Pisa2® and RomanPisa® Installation Guide

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Risi Stone Systems has attempted to ensure that all information contained in this guide is correct. However, there is the possibility that this guide may contain errors. Review all designs with your local sales representative prior to construction. Final determination of the suitability of any information or material is the sole responsibility of the user.
Introduction

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For the duration of this book, “Pisa2” will be used to refer to both the Pisa2 and RomanPisa systems unless otherwise specified.

The Pisa2 system is a solid, modular concrete retaining wall system that is used to stabilize and contain earth embankments, large or small.

The Pisa2 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 Pisa2 system. Today, the Pisa2 system and several other retaining wall systems licensed by Risi Stone Systems are manufactured and installed across North America and internationally.

In the Pisa2 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 Pisa2 system can be constructed in two basic configurations: a Pisa2 Conventional SRW or a Pisa2 Geogrid Reinforced SRW.

There are many applications for Pisa2 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 Pisa2 landscape uses are planters, driveway edging, steps, tree wells, and smaller garden retaining walls. Most landscape applications call for walls under 1.0 m (3 ft) 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 Pisa2 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 Pisa2 system is supported by the local manufacturers and Risi Stone Systems. 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 Pisa2 system and has plenty of experience installing it. The RisiWall design software also helps to provide solutions for specific site designs. Unique applications often necessitate the assistance of a professional engineer. Risi Stone Systems can provide these solutions through its Engineering Design Assistance program.

features•advantages•benefits

The Pisa2 system has a number of features that make the system unique. Each of these features has been developed to give a Pisa2 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.

**Tongue and Groove Interlock**
Interlocking mechanism molded 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 19 kg (45 lb) units are well-balanced, easy to handle, and have a molded 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.

**Pisa2 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.

**ReversaCap or PisaStone Coping**
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.

**RisiLights**
Provide illumination for stairs or landscape accents; blend into the wall during daylight.
• Units are shipped as kits available for 110V and 12V applications.
• Easy to install.

**RisiSounds**
Provides an audio speaker system that blends into the wall.
• Units are shipped preassembled and only require connection to the audio source.
• Easy to install.

**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.
# Introduction

The Pisa2® / RomanPisa® System Units are designed for installation in various applications. Below are the details of each unit type, including their dimensions and weights.

## Block Details

<table>
<thead>
<tr>
<th>Pisa2® / RomanPisa® System Units</th>
<th>Face Width</th>
<th>Back Width</th>
<th>Height</th>
<th>Depth</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard Unit</strong></td>
<td>8 in</td>
<td>8 in</td>
<td>6 in</td>
<td>12 in</td>
<td>45 lbs</td>
</tr>
<tr>
<td></td>
<td>200 mm</td>
<td>200 mm</td>
<td>150 mm</td>
<td>300 mm</td>
<td>21 kg</td>
</tr>
<tr>
<td><strong>Tapered Unit</strong></td>
<td>8 in</td>
<td>6 ¾ in</td>
<td>6 in</td>
<td>12 in</td>
<td>43 lbs</td>
</tr>
<tr>
<td></td>
<td>200 mm</td>
<td>174 mm</td>
<td>150 mm</td>
<td>300 mm</td>
<td>20 kg</td>
</tr>
<tr>
<td><strong>Jumbo Unit</strong></td>
<td>12 in</td>
<td>12 in</td>
<td>6 in</td>
<td>9 in</td>
<td>66 lbs</td>
</tr>
<tr>
<td></td>
<td>300 mm</td>
<td>300 mm</td>
<td>150 mm</td>
<td>225 mm</td>
<td>30 kg</td>
</tr>
<tr>
<td><strong>Half Unit</strong></td>
<td>4 in</td>
<td>4 in</td>
<td>6 in</td>
<td>12 in</td>
<td>23 lbs</td>
</tr>
<tr>
<td></td>
<td>100 mm</td>
<td>100 mm</td>
<td>150 mm</td>
<td>300 mm</td>
<td>11 kg</td>
</tr>
<tr>
<td><strong>Corner Unit</strong></td>
<td>12 in (20 in)*</td>
<td>12 in (20 in)*</td>
<td>6 in</td>
<td>8 in</td>
<td>46 lbs (78 lbs)*</td>
</tr>
<tr>
<td></td>
<td>300 mm (500 mm)*</td>
<td>300 mm (500 mm)*</td>
<td>150 mm</td>
<td>200 mm</td>
<td>21 kg (35 kg)*</td>
</tr>
<tr>
<td><strong>ReversaCap® Coping Unit</strong></td>
<td>8 in</td>
<td>7 in</td>
<td>3 in</td>
<td>14 in</td>
<td>22 lbs</td>
</tr>
<tr>
<td></td>
<td>200 mm</td>
<td>175 mm</td>
<td>75 mm</td>
<td>356 mm</td>
<td>10 kg</td>
</tr>
<tr>
<td><strong>PisaStone® Coping Unit</strong></td>
<td>24 in</td>
<td>24 in</td>
<td>3 in</td>
<td>12 in</td>
<td>68 lbs</td>
</tr>
<tr>
<td></td>
<td>600 mm</td>
<td>600 mm</td>
<td>75 mm</td>
<td>300 mm</td>
<td>31 kg</td>
</tr>
</tbody>
</table>

* Manufacturer may provide the larger corner unit.
system variations

Due to local conditions and preferences, the licensed manufacturer may produce either the Pisa2 or the RomanPisa system, or both. The Pisa2 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 Pisa2 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 Pisa2 system application.

