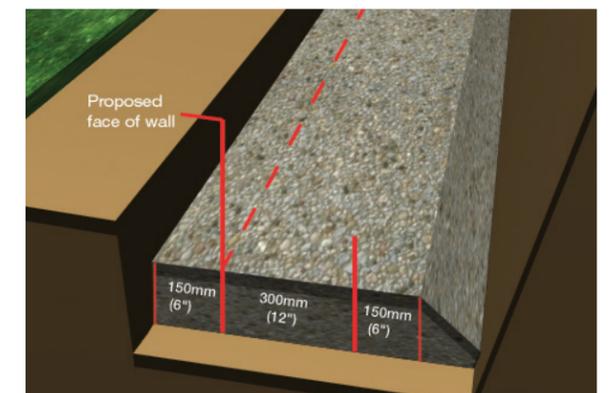
Once the foundation trench has been excavated to the specified elevations, the native foundation soil must be checked by the GRE. The foundation soil must have the required allowable bearing capacity specified in the design.



### PREPARE THE COMPACTED GRANULAR BASE

Start the base at the lowest elevation of the wall. The base should be composed of well-graded, free-draining (less than 8% fines), angular granular material, and compacted to a minimum of 98% SPD. The minimum base thickness is 150mm (6 in) or as required by the GRE to reach competent founding soil.

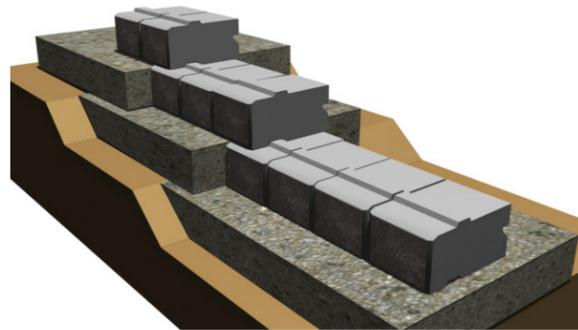
A layer of unreinforced concrete (50mm [2 in] thick) may be placed on top of the of the granular material to provide a durable levelling surface for the base course. At the direction of the GRE, geotextile might be required under the granular base. The minimum base dimensions are 600mm (24 in) wide (front to back) and 150mm (6 in) deep. The additional 150mm (6 in) trench width allows for the placement of the drain.



## CONVENTIONAL SRW INSTALLATION PROCEDURE

### STEP THE BASE

When the grade in front of the wall slopes up or down, the base must be stepped to compensate. Working out the stepped base as the wall steps up in elevation, the foundation steps must be located to ensure the minimum embedment is achieved. The height of each step is 150mm (6 in) – the height of one course. The 19mm (¾ in) offset must be accounted for at each step.



### PLACE FILTER CLOTH

Lay the approved filter fabric (geotextile) along the bottom of the rear of the trench and extend up the exposed excavation to the proposed wall height. Leave adequate material at the top to fold back towards the wall (completely containing the drainage material). Stake the filter cloth against the slope during construction.



### PLACE THE DRAIN

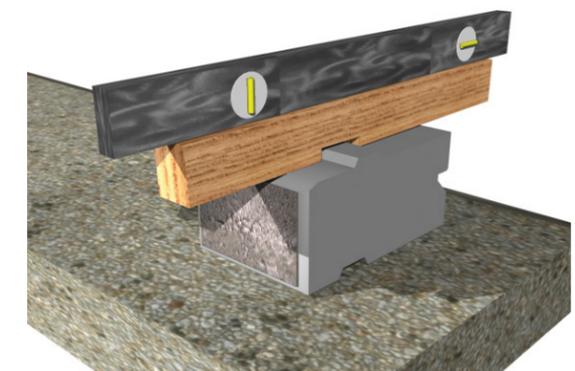
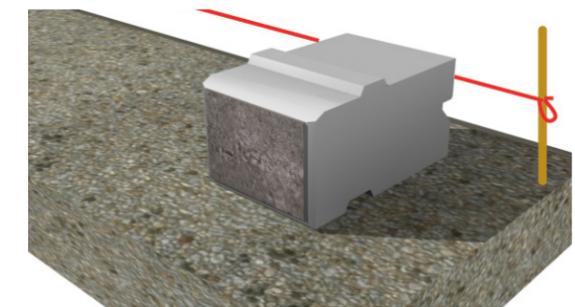
Various options for drain placement may exist, depending on how the pipe is to be outlet (refer to Drainage). The drain may be outlet through the wall face or connected to a positive outlet (storm drain). The drainage system is extremely important and outlets must be planned prior to construction. In the case of connecting to a positive outlet, the drain should be placed at the lowest possible elevation and sloped at a minimum of 2%. At the rear of the base,

allow the granular material to slope down on the sides towards the drain trench. In the 150mm (6 in) area behind the base, place the approved drain tile (perforated drain with filter sock) on top of the filter cloth and minimal granular coverage.



### PLACE THE FIRST COURSE

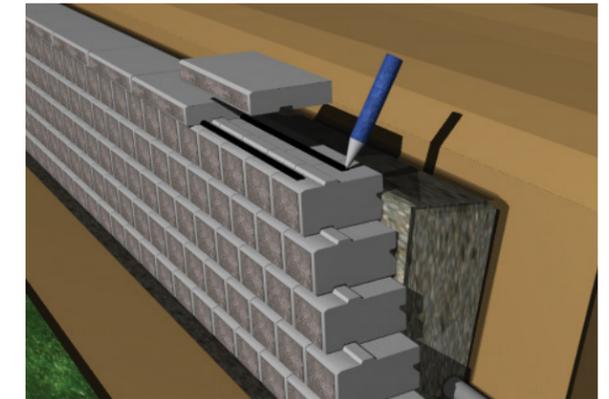
Split units apart using a chisel and hammer if not already pre-split by manufacturer. Position a level string to mark location of the back of the first course (should be 300mm [12 in] from the proposed wall face). Place the first course of Pisa units side-by-side (touching) on the granular base. Ensure units are level front to back and left to right. Extra care should be taken at this stage as it is critical for accurate alignment.



## CONVENTIONAL SRW INSTALLATION PROCEDURE

### PLACE COPING UNIT

Various coping units are available depending on the alignment of the wall and desired look. A layer of concrete adhesive must be applied to the top course in order to fix the coping units in place. Place the coping unit firmly on top of the adhesive, ensuring both surfaces are free of debris, and apply pressure to secure. Follow adhesive installation guidelines.



### STACK UNITS

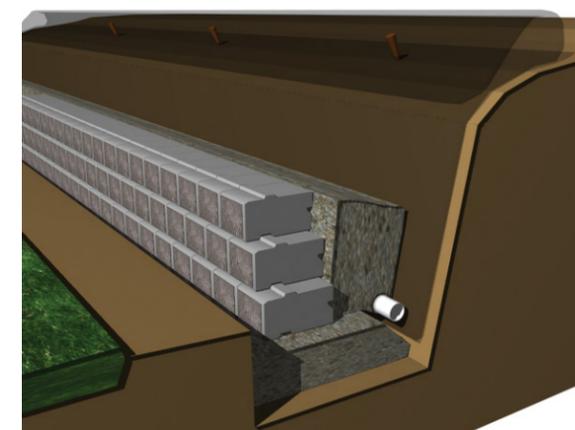
Sweep top of underlying course and stack next course in a running bond pattern so that middle of the unit is above the joint between adjacent units below (100mm [4 in] offset). Continue stacking courses to a maximum of four courses (600mm [24 in]) before backfilling.

### BACKFILL DRAINAGE MATERIAL

A free-draining, 19mm (¾ in) clear stone drainage material is placed immediately behind the wall facing and compacted with a light manual tamper. The drainage layer must be a minimum of 300mm (12 in) thick and protected from the native material by the filter cloth.

### CONTINUE STACKING AND BACKFILLING

Continue stacking units and backfilling as described above until the desired height is reached, based on the design.



### ENCAPSULATE THE DRAINAGE LAYER AND FINISH GRADING

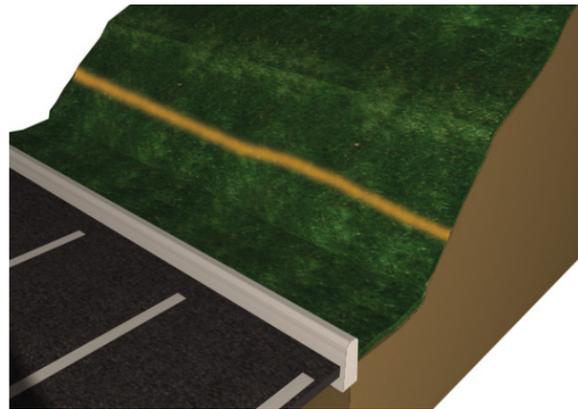
Fold the excess filter fabric over the top of the drainage layer and extend up the back face of the coping unit. Ideally, place an impervious layer of soil on top of the filter fabric and compact manually, providing for the required grading and/or swales. For other treatments such as pavers, concrete, or asphalt, care must be taken to ensure that heavy compaction/paving equipment remains a minimum of 1.0m from the back of the coping unit. Slope the surface above and below the wall to ensure water will flow away from and not accumulate near the wall units. See Finishing Details for ideas on tapering down and ending the wall.



## REINFORCED SRW INSTALLATION PROCEDURE

### PLAN

With your final design in hand, begin to establish the wall location and proposed grades. Locate all utilities and contact local utility companies before digging. Mark a line where the front of the wall will be placed, keeping in mind the 19mm (¾ in) setback per course.



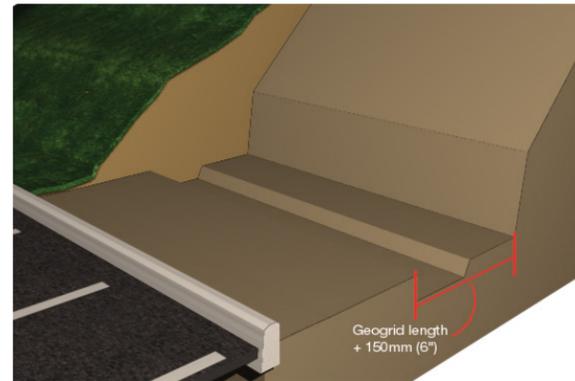
### EXCAVATE REINFORCED ZONE

The excavation must be carefully planned and consider several elements. Based on the type of soil being excavated, the GRE must determine the maximum allowable "cut" angle the excavation can sustain. This angle ensures the stability of the excavation during construction. The required geogrid length (as shown in the design) plus 150mm (6 in) defines the minimum width at the base of the excavation. Measuring from 150mm (6 in) in front of the wall face, extend a line back the base width determined above. At the rear of the base dimension, an imaginary line should be extended up the slope at the allowable angle. Where this line breaks the slope surface is the beginning of the excavation. Excavation must then begin at the top of the slope and progress downwards at the acceptable angle. Excavation continues until the slope is cleared and a flat area at the base is exposed extending 150mm (6 in) past the proposed face of the wall.

### EXCAVATE GRANULAR BASE

Excavate a trench for the granular base. The front of the trench should be 150mm (6 in) from the planned face of the wall. The trench should be a minimum of 750mm (30 in) wide (front to back) and 300mm (12 in) deep. This depth assumes one unit is buried (unit height of 150mm [6 in]) plus the compacted granular base minimum depth of 150mm (6 in). As wall height increases, depth of embedment also increases, normally about 10% of the

wall height. Greater embedment depths may be required to account for slopes more than 3H:1V in front of the wall, scour protection in water applications, global stability, or as specified in the design. The rear 150mm (6 in) of the trench is excavated to account for the drain.



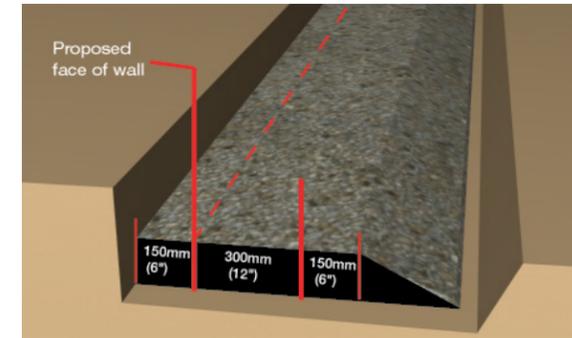
### VERIFY FOUNDATION SUBGRADE

Once the wall has been excavated, the native foundation soil must be checked by the GRE. The foundation soil in a geogrid-reinforced SRW is considered to be the material underneath both the facing and reinforced zone - that is, the entire wall footprint. This verification should not just be limited to the soil underneath the granular footing. The foundation soil must have the required allowable bearing capacity specified in the design.

### PREPARE THE COMPACTED GRANULAR BASE

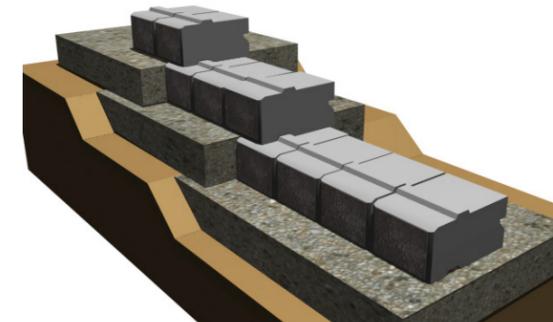
The base should be started at the lowest elevation of the wall. The base should be composed of well-graded, free-draining (less than 8% fines), angular granular material, and be compacted to a minimum of 98% SPD. The minimum base thickness is 150mm (6 in) or as required by the GRE. A layer of unreinforced concrete (50mm [2 in] thickness) may be placed on top of the granular material to provide a durable levelling surface for the base course. The minimum base dimensions are 600mm (24 in) wide (front to back) and 150mm (6 in) deep. The additional 150mm (6 in) trench width allows for the placement of the drain.

## REINFORCED SRW INSTALLATION PROCEDURE



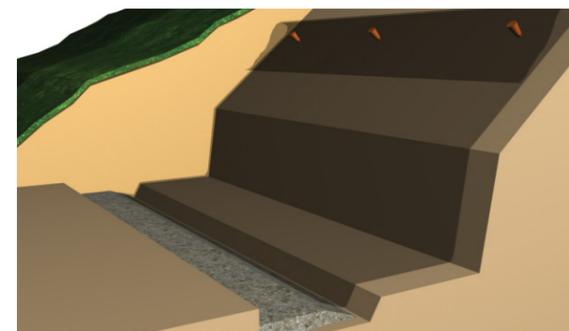
### STEP THE BASE

When the grade in front of the wall slopes up or down, the base must be stepped to compensate. Working out the stepped base as the wall steps up in elevation, the foundation steps must be located to ensure the minimum embedment is achieved. The height of each step is 150mm (6 in) - the height of one course. The 19mm (¾ in) offset must be accounted for at each step.



### PLACE FILTER CLOTH

Lay the approved filter fabric (geotextile) along the bottom of the rear (150mm [6 in]) of the excavation and extend up the exposed cut face to the proposed wall height. Leave adequate material at the top to fold back towards the wall (completely containing the infill material). Stake the filter cloth against the slope during construction.



### PLACE THE DRAIN

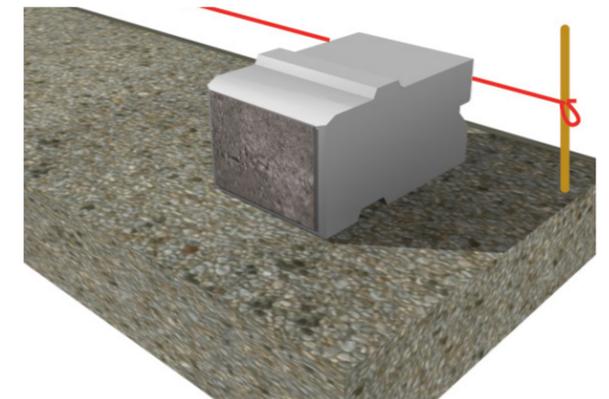
Various options for drain placement may exist, depending on how the pipe is to be outlet (refer to Drainage). The drain may be outlet through the wall face or connected to a positive outlet (storm drain).

The drainage system is extremely important and outlets must be planned prior to construction. In the case of connecting to a positive outlet, the drain should be placed at the lowest possible elevation and sloped at a minimum of 2%. At the rear of the base, allow the granular material to slope down on the sides towards the drain trench. In the 150mm (6 in) area behind the base, place the approved drain tile (perforated drain with filter sock) on top of the filter cloth and minimal granular coverage.



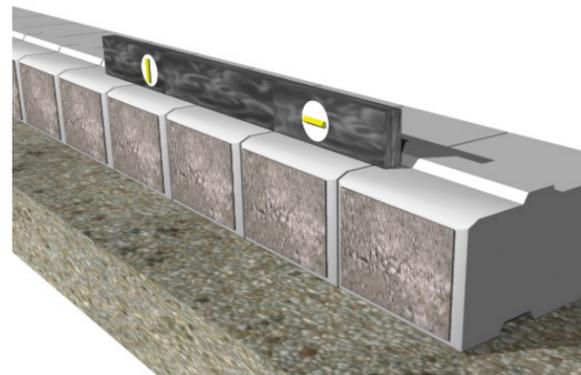
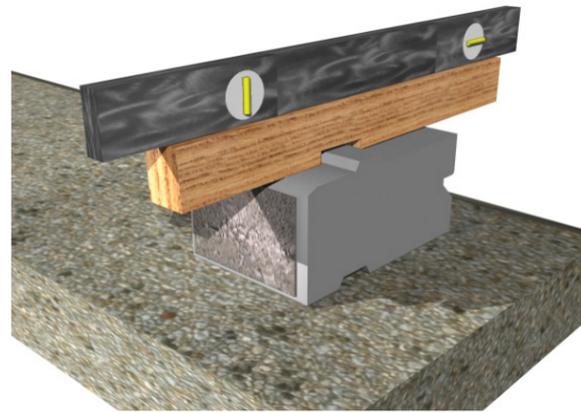
### PLACE THE FIRST COURSE

Split units apart using a chisel and hammer if not already pre-split by manufacturer. Position a level string to mark location of first course (should be 450mm [18 in] from the front edge of the granular base). Place the first course of Pisa units side-by-side (touching) on the granular base.



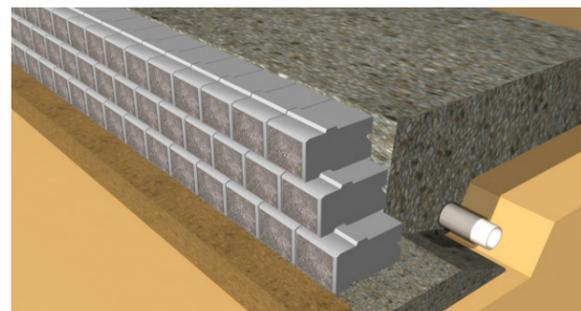
Ensure units are level front to back and left to right. Extra care should be taken at this stage as it is critical for accurate alignment.

## REINFORCED SRW INSTALLATION PROCEDURE



### STACK THE UNITS

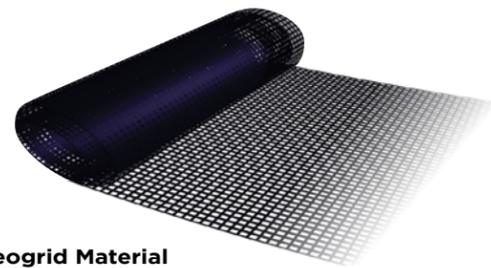
Sweep top of underlying course and stack next course in a running bond pattern so that the middle of the unit is above the joint between adjacent units below. Continue stacking courses up to the elevation of the first layer of geogrid or to a maximum of four courses (600mm [24in]) before backfilling.



### BACKFILL

Begin backfilling the wall. Risi Stone Inc. recommends using a well-graded, free-draining (less than 8% fines), angular granular material. The infill material is placed in

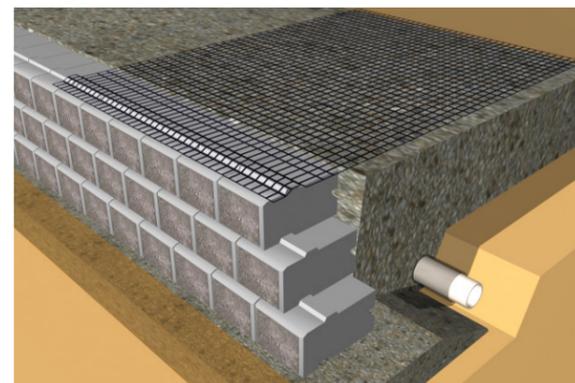
maximum 150mm–200mm (6in–8in) lift thicknesses and compacted to a minimum of 95% SPD. The compaction must be checked by the GRE at regular intervals. Continue backfilling up to the elevation of the first layer of geogrid reinforcement. Caution must be taken to ensure the allowable lift thickness is not exceeded and/or heavy compaction equipment is not operated within 1m (3.25ft) of the back of the wall (only hand-operated plate compactor). Overcompaction behind the wall facing will result in an outward rotation of the units and poor vertical alignment. Refer to Alternate Backfill Materials for other infill options.



**Geogrid Material**

### INSTALL GEOGRID REINFORCEMENT

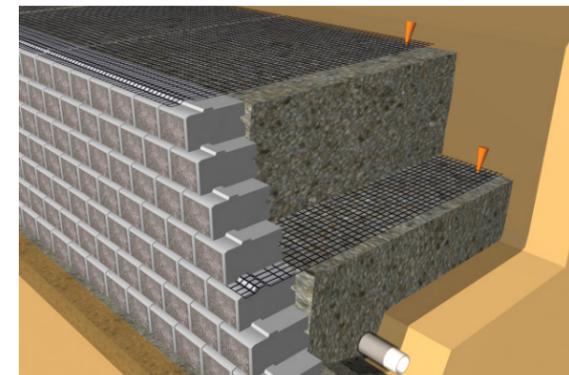
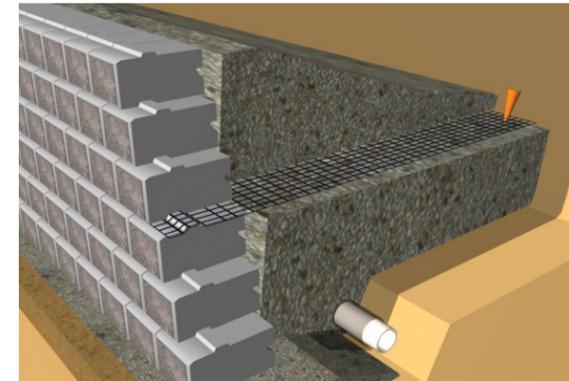
Ensure the geogrid reinforcement specified in the design matches the product on site (no substitutes are acceptable without consent of design engineer). Cut the geogrid from the roll to the specified length, ensuring the geogrid is being cut perpendicular to the direction of primary strength. Ensuring the Pisa units are free of debris, lay the geogrid on top of the units to within 25mm (1in) of the face. Place the next course of Pisa units (as described above) to secure the geogrid in place. Pull the geogrid reinforcement taut across the infill material to its full length and stake in place to maintain tension. The backfill material should be level with the back of the Pisa unit, allowing the geogrid to be laid out horizontally.



## REINFORCED SRW INSTALLATION PROCEDURE

### BACKFILL OVER GEOGRID REINFORCEMENT

Backfill next lift of granular infill material on top of the geogrid reinforcement, placing the loose material at the front of the wall, and raking it back, away from the face (this method maintains tension in the geogrid during backfilling). Continue stacking and backfilling until the next layer of geogrid reinforcement is reached.

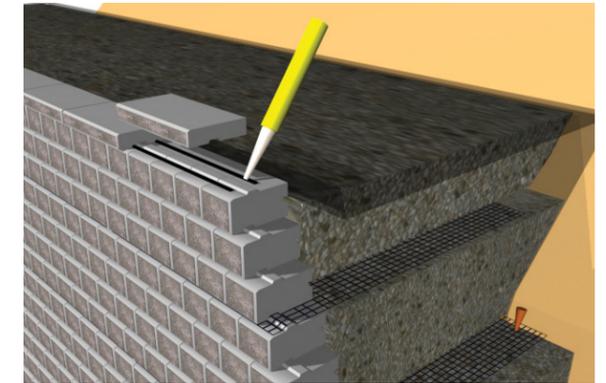


### CONTINUE STACKING AND BACKFILLING

Continue placing the Pisa units, backfilling, and laying the geogrid reinforcement as described above until the desired wall height is reached.

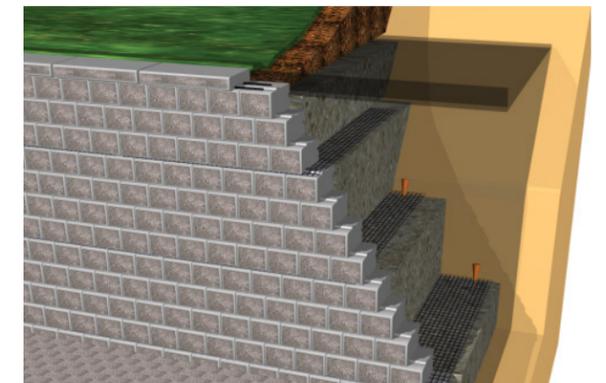
### PLACE COPING UNIT

Various coping units are available depending on the alignment of the wall and desired look. Concrete adhesive must be applied to the top course in order to fix the coping units in place. Place the coping unit firmly on top of the adhesive, ensuring both surfaces are free of debris, and apply pressure to secure. Follow adhesive installation guidelines.