PisaStone – All manufacturers produce ReversaCap coping units to finish off the Pisa2 or RomanPisa retaining wall. Some also produce the PisaStone retaining wall system, which will allow customers a choice of coping units: ReversaCap 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.

Closed-End Coping – Some manufacturers of Pisa2 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 Pisa2 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 Pisa2 stone may be chamfered on the top and bottom only (standard unit is chamfered on all four sides of the face).

The licensed manufacturer may produce the Pisa2 or RomanPisa systems with one or more minor variances. These differences in no way affect the performance of the wall.

Colours – Each manufacturer of Pisa2 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.
RisiLights® are used to illuminate walkways, steps, and terraces. They are manufactured to the highest quality standards and are shipped complete with instructions. The only additional items needed are the light bulb, the appropriate underground electrical cable, and a transformer for 12V systems.

RisiLights® are ready to be installed using a conventional 110V or 12V power supply. When ordering, please make sure that you specify the correct voltage for your installation.

A timer or photoelectric control unit may be used with RisiLights®, but should be installed at the power source. This allows all of the units in that circuit to be centrally controlled. Multiple units of RisiLights® may be connected in a parallel circuit with a second external wire continuing to the next light through the second opening in the rear of the unit.

RisiSounds® allow you to provide an unobtrusive music or intercom system to your landscape. RisiSounds® are manufactured to the highest quality standards, and shipped complete with instructions. The only additional item needed is the appropriate underground cable connected to an audio source.

Multiple units of RisiSounds® may be connected in a circuit with a second external wire continuing to the next unit through the second opening in the rear of the unit.

Both RisiLights® and RisiSounds® virtually disappear into the wall surface. The high strength fibreglass housing and acrylic faceplate of the lights and speakers have been textured and colour matched to look like their adjacent Pisa2® or PisaStone® units when installed. For more detailed product information, please visit risistone.com.
The following procedure is recommended for the construction of Pisa2 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.
- **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.

**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 SRW designer.
- **The design** may be provided by Risi Stone Systems 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. (See Following the Design)

**Qualified Professional Engineer Hired for Inspection/Certification**

We recommend that inspection and certification of the proposed Pisa2 SRW should be conducted by a qualified third-party engineer. Inspection should not be limited to soil and compaction testing, but include all aspects of the installation.

The scope of the Certifying Engineer's responsibilities include, but are not limited to:
- Inspection of all materials used in construction (SRW units, backfill, drainage materials, reinforcement, other structures);
- Verification that the design is compatible with the site in all respects;
- Identification of discrepancies between plan and/or SRW design and actual site conditions and subsequent notification of designer;
- Continuous evaluation of site conditions, compaction testing, foundation bearing capacity, excavation procedures, construction practices for safety and compliance with design;
- Ensuring the wall is constructed according to the design; and
- Providing a letter to the owner certifying the construction of the wall upon completion.

**Pre-Construction Meeting**
- **It is recommended** 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 be doing future work that could influence the wall (e.g. paving, installing a wood fence, etc.) should be included in the meeting to understand the limitations of the wall and address precautions that should be undertaken.
- Experience has shown that this simple step prevents a multitude of potential problems!

**Proper Installation**
- **Adherence to design**, specifications, details, guides, and good construction practice is necessary.
- Conducted under supervision of Certifying Engineer.

**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.
understanding the design

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

Typical Design
Non-site–specific design(s) selected from Risi Stone Systems’ 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
A site-specific design produced for preliminary purposes. Conducted when some component of the required design information is not yet available. The design includes all elements necessary 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 drawing(s), elevation view(s), specifications, quantity calculations, details, statement of limitations, etc. This type of design is usually not sealed by the designer.

Final Design
Identical to the preliminary design with the exception that all necessary information has been established and the design has been deemed ready for construction. This type of design is normally 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 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 such as fences and handrails, 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 the structure.

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 Systems conducts analysis using the RisiWall design software (available at risiwall.com), a state-of-the-art SRW design program with over a decade of research and development built into it. Risi Stone Systems’ design reports feature the RisiWall 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 RisiWall 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 handrail treatments, corner details, curves, stepping foundation, steps, swales, 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.
Installation

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The following are the basic steps involved in constructing a conventional (non-geogrid-reinforced) Pisa2 Segmental Retaining Wall. These steps are to be used in conjunction with all relevant details provided in the Details section of this book.

Refer to Overview of a Successful Project before beginning. This will ensure the project goes smoothly.

**plan**

With your final design in hand and Certifying Engineer (CE) close by, 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 (3/4 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 block. 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 CE.

**verify foundation subgrade**

Once the foundation trench has been excavated to the specified elevations, the native foundation soil must be checked by the CE. 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 CE 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 CE, 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.

**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 1 course. The 19mm (3⁄4 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 *Details – Drainage*). The drain may be outlet through the wall face or connected to a positive outlet (sewer). 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 Pisa2 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.
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 blocks below (100mm [4 in] offset). Continue stacking courses to a maximum of 4 courses (600mm [24 in]) before backfilling.

backfill drainage material

A free-draining, 19mm (3/4 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 in Steps 10 & 11 until the desired height is reached, based on the design.

place coping unit

Various coping units are available depending on the alignment of the wall and desired look. All coping units are 75mm (3 in) in height. 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.

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 the Details section for ideas on tapering down and ending the wall.
The following are the basic steps involved in constructing a reinforced Pisa2 Segmental Retaining Wall. These steps are to be used in conjunction with all relevant details provided in the Details section of this book.

Refer to Overview of a Successful Project before beginning. This will ensure the project goes smoothly.

**plan**

With your final design in hand and Certifying Engineer (CE) close by, 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 (3/4 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 CE 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 block. 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 CE. 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 CE. 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.

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 Details – Drainage). The drain may be outlet through the wall face or connected to a positive outlet (sewer). 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.

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 1 course. The 19mm (¾ in) offset must be accounted for at each step.
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 Pisa2 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.

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 blocks below. Continue stacking courses up to the elevation of the first layer of geogrid or to a maximum of 4 courses (600mm [24 in]) before backfilling.

backfill

Begin backfilling the wall with 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 CE 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 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.

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 Pisa2 units are free of debris, lay the geogrid on top of the blocks to within 25mm (1 in) of the face. Place the next course of Pisa2 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 Pisa2 unit, allowing the geogrid to be laid out horizontally.

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 units and backfilling until the next layer of geogrid reinforcement is reached.

continue stacking and backfilling

Continue placing the Pisa2 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. All coping units are 75mm (3 in) in height. 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 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.
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RomanPisa® patterns

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<td>6 x 8 in</td>
<td>6 x 12 in</td>
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**pattern one**
Per 100 ft²: 164 Standard (54 ft²) 110 Half (18 ft²) 56 Jumbo (28 ft²)

**pattern two**
Per 100 ft²: 164 Standard (54 ft²) 110 Half (18 ft²) 56 Jumbo (28 ft²)

**pattern three**
Per 100 ft²: 160 Standard (53 ft²) 42 Half (7 ft²) 80 Jumbo (40 ft²)

**pattern four**
Per 100 ft²: 139 Standard (46 ft²) 47 Half (8 ft²) 93 Jumbo (46 ft²)

**pattern five**
Per 100 ft²: 150 Standard (50 ft²) 75 Half (12 ft²) 75 Jumbo (38 ft²)

**pattern six**
Per 100 ft²: 150 Standard (50 ft²) 75 Half (12 ft²) 75 Jumbo (38 ft²)

**pattern seven**
Per 100 ft²: 124 Standard (41 ft²) 73 Half (12 ft²) 94 Jumbo (47 ft²)
splitting Pisa2 units
Pisa2 units are 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 Pisa2 units
Standard Pisa2 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 Pisa2 units with an existing splitting groove. Otherwise, saw cut the tongue along a line 19mm (3⁄4”) from the rear of the base of the tongue, then split back portion off with hammer and chisel. Removal of the rear 19mm (3⁄4”) 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.
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 (1 in) 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. It may be necessary to remove bumps and bulges from the face to achieve a tighter fit.

Cut unit as required for desired angle and continue placing base course units on adjacent wall. Remove shear keys as necessary to allow for the next course.
Run alternate wall through corner as shown to achieve an interlocked corner.

Cut unit as required for desired angle and place standard units to complete the course. Remove shear keys as necessary to allow for the next course.

Repeat until desired wall height is achieved.

The geogrid should be placed within 25mm (1 in) 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.
The geogrid from the two side walls will overlap and should be separated by a minimum of 75mm (3 in) of compacted soil. Alternatively, the geogrid reinforcement could be placed in the perpendicular principle direction in the cross-over area on the succeeding course.

Place standard units to complete the course.

Repeat until desired wall height is achieved.

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.

The geogrid from the two side walls will overlap and should be separated by a minimum of 75mm (3 in) of compacted soil. Alternatively, the geogrid reinforcement could be placed in the perpendicular principle direction in the cross-over area on the succeeding course.
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.
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 Pisa2 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 Pisa2, 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.

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.
concave curve

For concave curves, the Pisa2 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 (¾ in) 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. If the base course is installed with too tight a radius, the upper courses may have to be cut to fit.

Geogrid layers should be placed within 25mm (1 in) 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 Pisa2 units so the geogrid does not overlap until it enters the soil zone.

Place additional courses, remembering that the radius decreases by 19mm (¾ in) every course until desired height is achieved.

convex curve

The Pisa2 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 (¾ in) 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 (¾ in) every course until desired height is achieved.
Geogrid layers should be placed within 25mm (1 in) 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.