### ENCAPSULATE THE GRANULAR INFILL AND FINISH GRADING

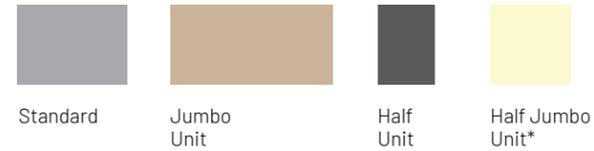
Fold the excess filter fabric over the top of the infill zone (reinforced zone) and extend up the back face of the coping unit. Ideally, place an impervious layer of soil on top of the filter fabric and compact manually, providing for the required grading and/or swales. For other treatments such as pavers, concrete, or asphalt, care must be taken to ensure that heavy compaction/paving equipment remains a minimum of 1.0m (3.25ft) from the back of the coping unit. Slope the surface above and below the wall to ensure water will flow away from and not accumulate near the wall units.



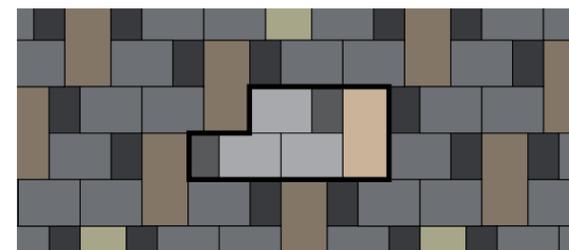


## PATTERNS

\*(Must be cut by installer)



RomanPisa is available in some areas with extra units to create a more natural looking wall. Components include the Standard Unit, a Jumbo unit that is 50% wider than the standard unit, and a Half unit that is 50% narrower than the standard unit. Some of the patterns also require the installer to cut some Jumbo units in half to achieve the right look.



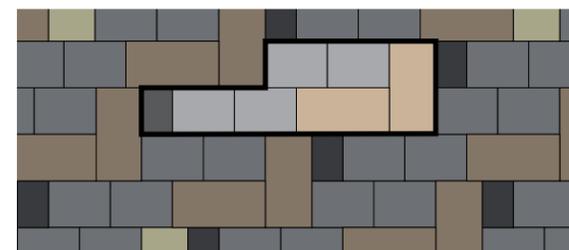
pattern **one**

Per 100 ft<sup>2</sup>: 164 Standard (54 ft<sup>2</sup>) 110 Half (18 ft<sup>2</sup>)  
56 Jumbo (28 ft<sup>2</sup>)



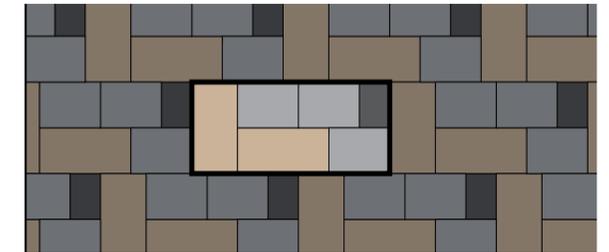
pattern **two**

Per 100 ft<sup>2</sup>: 164 Standard (54 ft<sup>2</sup>) 110 Half (18 ft<sup>2</sup>)  
56 Jumbo (28 ft<sup>2</sup>)



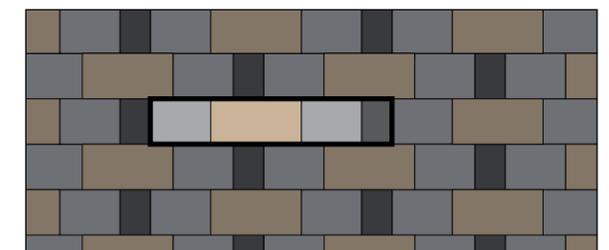
pattern **three**

Per 100 ft<sup>2</sup>: 160 Standard (53 ft<sup>2</sup>) 42 Half (7 ft<sup>2</sup>)  
80 Jumbo (40 ft<sup>2</sup>)



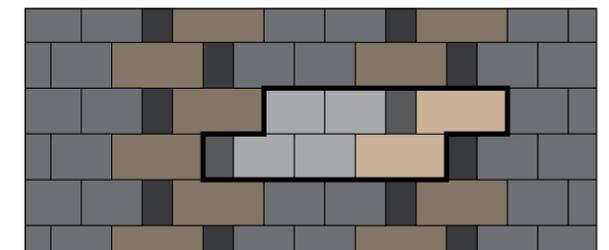
pattern **four**

Per 100 ft<sup>2</sup>: 139 Standard (46 ft<sup>2</sup>) 47 Half (8 ft<sup>2</sup>)  
93 Jumbo (46 ft<sup>2</sup>)



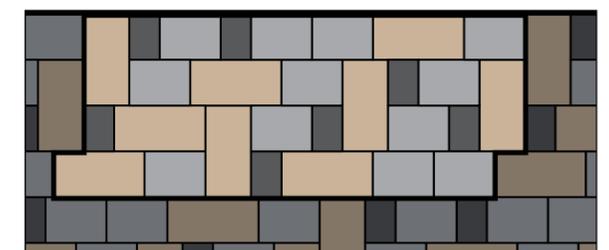
pattern **five**

Per 100 ft<sup>2</sup>: 150 Standard (50 ft<sup>2</sup>) 75 Half (12 ft<sup>2</sup>)  
75 Jumbo (38 ft<sup>2</sup>)



pattern **six**

Per 100 ft<sup>2</sup>: 150 Standard (50 ft<sup>2</sup>) 75 Half (12 ft<sup>2</sup>)  
75 Jumbo (38 ft<sup>2</sup>)



pattern **seven**

Per 100 ft<sup>2</sup>: 124 Standard (41 ft<sup>2</sup>) 73 Half (12 ft<sup>2</sup>)  
94 Jumbo (47 ft<sup>2</sup>)

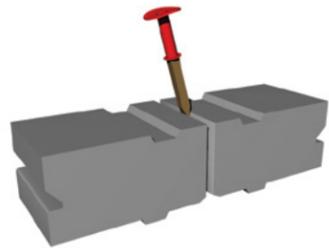
## DETAILS

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## WALL DETAILS

### SPLITTING PISA UNITS

Pisa units may be delivered to the site as an unsplit double unit. Using a hammer and chisel, split the double unit along the splitting groove provided. This technique results in a fresh, exposed-aggregate appearance.

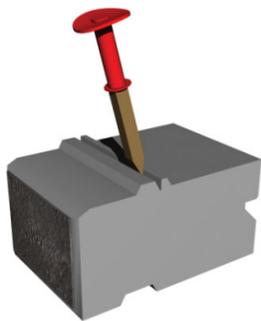


### CREATING VERTICAL PISA UNITS

Standard Pisa units feature an offset tongue and groove to maintain a 1H:8V automatic alignment. In cases where a vertical wall is required, the tongue may be modified to allow a vertical alignment.

Some manufacturers produce Pisa units with an existing splitting groove. Otherwise, saw cut the tongue along a line 19mm (¾ in) from the rear of the base of the tongue, then split back portion off with hammer and chisel. Removal of the rear 19mm (¾ in) cancels out the offset and creates a vertical alignment.

Caution should be taken when constructing vertical walls, as no margin for lateral movement exists. It is recommended that the base of a vertical wall be sloped back (approx. 2%) to accommodate natural lateral movements and rotation that may occur during and after wall construction.



### ROCK FACING REVERSACAP

To achieve a split-rock face on the ReversaCap coping unit, use a hammer and chisel to score the top and sides, then flip the unit upside down and use the existing splitting groove to remove the front portion of the unit. This may require a couple of break points along the groove to achieve a clean break.

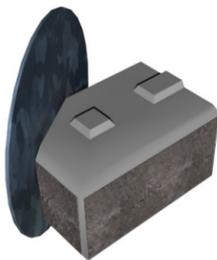


### CREATING A 45° CORNER UNIT

A left/right 45° outside corner unit begins with a left/right 90° outside corner unit.



Sawcut the smooth side of the corner unit at a 45° angle. The cut begins 140mm (5.5 in) from the rear of the unit.



Score the top and bottom of the opposite side of the unit to a depth of approximately 12mm (0.5 in) at a 45° angle. The score line starts 200mm (7.87 in) from the rear of the unit.

Using a chisel and hammer, break off the corner of the unit to reveal a rock-faced 45° unit.

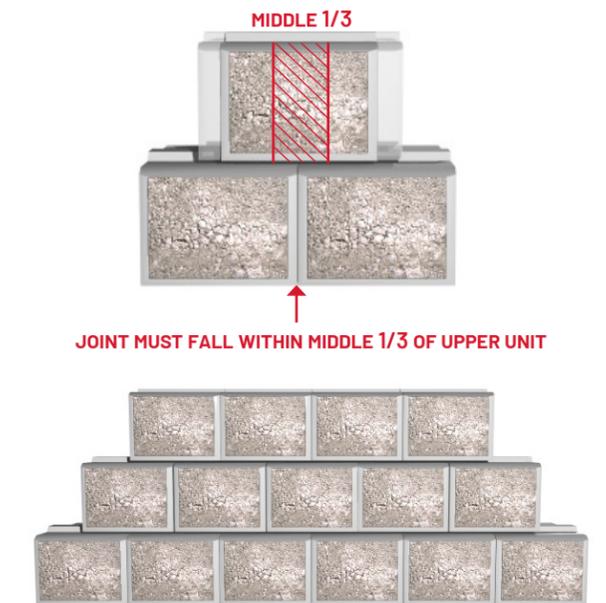


Remove knob.



### RUNNING BOND PATTERN

Stack the units in a running bond pattern so that middle of the upper unit is above the joint between adjacent blocks below.



*[Note: When certain details – such as corners and curves – are incorporated into the wall, the running bond pattern may shift slightly. A small deviation from the perfect running bond pattern is allowable. However, this deviation should be corrected as soon as the wall layout allows.]*

## CORNERS

### INSIDE 90° CORNER

Place units on base course leading to the corner. Place corner unit so that the smaller rough face will be hidden in the final construction. It may be necessary to remove bumps and bulges from the larger rough face to achieve a tighter fit.

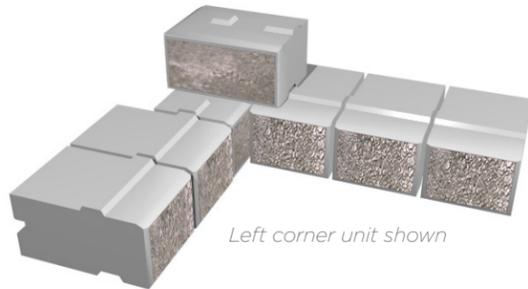


Right corner unit shown

Continue placing base course units on adjacent wall. The smooth face of the corner unit allows for a tight fit.

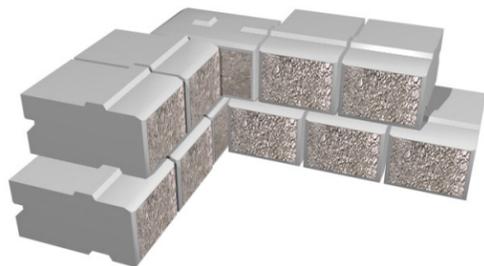


Commence second course by placing alternate corner unit to interlock corner.

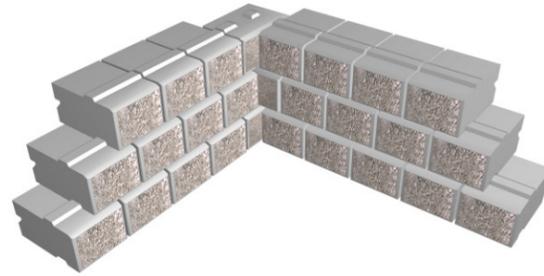


Left corner unit shown

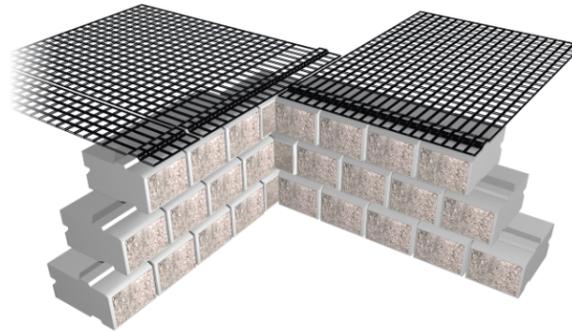
Place standard units to complete the course.



Repeat until desired wall height is achieved.



The geogrid should be placed within 25mm (1in) of the face of the block. As it is only necessary to have geogrid extending directly away from the wall, a gap will result in the geogrid layer as shown.