The PisaStone coping units can be saw cut to create a curve. Attach the PisaStone coping units to the Pisa2 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.
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 Pisa2 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 Pisa2 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 [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. 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 (¾ in 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
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 Pisa2 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 Pisa2 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 (¾ 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 Step 3 for each layer of geogrid encountered by the sonotube.

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

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.

Guardrails

For areas adjacent to roadways and parking lots, flexible steel beam guardrails may be placed behind a geogrid reinforced Pisa2 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 1 m (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.
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.

**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 (12 in) thick, composed of a gap-graded, free-draining, angular clear stone (19mm [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 (6 in) and cut. The drainage layer must be fully encapsulated with a 150mm (6 in) 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 soil to prevent the migration of fines. The use of an imported granular material in the reinforced zone has many other advantages above and beyond its good drainage properties (see Specifications – Soils).
### Outlet to Catchbasin / 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 Pisa2 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.
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).

water applications

Pisa2 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, ice effects, etc.

The Pisa2 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.

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 Pisa2 structure. Refer to the NCMA manual for drainage options under various groundwater conditions.
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 minimum 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 Pisa2 units from the other part of the walls by 25mm expansion joint material.

The picture shows the bottom of Pisa2 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 Pisa2 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.
**concave**

The Pisa2 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 (6 in) base at each riser. Compaction at each step (to 98% SPD) is crucial to resisting settlement due to continuous pedestrian loading.

Locate the centre of the curve and lay out the curve on site. (Minimum radius for a Pisa2 wall is 2.44m [8ft]). Build the first riser with Pisa2 standard units along the marked line. See Details – Curves – Concave 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 unit might be necessary.

Repeat Step 2 to continue the risers.

**convex**

Locate the center of the curve and mark the curve on site. Minimum radius for Pisa2 wall is 2.44m (8ft). Build the first riser with Pisa2 Tapered Units along the marked line. See Details – Curves – Convex 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.
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 unit might be necessary.

Repeat Step 2 to continue the risers.

Finish the wall.

**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 Step 2 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 security.

**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 vertical arrangement can be achieved by splitting back 19mm (3⁄4") off tongue to allow next courses to move forward if manufactured splitting groove is not available in your area. 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 Steps 2&3 to finish the wall. The two outside corner installation details are same as described in Details – Corners in this manual.

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 security 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. The vertical arrangement can be achieved by splitting back 19mm (3⁄4 in) off tongue to allow next courses
to move forward if manufactured splitting groove is not available in your area. If the side walls are designed to be battered, each riser will be 38mm (1.5 in) 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. Detail installation of the two inside corners of the wall is the same as described in Details – Inside Corner in this manual.

If required, place geogrids to reinforce the wall.
terraces

central 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 the height of the lower wall.

reinforced SRWs
Reinforced SRW walls 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.

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 walls diverge 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.

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.

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.
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.

structures

Retaining walls constructed near structures must be placed outside of the zone of influence of the footing as required by 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.

trees

When planting trees or shrubs behind Pisa2 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 a 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 Pisa2 blocks 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 Pisa2 wall and drainage layer.
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 Pisa2 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 precast cap.

**large pillars**

Infill large pillars with \( \frac{3}{4} \)in 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 a like corner units until base course is complete.

**Remaining Courses**
Establish second course by placing alternate corner unit upon 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 precast cap.
Specifications

- conventional srw specifications ................................................................. 43
- reinforced srw specifications ................................................................. 46
PART 1 – GENERAL

1.01 Description
A) The work covered by this section includes the furnishing of all labor, materials, equipment and incidentals for the design, inspection and construction of a modular concrete retaining wall including drainage system as shown on the Construction Drawings and as described by the Contract Specifications. The work included in this section consists of, but is not limited, to the following:
   a) Design, inspection and certification by a registered professional engineer.
   b) Excavation and foundation soil preparation.
   c) Furnishing and placement of the leveling base.
   d) Furnishing and placement of the drainage system.
   e) Furnishing and placement of geotextiles.
   f) Furnishing and placement of segmental retaining wall facing units.
   g) Furnishing and compaction of drainage and retained soils.

1.02 Related Work
A) Section 02100 – Site Preparation
B) Section 02200 – Earthwork

1.03 Reference Standards
A) Engineering Design
   b) NCMA TEK 2-4 – Specifications for Segmental Retaining Wall Units.
   c) NCMA SRWU-2 – Determination of Shear Strength between Segmental Concrete Units.
B) Segmental Retaining Wall Units
   a) ASTM C 140 – Sampling and Testing Concrete Masonry Units
   b) ASTM C 1262 – Evaluating the Freeze - Thaw Durability of Manufactured Concrete Masonry Units and Related Concrete Units.
   c) ASTM C 33 – Specification for Concrete Aggregates
   d) ASTM C 90 – Standard Specification for Load-Bearing Concrete Masonry Units
   e) ASTM C 595 – Specification for Blended Hydraulic Cements
C) Geotextile Filter
   a) ASTM D 4751 – Standard Test Method for Apparent Opening Size
D) Soils
   a) ASTM D 698 – Moisture Density Relationship for Soils, Standard Method
   b) ASTM D 422 – Gradation of Soils
   c) ASTM D 424 – Atterberg Limits of Soils
   d) ASTM D G51 – Soil pH
E) Drainage Pipe
   a) ASTM D 3034 – Specification for Polyvinyl Chloride (PVC) Plastic Pipe
   b) ASTM D 1248 – Specification for Corrugated Plastic Pipe
F) Where specifications and reference documents conflict, the Owner or Owner’s representative shall make the final determination of applicable document.

1.04 Approved Products
A) Pisa2 Segmental Retaining Wall System as supplied by the Risi Stone Systems Authorized Manufacturer.
B) Colour to be [_______].

1.05 The Contractor
A) The term Contractor shall refer to the individual or firm who will be installing the retaining wall.
B) The Contractor must have the necessary experience for the project and have successfully completed projects of similar scope and size.

1.06 Delivery, Material Handling and Storage
A) The installing contractor shall check all materials delivered to the site to ensure that the correct materials have been received and are in good condition.
B) The Contractor shall store and handle all materials in accordance with manufacturer’s recommendations and in a manner to prevent deterioration or damage due to moisture, temperature changes, contaminants, breaking, chipping, or other causes.

1.07 Engineering Design and Certification
A) The term Engineer shall refer to the individuals or firms who have been retained by the Contractor to provide design and inspection services for the retaining wall. The Design Engineer may be a different individual or firm from the Inspecting Engineer as the Manufacturer may provide this service. The Engineer(s) must be qualified in the area of segmental retaining wall design and construction and must be licensed to practice engineering in the Province or State that the wall is to be constructed.
B) The Engineer(s) will perform the following tasks:
   a) Produce sealed construction drawings and detailed design calculations, completed in accordance with the design requirements outlined in Part 3 of these specifications.
   b) Review the site soil and geometric conditions to ensure the designed wall is compatible with the site prior to construction.
   c) Inspect the site conditions, materials incorporated into the retaining wall, and the construction practices used during the construction.
   d) Provide the Contractor with a letter after completion, certifying the design meets the requirements of this specification, the design was compatible with the site, and the wall was constructed according to design.
1.08 Submittals
A) The Contractor shall submit the following information for approval thirty (30) days prior to the construction of the segmental retaining wall.
   a) Design Submittal – Provide three (3) sets of stamped construction drawings and detailed design calculations, completed and sealed by the Engineer in accordance with the design requirements outlined in Part 3 of this specification.
   b) Materials Submittal – Manufacturer’s certifications, stating that the SRW units and imported aggregates and soils meet the requirements of this specification and the Engineer’s design.
   c) Installer Qualifications - The Contractor must be able to demonstrate that their field construction supervisor has the necessary experience for the project by providing documentation showing that they have successfully completed projects of similar scope and size.

1.09 Measurement for Payment
A) Payment for earthworks to prepare the site for the retaining wall construction will be based on the contract unit price per cubic metre (or cubic yard) for site cut and fill earthwork as detailed in the Site Plan. Additional earthwork as directed and approved in writing by the Owner, or Owner’s representative, shall be paid for under a separate pay item.
B) Payment for the retaining wall system will be based on the contract price per square metre (or square foot) of vertical wall face area as shown on the construction drawings. The vertical wall face area shall be measured from the top of the base or footing to the top of the copings multiplied by the length of the wall. The contract unit price shall include the cost of all engineering, labour, materials, and equipment used to install the leveling base or spread footing, wall modules, drainage materials, retained soil, and site clean up. Additional items as directed and approved in writing by the Owner, or Owner’s representative, shall be paid for under a separate pay item.

PART 2 – MATERIALS

2.01 Definitions
A) Modular concrete retaining wall units are dry-cast solid concrete units that form the external facia of a modular unit retaining wall system.
B) Coping units are the last course of concrete units used to finish the top of the wall.
C) Retained soil is an in-situ soil or a specified soil that is placed behind the wall drainage material.
D) Foundation soil is the in-situ soil beneath the wall structure.
E) Drainage aggregate is a free draining soil with natural soil filtering capabilities, or a free draining soil encapsulated in a suitable geotextile, or a combination of free draining soil and perforated pipe all wrapped in a geotextile, placed directly behind the modular concrete units.
F) Drainage pipe is a perforated polyethylene pipe used to carry water, collected at the base of the retaining wall, to outlets in order to prevent pore water pressures from building up behind the wall facing modules.
G) Non-woven geotextiles are permeable synthetic fabrics formed from a random arrangement of fibers in a planar structure. They allow the passage of water from one soil medium to another while preventing the migration of fine particles that might clog a drainage medium.
H) All values stated in metric units shall be considered as accurate. Values in parenthesis stated in imperial units are the nominal equivalents.