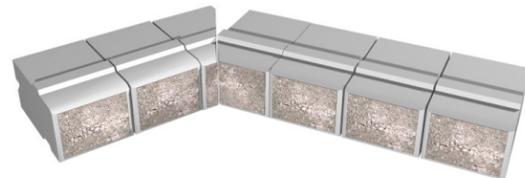


### INSIDE ODD-ANGLED CORNER

This orientation can be used for any inside angle, including 90°. Place units on base course leading to the corner. Cut left corner off the innermost unit at an angle equal to ½ the desired off angle, leaving ¾ of face.



Cut right corner off adjacent unit at the same angle, leaving ¼ of the face, and continue placing base course units on adjacent wall.



Cut right corner at desired angle, leaving ¾ of the face.



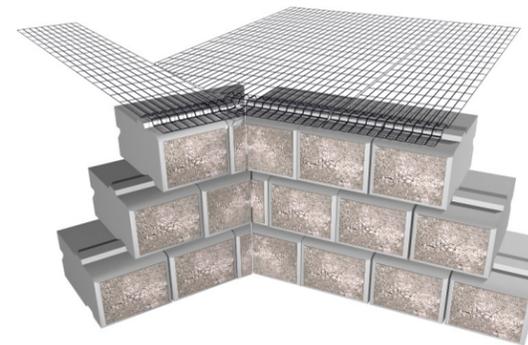
Cut left corner at desired angle, leaving ¼ of the face, and place standard units to complete the course.



Repeat until desired wall height is achieved.

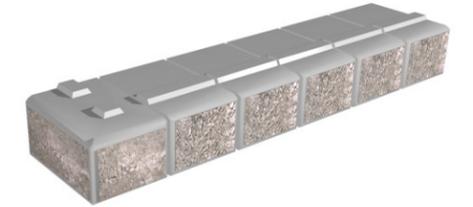


The geogrid should be placed within 25mm (1in) of the face of the block. As it is only necessary to have geogrid extending directly away from the wall, a gap will result in the geogrid layer as shown.

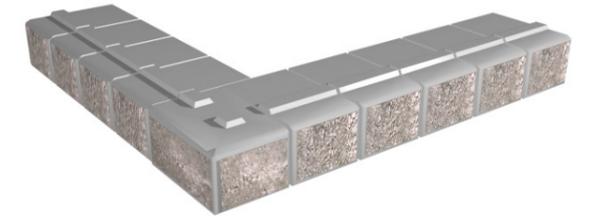


### OUTSIDE 90° CORNER

Place units on base course leading to the corner. Place corner unit (right corner shown) so both rough faces will be exposed in the final construction.



Continue placing base course units on adjacent wall.



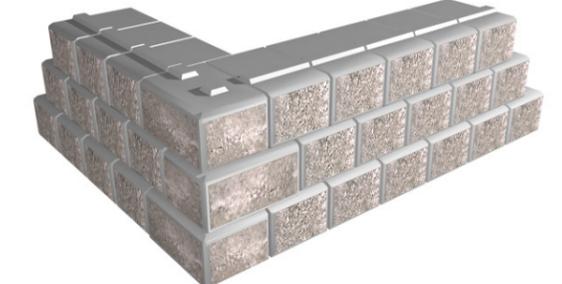
Commence second course by placing alternate corner unit (left corner shown) to interlock corner.



Place standard units to complete the course.



Repeat until desired wall height is achieved.



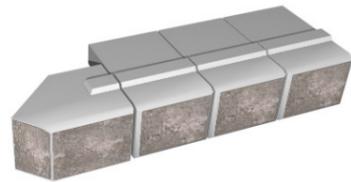
## CORNERS

The geogrid from the two side walls will overlap and should be separated by a minimum of 75mm (3in) of compacted soil. Alternatively, the geogrid reinforcement could be placed in the perpendicular principle direction in the cross-over area on the succeeding course.



### OUTSIDE 45° CORNER

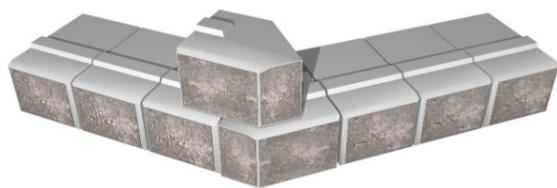
Place units on base course leading to the corner. Place modified corner unit (modified left corner shown) so both rough faces will be exposed in the final construction.



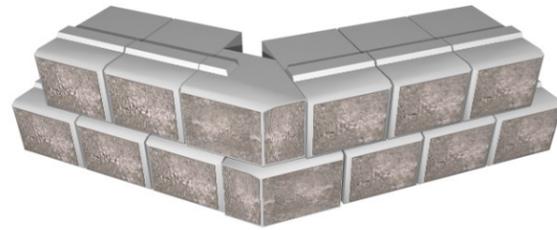
Continue placing base course units on adjacent wall.



Commence second course by placing alternate modified corner unit (modified right corner shown) to interlock corner.



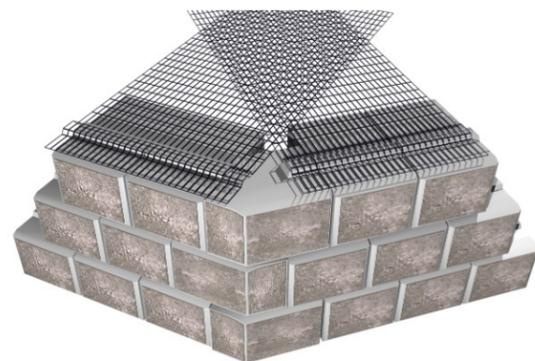
Place standard units to complete the course.



Repeat until desired wall height is achieved.



The geogrid from the two side walls will overlap and should be separated by a minimum of 75mm (3in) of compacted soil. Alternatively, the geogrid reinforcement could be placed in the perpendicular principle direction in the cross-over area on the succeeding course.

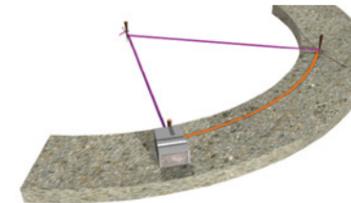


## CURVES

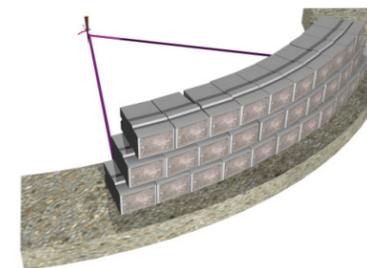
### CONVEX CURVE

The Pisa system is able to create a 2.4m (8ft) radius with the tapered units on a convex curve; however, in preparation for the bottom course, remember that the radius will decrease by 19mm (3/4in) every course. Therefore, the smallest curve will result on the uppermost course. Also, the vertical joints will start to line up on successive courses, making it necessary to place half units at random locations.

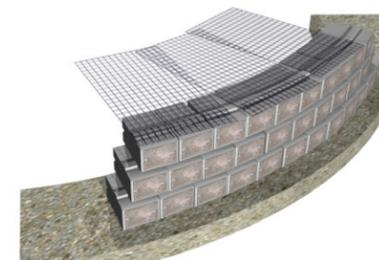
Once the radius to be used is decided upon and the necessary curve for the base course is calculated, the base can be roughly outlined with spray paint. Upon completion of the base, the starting and ending points of the curve can be staked. The curve should be marked with paint to ensure the proper radius is established. If the base course is installed with too tight a radius, the upper courses may have to be cut to fit.



Place additional courses, remembering that the radius decreases by 19mm (3/4in) every course until desired height is achieved.



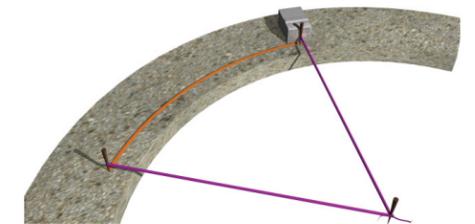
Geogrid layers should be placed within 25mm (1in) of the front face of the block. The geogrid will overlap and should have 75mm (3in) of compacted soil between the layers. The geogrid should be placed on the Pisa units so the geogrid does not overlap until it enters the soil zone.



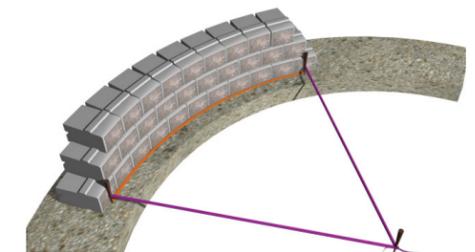
### CONCAVE CURVE

For concave curves, the Pisa standard units are able to create a minimum 2.4m (8ft) radius. The smallest radius will occur on the bottom course. Each additional course will result in a 19mm (3/4in) increase in the radius. Also, the vertical joints will start to line up on successive courses, making it necessary to place half units at random locations.

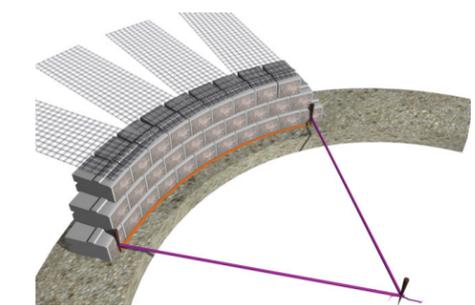
Once the radius to be used is decided upon and the necessary curve for the base course is calculated, the base can be roughly outlined with spray paint. Upon completion of the base, the starting and ending points of the curve can be staked. The curve should be marked with paint to ensure the proper radius is established.



Place additional courses, remembering that the radius decreases by 19mm (3/4in) every course until desired height is achieved.



Geogrid layers should be placed within 25mm (1in) of the front face of the block. It will be necessary to have gaps between adjacent sections of geogrid. At alternating geogrid elevations the geogrid sections should be positioned so they overlap the gaps in the geogrid on the layers below.



## COPING

A coping stone is the last course of units placed on a wall. It could easily be termed the capping unit. The coping unit aesthetically and structurally completes a wall's construction. For the Pisa system it is important to use an adhesive to secure the coping unit to the top of the wall.

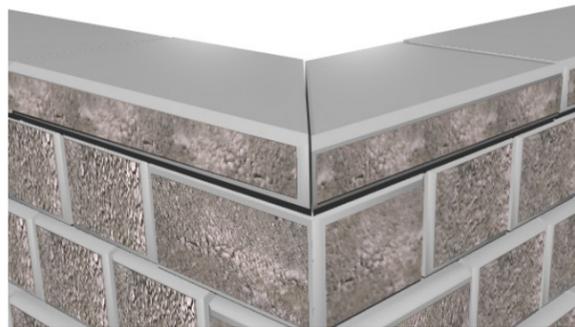
### REVERSACAP COPING UNIT

We recommend that ReversaCap coping units be used for inside and outside 90° corners. ReversaCap combines the ability to cope both straight and small radius curves using one type of unit. The units are manufactured with a smooth face, a thin slice can be removed from the face of the unit to create a rough finish.



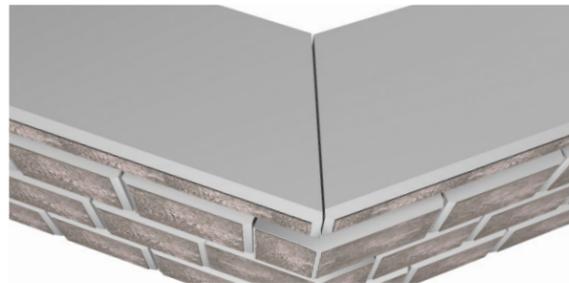
### PISASTONE COPING UNIT

If you are using PisaStone coping units, mitre cut the units to create 90° inside and outside corners. Like Pisa, the units are separated using a hammer and chisel. It is important to use an adhesive to secure the PisaStone coping unit to the top of the wall. PisaStone coping units are best suited to coping straight sections of wall. Closed-end coping units can be used to hide the tongue and groove connection, seen on the side of the unit where the top of the wall steps down.



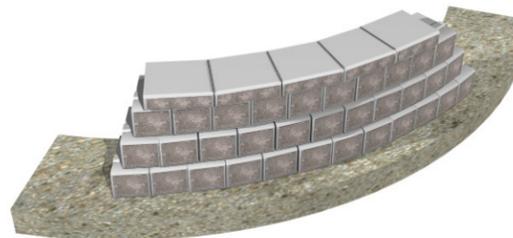
### ODD-ANGLED CORNER

If you have to construct an odd-angled corner, we recommend using a mitre-cut PisaStone coping unit. A mitre corner uses two PisaStone coping units that meet at an odd-angled corner (see photo below). The coping units will have to be cut (mitred) to butt up next to each other at the same angle as the corner. The mitre angle is determined by taking the corner angle and dividing by two. For example, if you have a 60° corner, you will have to mitre the coping unit at a 30° angle.