2.02 Products
A) Concrete Segmental Retaining Wall Units
   a) The concrete wall modules shall be 150 x 200 x 300 mm (6 x 8 x 12 inches) with a maximum tolerance of plus or minus 3 mm (1/8 in.) for each dimension.
   b) The retaining wall modules shall be solid units and have a minimum weight of 20.4 kg (45 lbs.) per unit.
   c) The concrete wall modules shall have an integral shear key connection that shall be offset to permit a minimum wall batter of 1H : 8V.
   d) The concrete wall modules shall have a minimum 28-day compressive strength of 35 MPa (5000 psi) as tested in accordance with ASTM C 140. The concrete shall have a maximum moisture absorption rate of 5 percent to ensure adequate freeze-thaw protection.
B) Retained Soil
   a) The retained soil shall be on site soils unless specified otherwise in the Construction Specifications or as directed by the Owner or Owner’s Representative. If imported fill is required, it shall be examined and approved by the Engineer.
C) Foundation Soil
   a) The foundation soil shall be the native undisturbed on site soils. The foundation soil shall be examined and approval by the Engineer prior to the placement of the base material.
D) Levelling Base Material
   a) The footing material shall be non-frost susceptible, well graded compacted crushed stone (GW-Unified Soil Classification System), or a concrete leveling base, or as shown on the Construction Drawings.
E) Drainage Soil
   a) The drainage soil shall be a free draining angular granular material of uniform particle size smaller than 25 mm (1 in.) separated from the retained soil by a geotextile filter. The drainage soil shall be installed directly behind the SRW units.
F) Drainage Pipe
   a) The drainage pipe shall be perforated corrugated HDPE or PVC pipe, with a minimum diameter of 100 mm (4 in.), protected by a geotextile filter to prevent the migration of soil particles into the pipe, or as specified on the construction drawings.
G) Geotextile Filter
   a) The non-woven geotextile shall be installed as specified on the construction drawings. Although selection of the appropriate geotextile specifications is site soil specific, a commonly used geotextile for filtration will have an Apparent Opening Size ranging between 0.149 and 0.210 mm (U.S. 100 to 70) and a minimum unit weight of 135 grams per square meter (5.0 oz /square yard). The coefficient of permeability will typically range between 0.1 and 0.3 cm/second.
H) Concrete Adhesive
   a) The adhesive is used to permanently secure the coping stone to the top course of the wall. The adhesive must provide sufficient strength and remain flexible.

PART 3 – WALL DESIGN

3.01 Design Standard
A) The Engineer is responsible for providing a design that shall consider the external, internal, and local stability of the SRW system. It is the responsibility of the Certifying Engineer or Site Geotechnical Engineer to determine if further design considerations must be implemented to ensure adequate global/overall slope stability, and or if the foundation soils will require special treatment to control total and differential settlement. The design life of the structure shall be 75 years unless otherwise specified in the construction drawings.
B) The segmental retaining wall shall be designed in accordance with recommendations of the NCMA Design Manual for Segmental Re
The following is a summary of the minimum factors of safety for the various modes of failure evaluated in the proposed design.

<table>
<thead>
<tr>
<th>Mode of Failure</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Stability</td>
<td>1.5</td>
</tr>
<tr>
<td>Internal Stability</td>
<td>1.5</td>
</tr>
<tr>
<td>Base Sliding</td>
<td>1.5</td>
</tr>
<tr>
<td>Overturning</td>
<td>1.5</td>
</tr>
<tr>
<td>Bearing Capacity</td>
<td>2.0</td>
</tr>
<tr>
<td>Global Stability</td>
<td>1.3</td>
</tr>
<tr>
<td>Shear Capacity</td>
<td>1.5</td>
</tr>
</tbody>
</table>

3.02 Soil

A) Design parameters: The following soil parameters shall be assumed for the design unless otherwise shown on the plans or specified by the Engineer.

- **Retained Soil:**
  - Unit Weight = [______] kN/cu.m (lb/cu.ft)
  - Friction Angle = [______] °
  - Cohesion = 0 kPa (lb/sq.ft)

- **Foundation Soil:**
  - Unit Weight = [______] kN/cu.m (lb/cu.ft)
  - Friction Angle = [______] °
  - Cohesion = 0 kPa (lb/sq.ft)

3.03 Design Geometry

A) The length, height, and overall elevations of the retaining wall must comply with the requirements of the proposed elevation detail, station information, and site grading plan.

B) The structures’ design height, H, shall be measured from the top of the leveling pad to the top of the wall where ground surface intercepts the wall facing.

C) Slopes above and below all sections of the segmental retaining wall are detailed in the site grading plan.

D) The minimum wall embedment shall be the greater of 1) the height of a SRW unit, 2) 150 mm (0.5 ft), or 3) the minimum embedment required because of the slope below the wall:

<table>
<thead>
<tr>
<th>Slope Below Wall</th>
<th>Minimum embedment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level</td>
<td>H/10</td>
</tr>
<tr>
<td>3 : 1 (18.4°)</td>
<td>H/10</td>
</tr>
<tr>
<td>2 : 1 (26.5°)</td>
<td>H/7</td>
</tr>
</tbody>
</table>

C) The following surcharges shall be applied to the top of each design cross section based on the following proposed uses above the wall.

- **Use Above Wall:**
  - No Traffic: 0 kPa (0 lb/sq. ft)
  - Light Traffic: 4.8 kPa (100 lb/sq. ft)
  - Heavy Traffic: 12.0 kPa (250 lb/sq. ft)

3.04 State of Stress

A) The lateral earth pressure to be resisted by the self weight of the retaining wall shall be calculated using the Coulomb coefficient of earth pressure, Ka, times the vertical stress at the base of the wall. The coefficient of active earth pressure, Ka, shall be used from the top to the bottom of the wall. The coefficient of active earth pressure, Ka, shall be assumed independent of all external loads except sloping fills. For sloping fills, the coefficient of active earth pressure, Ka, appropriate for the sloping condition, using Coulomb earth pressure shall be used in the analysis.

3.05 Inclination of Failure Surface

A) A Coulomb failure surface passing through the base of the wall behind the facing units up to the ground surface at or above the top of wall shall be assumed in design of walls.

3.06 Settlement Control

A) It is the responsibility of the Certifying Engineer or Site Geotechnical Engineer to determine if the foundation soils will require special treatment to control total and differential settlement.

3.07 Global Stability

A) It is the responsibility of the Certifying Engineer or Site Geotechnical Engineer to determine if further design considerations must be implemented to ensure adequate global/overall slope stability.

PART 4 – CONSTRUCTION

4.01 Inspection

A) The Engineer is responsible for verifying that the contractor meets all the requirements of the specification. This includes the use of approved materials and their proper installation.

B) The Contractor's field construction supervisor shall have demonstrated experience and be qualified to direct all work related to the retaining wall construction.

4.02 Construction Tolerances

A) The following tolerances are the maximum allowable deviation from the planned construction,

<table>
<thead>
<tr>
<th>Control</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Control</td>
<td>+/- 1.25 inches over a 10 ft distance, +/- 3 inches total</td>
</tr>
<tr>
<td>Horizontal Control</td>
<td>+/- 1.25 inches over a 10 ft distance, +/- 3 inches total</td>
</tr>
<tr>
<td>Rotation</td>
<td>+/- 2 degrees from planned wall batter</td>
</tr>
<tr>
<td>Bulging</td>
<td>1.0 inch over a 10 ft distance</td>
</tr>
</tbody>
</table>

4.03 Site Preparation

A) The foundation soil shall be excavated or filled as required to the grades and dimensions shown on the Construction Drawings or as directed by the Owner or Owner's Representative.

B) The foundation soil shall be proof rolled and examined by the Engineer to ensure that it meets the minimum strength requirements according to the design assumptions. If unacceptable foundation soil is encountered, the contractor shall excavate the affected areas and replace with suitable quality material under the direction of the Engineer.

C) In cut situations, the native soil shall be excavated to the lines and grades shown on the Construction Drawings and removed from the site or stockpiled for reuse as retained soil.
4.04 Installing Drainage System
A) The approved non-woven geotextile shall be set against the back of the first retaining wall unit, over the prepared foundation, and extend towards the back of the excavation, up the excavation face and back over the top of the drainage material to the retaining wall, or as shown in the Construction Drawings.
B) The drainage pipe shall be placed behind the leveling base, or lower course of facing units as shown in the Construction Drawings or as directed by the Engineer. The pipe shall be at a minimum gradient of 2% to ensure adequate drainage to free outlets.
C) T-Sections and outlet pipes shall be installed on the drainage pipe at 15 m (50 ft.) centers or as shown on the Construction Drawings.
D) The remaining length of geotextile shall be pulled taut and pinned over the face of the retained soil. Geotextile overlaps shall be a minimum of 300 mm (1 ft.) and shall be shingled down the face of the excavation in order to prevent the infiltration of retained soil into the drainage layer.

4.05 Levelling Base or Spread Footing Placement
A) The leveling base material shall be crushed stone compacted to 98% Standard Proctor Density, or vibrated concrete along the grades and dimensions shown on the Construction Drawings or as directed by the Engineer. The minimum thickness of the leveling base shall be 150 mm (6 inches)

4.06 Installation of Modular Concrete Retaining Wall Units
A) The bottom row of retaining wall modules shall be placed on the prepared leveling base as shown on the Construction Drawings. Care shall be taken to ensure that the wall modules are aligned properly, leveled from side to side and front to back and are in complete contact with the base material.
B) The wall modules above the bottom course shall be placed such that the tongue and groove arrangement provides the design batter (i.e. setback) of the wall face. Successive courses shall be placed to create a running bond pattern with the edge of all units being approximately aligned with the middle of the unit in the course below it.
C) The wall modules shall be swept clean before placing additional levels to ensure that no dirt, concrete or other foreign materials become lodged between successive lifts of the wall modules.
D) A minimum of 4 courses of wall units can be placed above the level of the drainage material at any time.
E) The contractor shall check the level of wall modules with each lift to ensure that no gaps are formed between successive lifts.
F) Care shall be taken to ensure that the wall are not broken or damaged during handling and placement.

4.07 Drainage Soil
A) The drainage soil will be placed behind the retaining wall modules with a minimum width of 300 mm (1 ft.) and separated from other soils using the approved non-woven geotextile.
B) Drainage soil shall be placed behind the wall facing in maximum lifts of 6 inches and compacted to a minimum density of 95% Standard Proctor.
C) No heavy compaction equipment shall be allowed within 1 m (3 ft.) of the back of the wall facia.