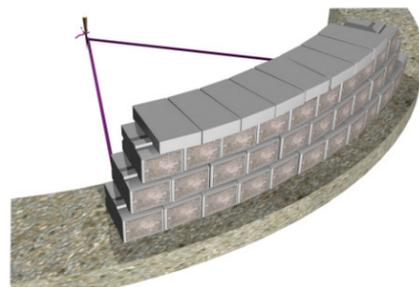


### COPINGS FOR CURVES

The PisaStone coping units can be saw cut to create a curve. Attach the PisaStone coping units to the Pisa units using an approved concrete adhesive.



The ReversaCap coping units can be placed with the wide face positioned the same way to create a curve. If the radius is greater or less than 2.4m (8ft), the ReversaCap coping units will require several cuts to create a continuous top surface.



## FENCES & RAILS

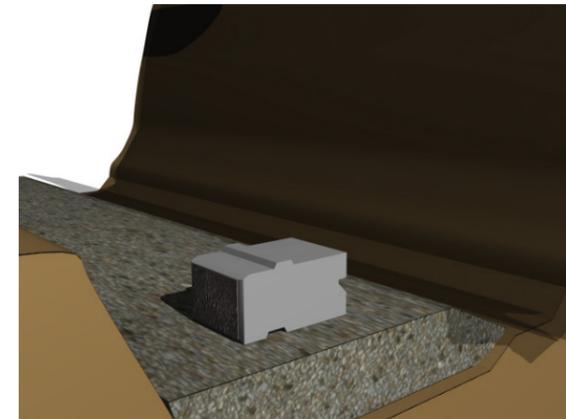
### CONVENTIONAL SRWS

Handrails/fences are usually required for most walls over 600mm (2.0ft) in height where pedestrians have access (check with your local building code). These handrails must act to resist potential lateral pedestrian loads. **Handrails must not be secured to the Pisa retaining wall.**

Concrete sonotubes, placed behind the wall, should be utilized to found the handrail into undisturbed native ground. Wood/vinyl fences (solid) that take a wind load produce extremely high loads and footing depth must be designed accordingly. The sonotubes must extend below the base of the wall into a firm "socket" of soil.

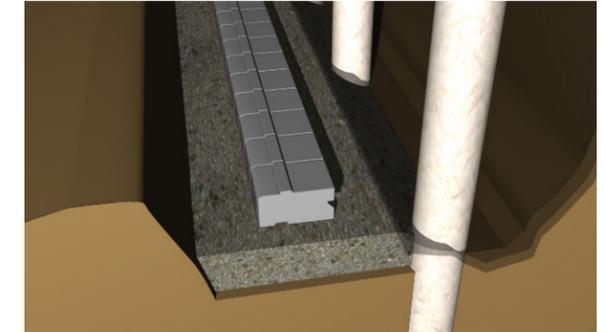
The depth must be sufficient to independently (i.e. without the aid of the Pisa retaining wall) resist the lateral handrail loads. This depth is normally a minimum of 1.2m (4.0ft) below the bottom of the wall for non-solid handrails, and deeper for solid (wood/vinyl) fences.

Excavate, prepare base, lay filter cloth against cut face, and define location of base course (see Installation - Conventional SRW).

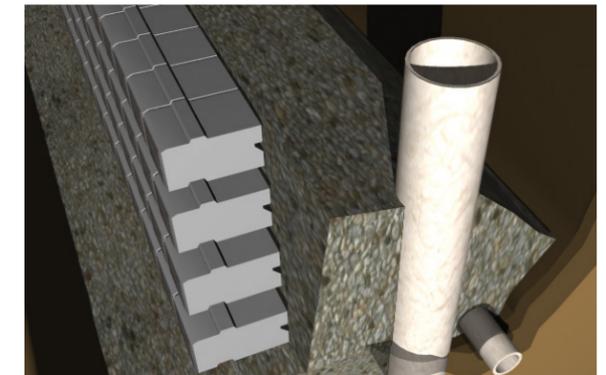


Identify the proposed location of the handrail foundations (sonotubes). Take into account the batter (setback) of the wall (19mm [¾in] per course) and the required offset at the top. It is preferable to leave a 300mm (12in) buffer zone between the outside of the sonotube and the back of the wall. If this is not possible, expansion joint material must be placed between the back of the coping unit and concrete sonotube.

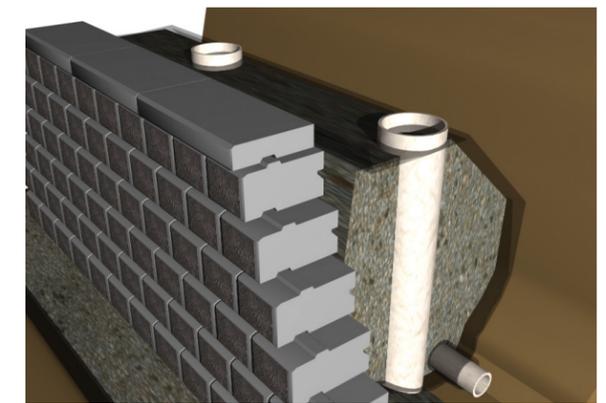
Refer to the design for the required depth, and auger the foundation hole into the native subgrade. The sonotube length is equal to the total wall height plus the required embedment. Place the sonotube into the "socket" of competent subgrade.



Construct the conventional SRW, stacking units and backfilling with drainage material. The recommended drainage material (¾in clear stone) should be lightly compacted with a hand tamper, ensuring proper confinement around the sonotube.

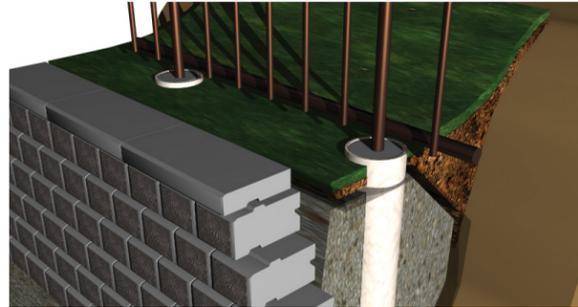


Secure the coping unit and fold filter cloth back over drainage material. Cut filter cloth at centerline of sonotube to allow the sonotube through, ensuring complete coverage of drainage material. Cover sonotubes prior to concrete pour to prevent debris from entering.



## FENCES & RAILS

Pour concrete in foundations in accordance with handrail design (reinforcing steel and/or dowels may be required). Install fence and finish grading.



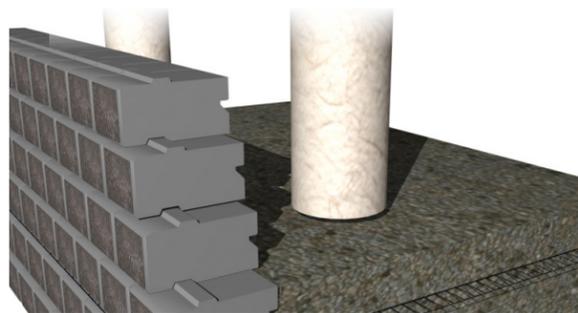
### GEOGRID-REINFORCED SRWS

Handrails/fences are usually required for most walls over 600mm (2.0ft) in height where pedestrians have access (check with your local building code). These handrails must act to resist potential lateral pedestrian loads. Handrails must not be secured to the Pisa retaining wall. Concrete sonotubes, placed behind the wall, should be utilized to found the handrail/fence into the reinforced soil zone.

Loads created by pedestrians and/or wind on the handrails/fences must be incorporated into the geogrid design. As the sonotube depth increases, the additional lateral force generated in each geogrid is reduced. Wood/vinyl fences (solid) that take a wind load produce extremely high loads. Generally, foundations for these types of structures should extend more than the height of the fence into the reinforced soil, and the geogrid layout designed accordingly. For handrails that allow wind to pass through, normal depth is approximately 1.2m (4ft).

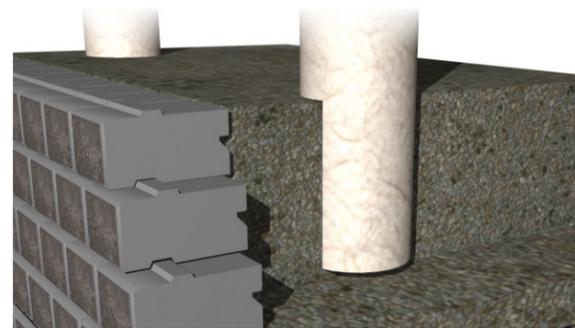
Construct the geogrid reinforced Pisa SRW up to the elevation corresponding to the underside of the handrail/fence foundation (concrete sonotube).

Identify the proposed location of the handrail/fence foundations (sonotubes). Take into account the batter (setback) of the wall (19mm (3/4 in) per course) and the



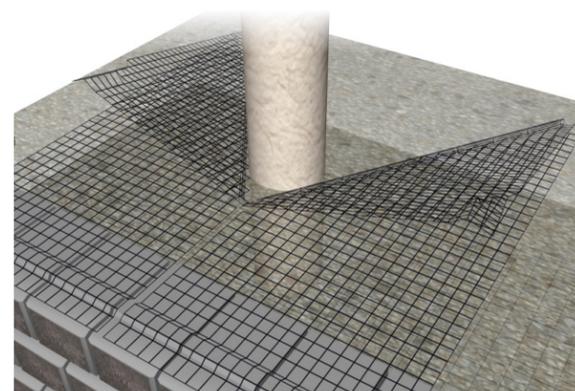
required offset at the top (It is preferable to leave a 300mm [12 in] buffer zone between the outside of the sonotube and the back of the wall. If this is not possible, expansion joint material must be placed between the back of the coping unit and concrete sonotube).

Place the sonotube and backfill around it to hold it in place. Continue stacking units, backfilling and compacting to 95% SPD until the next geogrid layer is reached.



Cut the geogrid perpendicular to the wall along the centerline of the sonotube, creating two geogrid panels – one on each side of the sonotube. Lay the geogrid flat in front of the sonotube. At the intersection with the sonotube, fold the geogrid flat against vertical side of the sonotube and then around the back, maintaining the edge of the geogrid along the centerline of the sonotube.

Lay the geogrid flat behind the sonotube and pull taut. Secure the geogrid in place at the face (with the next course) and at the rear (with stakes) and continue backfilling.



Repeat the previous step for each layer of geogrid encountered by the sonotube.

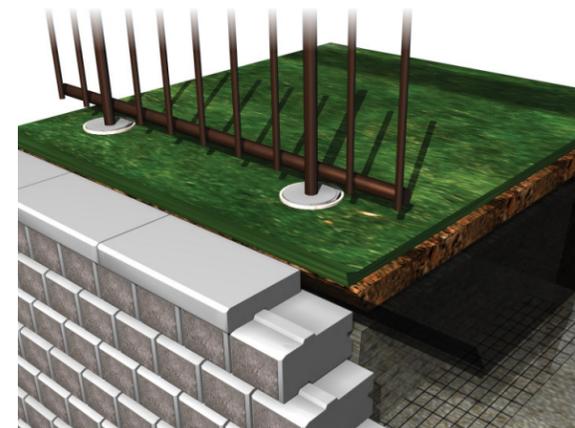
Secure the coping unit and fold filter cloth back over drainage material. Cut filter cloth at centerline of sonotube to allow the sonotube through (similarly to method used

to allow sonotube to penetrate geogrid layer), ensuring complete coverage of reinforced material. Cover sonotubes prior to concrete pour to prevent debris from entering.

Pour concrete in foundations in accordance with fence/



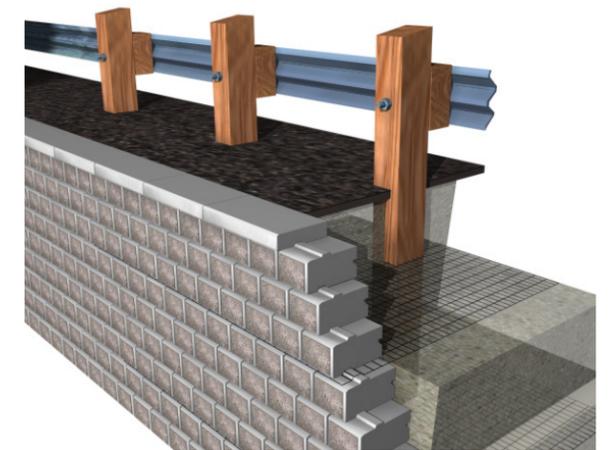
handrail design (reinforcing steel and/or dowels may be required). Install fence and finish grading.



## GUARDRAILS

For areas adjacent to roadways and parking lots, flexible steel beam guiderails may be placed behind a geogrid reinforced Pisa SRW in accordance with the applicable governing standards. Additional "crash" loads must be accounted for in the design of the wall.

Accepted procedures usually require the guiderail posts to be offset a minimum of 1m (3ft) from the back of the wall, extending a minimum of 1.5m (5ft) into the reinforced zone. It is recommended that the posts be placed as the wall is constructed (refer to handrail construction) and compaction surrounding the posts be carefully monitored to ensure optimum confinement.



## DRAINAGE

Proper drainage of a segmental retaining wall is one of the most critical aspects of design and construction. Unless otherwise stated, the design assumes that no hydrostatic pressures exist behind the wall.

To ensure this condition is met, water flow from all directions and sources must be accounted for in the design through proper grading and drainage measures, diverting water away from the wall whenever possible.

### INTERNAL DRAINAGE

This chart explains and illustrates the four different internal drainage possibilities.

### OUTLET TO CATCH BASIN / DRAIN

If the drain is being connected to a catchbasin or other positive outlet, it should be located at the lowest elevation possible. Placing the drain at the founding elevation ensures better drainage of the base and subsoils. A minimum 2% slope is recommended.

### OUTLET THROUGH FACE

If the drain is being outlet through the face of the wall, it is recommended that an approved, less pervious engineered fill material be compacted under the drain up to the grade in front of the wall. This measure collects water percolating through the reinforced zone and directs it to the drain, rather than allowing the base to become saturated. The outlet pipe should be a non-perforated PVC (connected through a T-joint) placed a minimum of 15m (45ft) on centre (or as required by the design). Cutting a half Pisa unit allows the pipe through the wall face without losing the running bond pattern. It is recommended that the area around the pipe be grouted to prevent the washout of fines. A concrete splash pad at the outlet pipe locations is recommended if large water flows are anticipated.

### NON-FREE-DRAINING REINFORCED ZONE

If the infill material being used to construct the reinforced zone is not considered to be free draining (>8% fines), a drainage layer is required immediately behind the face of the wall.

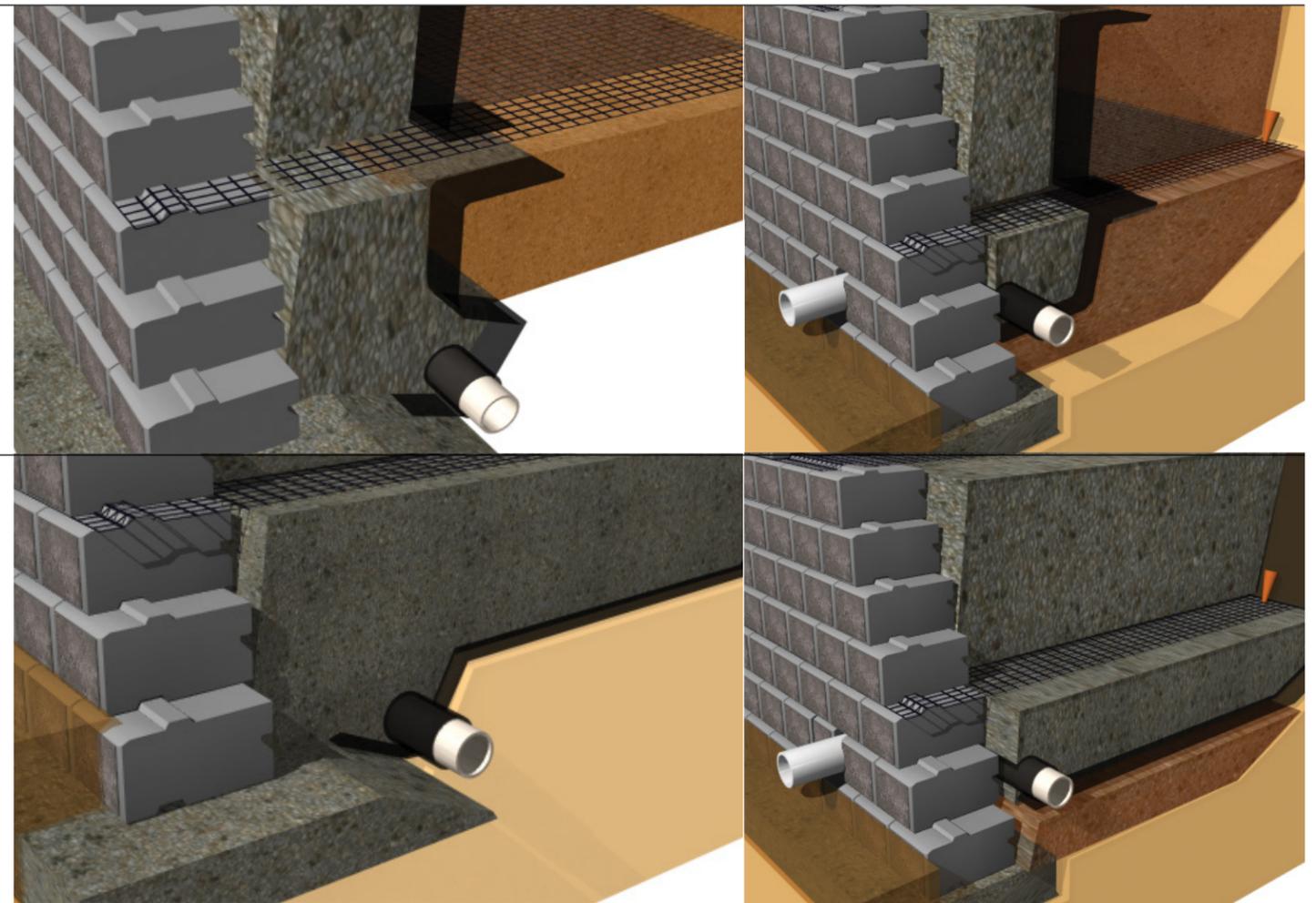
The drainage material must be a minimum of 300mm (12in) thick, composed of a gap-graded, free-draining, angular clear stone (19mm [ $\frac{3}{4}$ in]). An approved filter cloth must be placed between the drainage layer and the infill material to prevent the migration of fines and contamination of the drainage material. At each geogrid layer, the filter cloth must be pulled back into the reinforced zone a minimum of 150mm (6in) and cut.

The drainage layer must be fully encapsulated with a 150mm (6in) overlap at each geogrid elevation as shown.

### FREE-DRAINING REINFORCED ZONE

As the construction of a separate drainage layer immediately behind the facing units can be cumbersome and reduce efficiency, a popular option is to use a free-draining, granular material for the reinforced zone. It is recommended that this material be well-graded, with less than 8% fines.

An approved filter cloth should be placed between the reinforced zone and retained and foundation soil to prevent the migration of fines. The use of an imported granular material in the reinforced zone has many other advantages besides its good drainage properties (see Specifications - Soils).

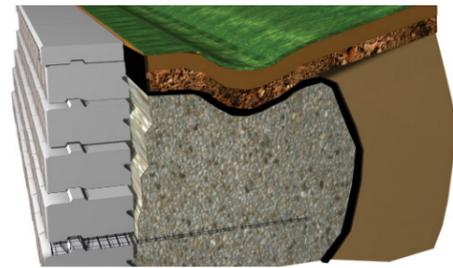


**EXTERNAL DRAINAGE**

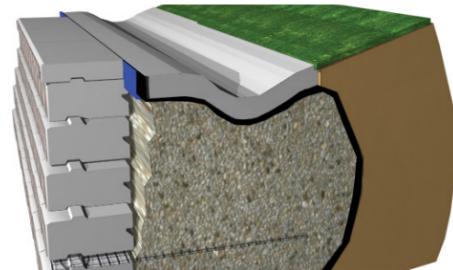
**Swales**

The use of swales above and below the walls to divert water away is an effective, low-cost method of ensuring good drainage. The swale must be composed of an impervious or low permeability material (asphalt / concrete or approved clay). The swale must be designed (dimensioned) by the Civil Engineer as part of the overall site drainage plan.

**Clay Swale**

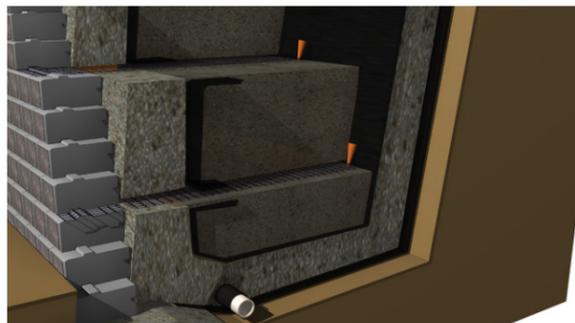


**Concrete Swale**



**Blanket / Chimney Drains**

Where high groundwater flows are anticipated, the use of blanket drains (drainage layer extended horizontally along the base of the wall) or chimney drains (drainage layer extended up the back of the infill zone to intercept groundwater flows) prevent infiltration in the Pisa structure. Refer to the NCMA manual for drainage options under various groundwater conditions.

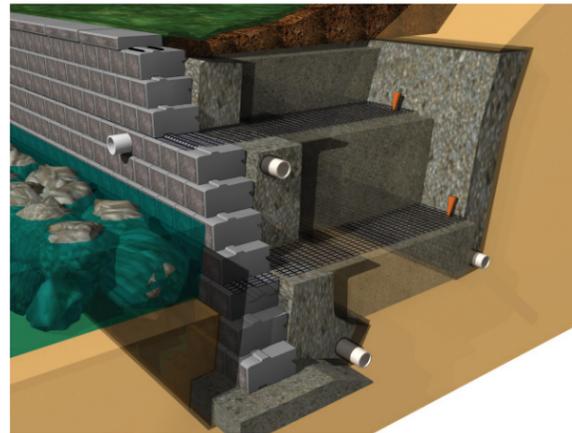


**WATER APPLICATIONS**

Pisa geogrid reinforced segmental retaining walls may be used in water applications such as lake/river shorelines, detention ponds, etc. A number of additional issues must be considered when designing and constructing in this type of application, such as erosion of the base/foundation, wave effects, perched water conditions, and ice effects.

The Pisa wall analysis must incorporate the effects of buoyant unit weights, rapid draw-down conditions, etc., when determining geogrid length, type, and placement.

The required wall embedment normally increases as the potential for erosion becomes a factor. A minimum 600mm (2ft) embedment is standard practice. As well, rip-rap or other forms of erosion protection may be required.



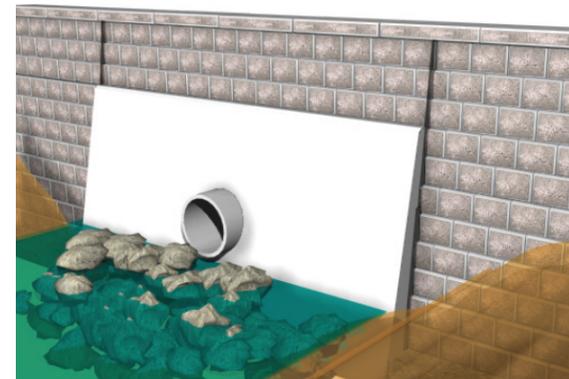
The footing may be concrete or standard granular wrapped in filter cloth to prevent washout. If the potential for rapid draw-down (water level falling quicker in front of the wall than the backfill material will allow) exists, the infill material must be chosen to reduce the effects. It is recommended that a clear-stone drainage layer be used in conjunction with a well-graded, free-draining, granular reinforced zone. The filter cloth used between the drainage layer and reinforced zone should be selected taking into account the two types of granular materials.

The placement of drains is based on the anticipated normal and high water levels. An outlet through the wall face should be placed above the normal and high water levels at maximum 15m (45ft) on centre. If the groundwater level is expected to fall below the foundation elevation, an additional drain should be added at this level. As well, a chimney or blanket drain may also be required depending on conditions. If ice or wave effects are anticipated, rip-rap protection must be designed accordingly.

**WALL AROUND BOX CULVERT**

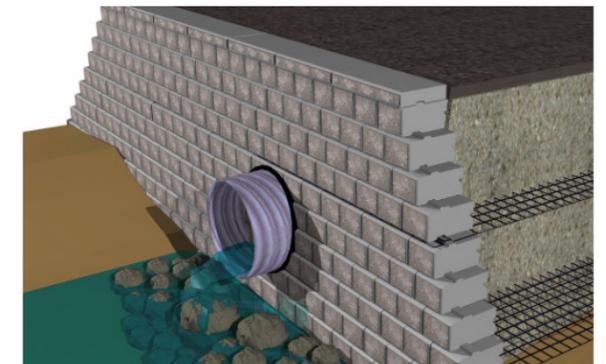
The key point in building this wall is to structurally separate the concrete headwall plus the above Pisa units from the other part of the walls by a 25mm asphalt-impregnated fibreboard expansion joint.

The picture shows the bottom of Pisa units resting on top of the headwall. However, this may not actually happen on site. A layer of mortar may have to be used to raise the elevation of the headwall to the top of the adjacent units.



**ROUND CULVERT THROUGH WALL**

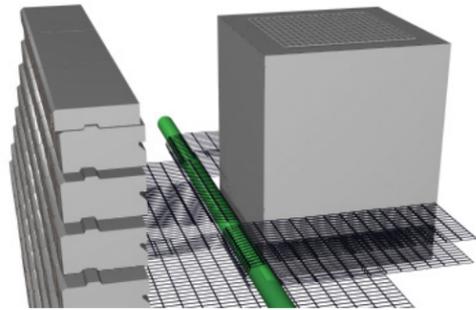
A culvert may be outlet through the face of the wall, providing the pipe has been designed to withstand the load of the wall above it and no excessive settlement is anticipated which may alter the alignment of the pipe. Once these issues have been addressed, the Pisa units can be cut to fit on site. A 25mm asphalt-impregnated fibre board expansion joint should be placed around the pipe to ensure a tight fit and prevent the infill material from washing out. Rip-Rap is also required to protect the base from washout.



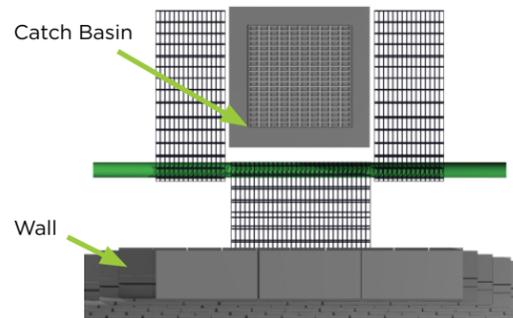
## OBSTRUCTIONS

### CATCH BASIN

When a catch basin is interfering with the placement of the geogrid reinforcement as specified by the site-specific design, the following steps can be taken.



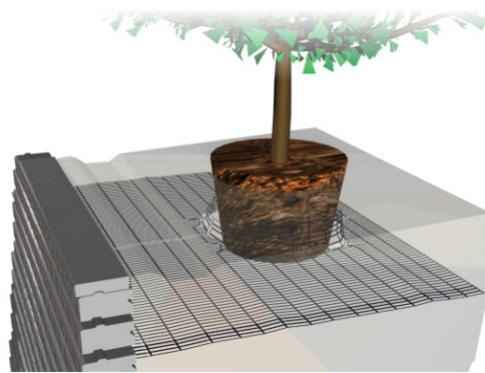
Select an appropriately sized steel pipe with a length of at least twice the width of the catch basin. Extend the geogrid from the specified layer and wrap it around the pipe back to the course below. Place a width of geogrid reinforcement (half the catch basin width) on either side of the catch basin, wrap around the pipe and extend into the infill material. Ensure that the geogrid extends the distance into the infill material as specified in the design.



### TREES

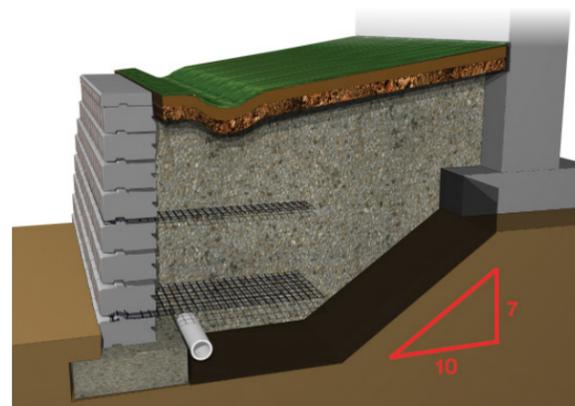
When planting trees or shrubs behind Pisa walls, a few steps must be taken to ensure the stability of the wall. The root ball should only impact the top two layers of the geogrid reinforcement. The geogrid should be cut perpendicular to the wall along the centerline of the root ball and placed flat. At the intersection with the root ball, geogrid should be folded up the sides around to the back, maintaining the edge of the geogrid along the centerline of the root ball. Small trees (max. 0.915m [3ft]) may be placed a minimum of 1.5m (5ft) from the face of the wall. Larger trees (max. 1.8m [6ft]) are to be placed a minimum

of 3m (10ft) from the face of the wall. The distances are required to avoid root growth into the Pisa units and to reduce the wind loading effects caused by the trees. Note that if multiple trees are to be planted, a qualified Engineer should be contacted to assess the impact of the geogrid cuts. A root barrier may also be required to avoid root growth towards the Pisa wall and drainage layer.



### STRUCTURES

Retaining walls constructed near structures must be placed outside of the zone of influence of the footing as required by the Geotechnical Engineer (typically a 7V:10H influence line). If there is a space limitation, it may be necessary to underpin the foundation of the structure.



## STEPS

The Pisa system offers the flexibility to create a wide variety of step configurations and designs. As with any SRW structure, proper base preparation is critical to success when constructing steps. We recommend that only a free-draining, well-graded, granular material be used for the 150 mm (6in) base at each riser. Compaction at each step (to 98% SPD) is crucial to resisting settlement due to continuous pedestrian loading.

### CONCAVE

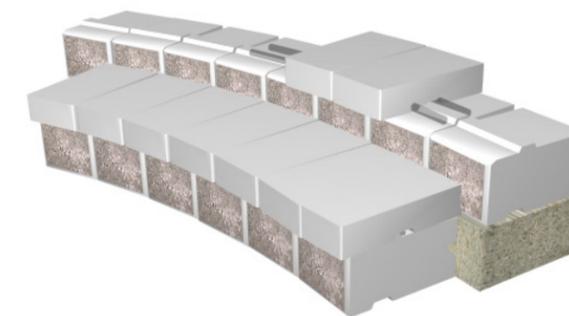
Locate the centre of the curve and lay out the curve on site. (Minimum radius for a Pisa wall is 2.44m [8ft]). Build the first riser with Pisa standard units along the marked line. See the section on Curves for instructions on laying the first course.

Position the ReversaCap coping units and secure with adhesive. Backfill the first course with the granular base

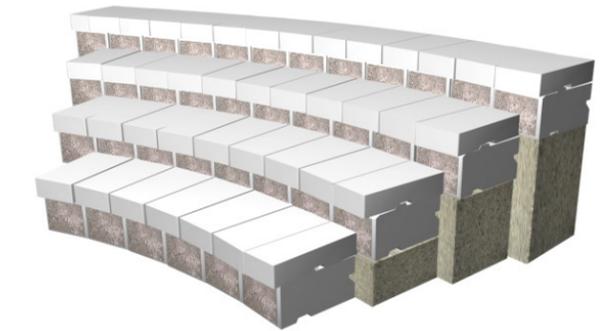


material and compact to 98% SPD. The top elevation of the base should be flush with the top elevation of lower units. The face of riser units must be in contact with the back of the coping units on the lower course. Make sure the new curve is parallel to the curve of lower riser.

Position the coping units on top and secure with adhesive. Some trimming and chipping of coping units might be necessary.

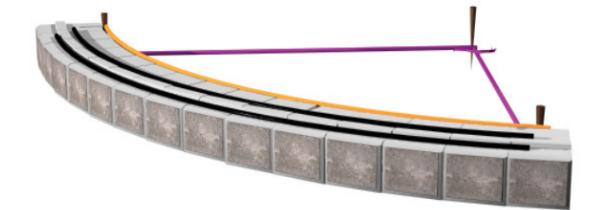


Repeat the previous stage to continue the risers to finish the steps.



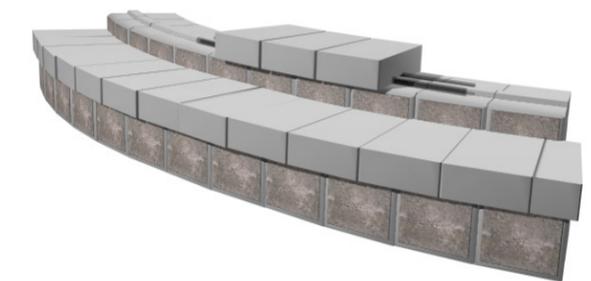
### CONVEX

Locate the center of the curve and mark the curve on site. (Minimum radius for Pisa wall is 2.44m [8ft]). Build the first riser with Pisa Tapered Units along the marked line. See the section on curves for instructions on laying the first course.

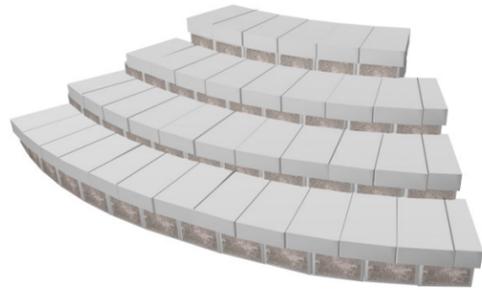


Position the ReversaCap coping units and secure with adhesive. Backfill the first course with the granular base material and compact to 98% SPD. The top elevation of the base should be flush with the top elevation of lower units.

The face of riser units must be in contact with the back of the coping units on the lower course. Make sure the new curve is parallel to the curve of lower riser. Position the coping units on top and secure with adhesive. Some trimming and chipping of coping units might be necessary.



Repeat the previous stage to continue the risers to finish the steps.

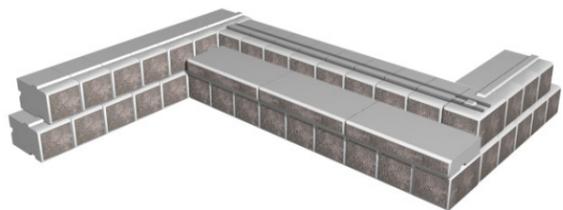


**PERPENDICULAR**

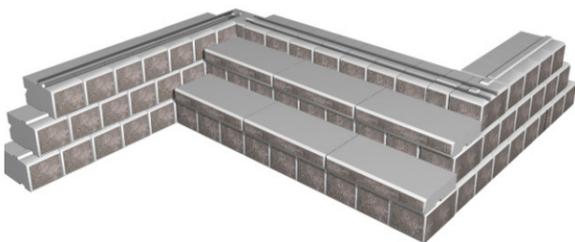
Start the wall with 90° inside and outside corners. At the inside corner, the wall is extended with two units to support the units that will be placed above.



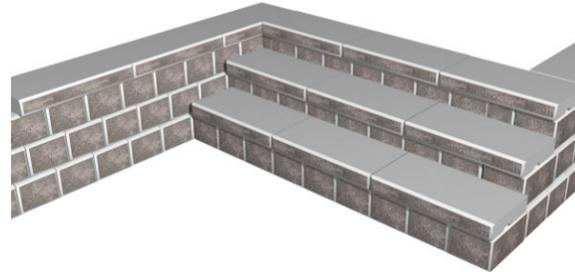
Position the coping units and secure with adhesive to finish the first course of riser. Backfill and compact to 98% SPD. The second riser is then positioned on the base so the face of the unit is in contact with the back of the coping unit at the first riser. Some trimming or chipping of the tongues on the outside corner will be necessary. Finish the second course of the remaining wall in running bond. Use a right corner unit on the top of the left corner unit at the extended part of inside corner.



Repeat the previous stage to finish the third course. Use a left corner unit at the inside corner this time. At the riser, one unit may have to be cut to fit in.



Finish the wall by placing the coping units with adhesive.



**INSET**

Start with two outside corner walls with a distance of one riser length in between.



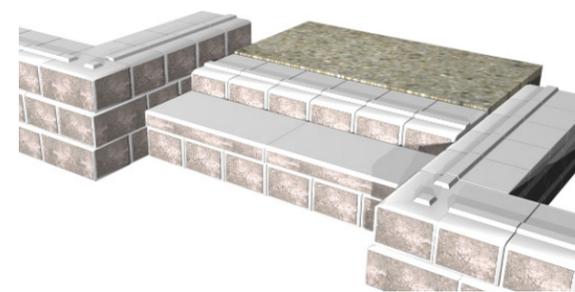
Build each wall up. The side walls can be built in either battered or vertical arrangement, as specified in the design. The side walls can be stepped up following the steps, but the side of riser (step) units must be in contact with the face of units in the side wall.



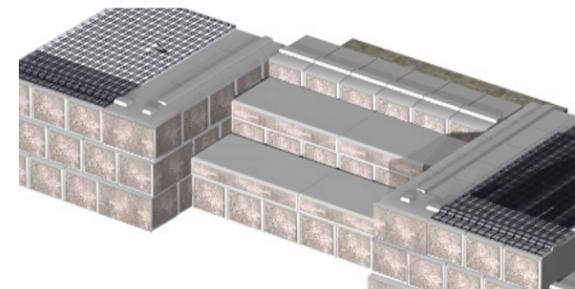
Place the first course of step units on the same foundation elevation as the side walls. A unit may have to be cut to make the riser fit between the side walls. Fill in base materials at the back of the riser and make it even with the top of the first course. The coping is then cut (if necessary), positioned, and secured with an adhesive.



Repeat the previous two stages to finish the steps.



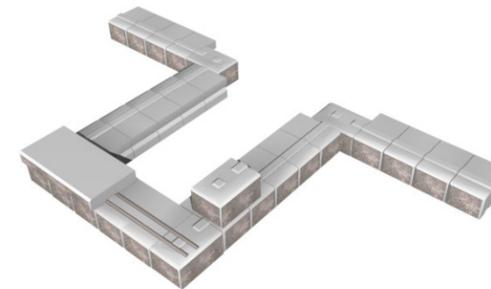
Place geogrid if required by design.



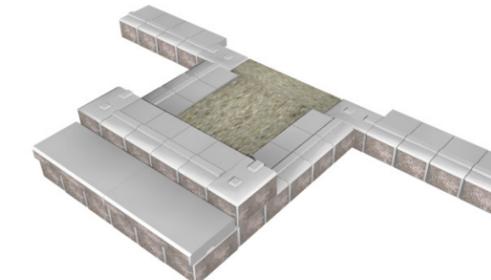
**PROTRUDING**

Start the wall with two inside 90° corners and two outside 90° corners. At the two outside corners, chop part of tongues off corner units and position the coping units with adhesive to form the first riser.

Place the next riser on the base with the face of units in



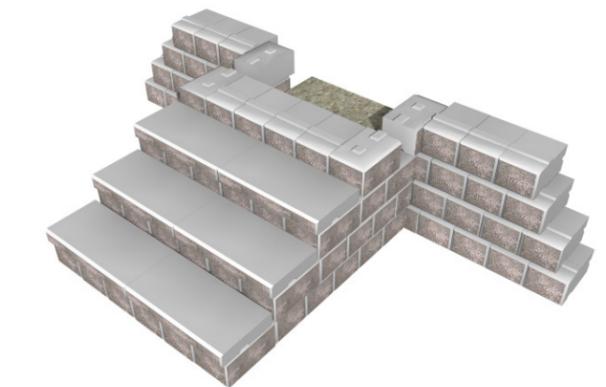
contact with the back of the coping units at the first riser. Some chopping will be necessary for the positioning of left and right corner units.



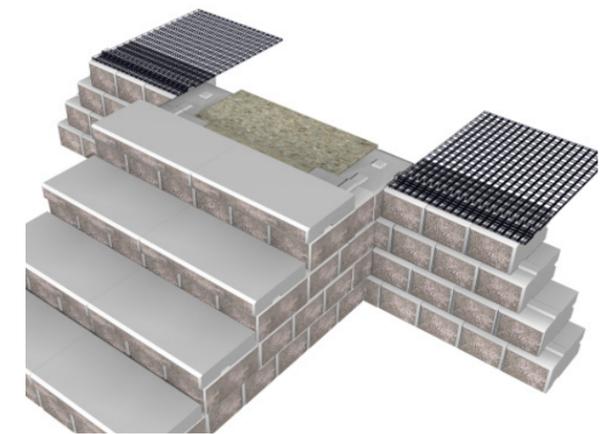
Continue to finish the second course of the wall. The side walls can be built in either battered or vertical arrangement as specified in the design. If the side walls are designed to be battered, each riser will be 38mm (1.5in) narrower than the course below.



Repeat the above steps to finish the wall. However, units may have to be cut to fit in the side wall.



If required, place geogrids to reinforce the wall.

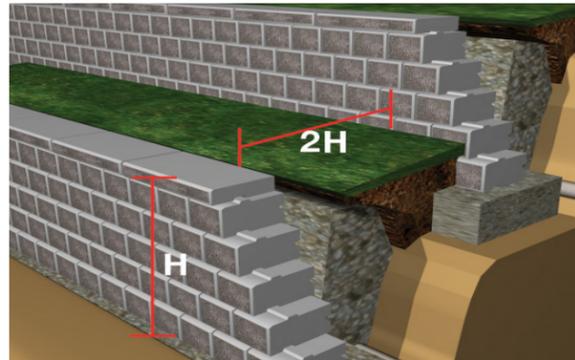


## TERRACES

### CONVENTIONAL SRWS

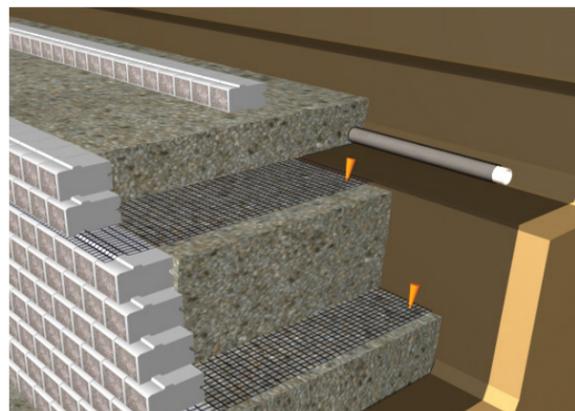
If done correctly, terracing can be an effective way to reduce loading and gain greater overall height, while still maintaining an aesthetic appearance.

Generally, a good rule of thumb is to space conventional walls apart by a distance equal to twice the height of the lower wall.



### REINFORCED SRWS

Reinforced SRWs can be designed to support upper terraces that are in close proximity to the back of the wall. Generally, the further the upper wall(s) are offset from the top of the lower wall, the less expensive the design will be. Once a minimum offset distance is established in the design, this must be adhered to throughout the structure.



The loads produced by terraced walls can be great. As an example, a small 0.6m (2.0ft) high wall produces a load equivalent to a heavy traffic surcharge on the lower wall.

These loads may be reduced by increasing the offset between the walls or increasing the foundation depth of the upper wall.

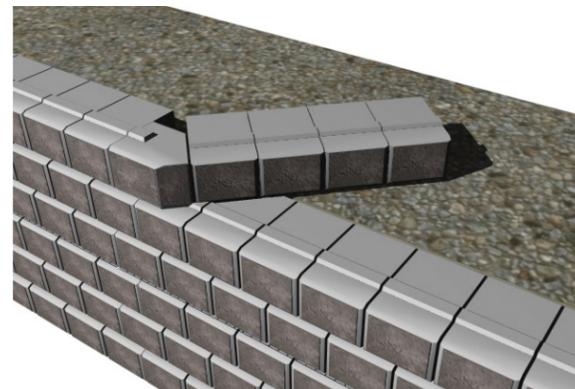
Wherever possible, the lower wall should be higher than the upper wall.

We recommend that a qualified engineer perform analysis and design for terraced structures and that the proposed configuration be checked for global stability.



### CONVERGING WALLS

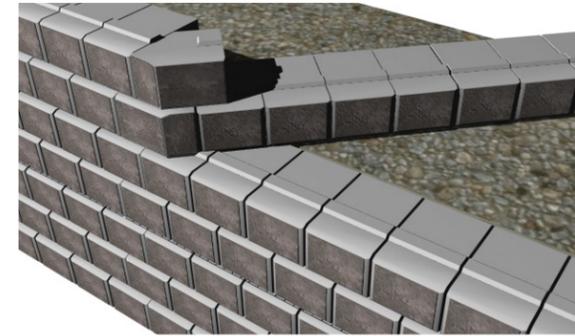
Terraced wall arrangements create additional considerations with respect to design and construction. One such consideration is the converging of two terraced walls into one.



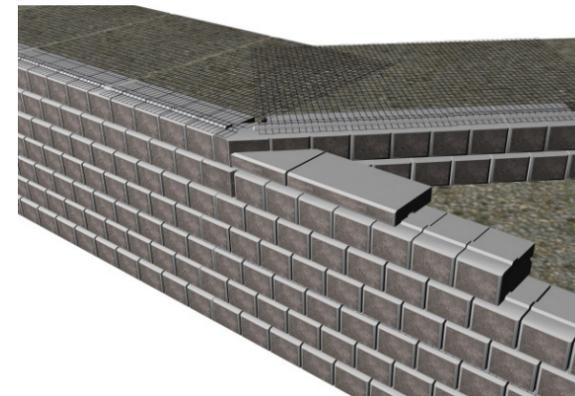
The low wall (Wall 1) must be designed based on the maximum height required. As Wall 1 splits into an upper (Wall 2) and lower wall, the lower wall must still be designed for the additional loading until the point where the upper wall has diverged far enough back to reduce the effect.

Construct the lower wall up to the transition height (height where the wall diverges into two).

Based on the plan, determine the location along the top of the lower wall where the upper wall will diverge. This split may be achieved using an outside corner (90°, 45°, etc.) or outside curve.



Prepare the base for the upper wall at the required angle or curve. As this offshoot wall will be resting partially on the existing lower wall and partially on the new base, the potential for differential settlement exists. Extra care must be taken to ensure the Wall 2 base has been properly compacted to 98% SPD. As this base is bearing on the reinforced zone of the lower wall, construction of this area is vital.



Continue constructing the upper wall and place the last standard course and coping on the lower wall. This will require a cut where this course abuts the beginning of the upper wall to ensure a tight fit.



Place filter cloth in the area between the upper and lower walls, ensuring the required reinforced zone of the lower wall and base of the upper wall are adequately protected. Grade as required.



## PILLARS

In areas where frost heave is a potential issue, increase the compacted granular base thickness.

*Shear keys will have to be trimmed in order to achieve vertical alignment of pillar. (Refer to Splitting- Creating Vertical Pisa Units)*

### SMALL PILLARS

#### Base Course

Place corner unit in desired location. Abut second corner unit against smooth portion of the original corner unit; be sure the second unit is identical to the original corner unit placed. Continue this process with corner units until pillar base course is complete.



#### Remaining Courses

Establish second course by placing alternate corner unit upon base course. Place remaining alternate (but identical) units until second course is complete. Continue this method of alternating corner units per course until desired pillar height is achieved.

Complete with coping units (cut to fit where available) or with a precast cap.



### LARGE PILLARS

Infill large pillars with 3/4in clear stone material for stability.

#### Base Course

Place corner unit in desired location. Abut standard unit against smooth portion of the original corner unit. Position second corner unit flush to smooth side of standard unit. Continue placing standard and corner units until base course is complete.



#### Remaining Courses

Establish the second course by placing alternate corner unit upon the base course. Follow by placing standard units and identical corner units until second course is complete. Continue this method of alternating corner units per course until desired pillar height is achieved. Maximum height is 4ft, but will depend on the site conditions. Finish with coping units (cut to fit where available) or a precast cap.



## FINISHING DETAILS

Typically it is inadvisable to end any retaining wall abruptly. If proper care is not taken at the ends of the wall, the infill or drainage material may be eroded, leading to undesirable settlement and possible failure. There are several ways to finish off the end of a retaining wall.

### 90° RETURN END

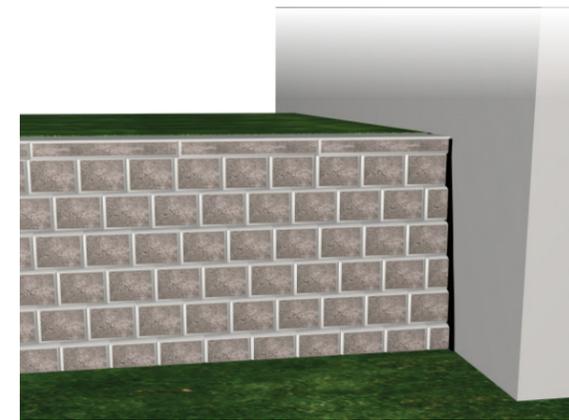
A return corner or curve could be constructed to run the wall into the slope that is being retained, thereby containing the granular material behind the wall.

### ABUT EXISTING STRUCTURE



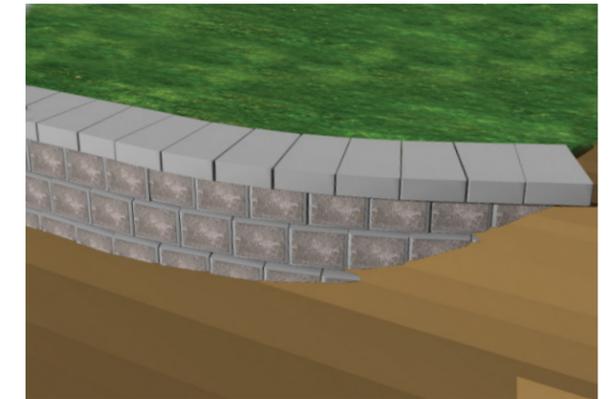
The wall could be abutted to an existing structure. This would involve cutting the retaining wall units in order to maintain the running-bond pattern. An expansion joint (25mm asphalt-impregnated fibreboard) should be constructed between the retaining wall and the structure.

This will allow the wall to move slightly while still containing the granular material. Note that if the existing structure's footing extends under the retaining wall for a short distance, this could lead to differential settlement and in turn, cracking of or separation between the units.



### CURVED RETURN

A curve could be constructed to run the wall into the slope that is being retained, thereby containing the granular material behind the wall.





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