4.08 Retained Soil
A) Retained soils shall be placed and compacted behind the drainage material in maximum lift thickness of 150 mm (6 in.). The retained soils shall be undisturbed native material or engineered fill compacted to a minimum density of 95% Standard Proctor.
B) No heavy compaction equipment shall be allowed within 1 m (3 ft.) of the back of the wall modules.

4.09 Finishing Wall
A) Items 4.05 to 4.08 shall be repeated until the grades indicated on the Construction Drawings are achieved.
B) Coping units shall be secured to the top of the wall with two 10 mm (3/8 inch) beads of the approved flexible concrete adhesive positioned 50 mm (2 inches) in front and behind the tongue of the last course of retaining wall units.
C) Finish grading above the wall to direct surface run off water away from the segmental retaining wall. Use a soil with a low permeability to restrict the rate of water infiltration into the retaining wall structure.

geogrid-reinforced srw

PART 1 – GENERAL

1.01 Description
A) The work covered by this section includes the furnishing of all labor, materials, equipment and incidentals for the design, inspection and construction of a modular concrete retaining wall including drainage system and reinforcement as shown on the Construction Drawings and as described by the Contract Specifications. The work included in this section consists of, but is not limited to, the following:
   a) Design, inspection and certification by a registered professional engineer.
   b) Excavation and foundation soil preparation.
   c) Furnishing and placement of the leveling base.
   d) Furnishing and placement of the drainage system.
   e) Furnishing and placement of geotextiles.
   f) Furnishing and placement of segmental retaining wall facing units.
   g) Furnishing and placement of geosynthetic reinforcement.
   h) Furnishing and compaction of infill, drainage, and retained soils.

1.02 Related Work
A) Section 02100 – Site Preparation
B) Section 02200 – Earthwork

1.03 Reference Standards
A) Engineering Design
   b) NCMA TEK 2-4 – Specifications for Segmental Retaining Wall Units.
   c) NCMA SRWU-1 – Determination of Connection Strength between Geosynthetics and Segmental Concrete Units.
   d) NCMA SRWU-2 – Determination of Shear Strength between Segmental Concrete Units.
B) Segmental Retaining Wall Units
   a) ASTM C 140 – Sampling and Testing Concrete Masonry Units
   b) ASTM C 1262 – Evaluating the Freeze-Thaw Durability of Manufactured Concrete Masonry Units and Related Concrete Units.
A) Modular concrete retaining wall units are dry-cast solid concrete units that form the external facia of a modular unit retaining wall system.

B) Payment for the retaining wall system will be based on the contract price per square metre (or square foot) of vertical wall face area as shown on the construction drawings. The vertical wall face area shall be measured from the top of the base or footing to the top of the coping course multiplied by the length of the wall. The contract unit price shall include the cost of all engineering, labor, materials, and equipment used to install the leveling base or spread footing, wall modules, drainage materials, infill soil, geosynthetic reinforcement, retained soil, and site clean up. Additional vertical wall face area as directed and approved in writing by the Owner, or Owner’s representative, shall be paid for under a separate pay item.

C) Colour to be [______].

D) The installing contractor shall check all materials delivered to the site to ensure that the correct materials have been received and are in good condition.

E) The Contractor shall store and handle all materials in accordance with manufacturer’s recommendations and in a manner to prevent deterioration or damage due to moisture, temperature changes, contaminants, breaking, chipping, or other causes.

F) The Contractor shall submit the following information for approval thirty (30) days prior to the construction of the segmental retaining wall.

   a) Design Submittal – Provide three (3) sets of stamped construction drawings and detailed design calculations, completed and sealed by the Engineer in accordance with the design requirements outlined in Part 3 of these specifications.
   b) Materials Submittal – Manufacturer’s certifications, stating that the SRW units, the geosynthetic reinforcement, and imported aggregates and soils meet the requirements of this specification and the Engineer’s design.
   c) Installer Qualifications – The Contractor must be able to demonstrate that their field construction supervisor has the necessary experience for the project by providing documentation showing that they have successfully completed projects of similar scope and size.

G) Where specifications and reference documents conflict, the Owner or Owner’s Representative shall make the final determination of applicable document.

1.04 Approved Products
A) Pisa2 Segmental Retaining Wall System as supplied by the Risi Stone Systems Authorized Manufacturer.
B) Colour to be [______].

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   a) Design Submittal – Provide three (3) sets of stamped construction drawings and detailed design calculations, completed and sealed by the Engineer in accordance with the design requirements outlined in Part 3 of this specification. A detailed explanation of the design properties for the geosynthetic reinforcements shall be submitted with the design.
   b) Materials Submittal – Manufacturer’s certifications, stating that the SRW units, the geosynthetic reinforcement, and imported aggregates and soils meet the requirements of this specification and the Engineer’s design.
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1.07 Engineering Design and Certification
A) The term Engineer shall refer to the individuals or firms who have been retained by the Contractor to provide design and inspection services for the retaining wall. The Design Engineer may be a different individual or firm from the Inspecting Engineer as the Manufacturer may provide this service. The Engineer(s) must be qualified in the area of segmental retaining wall design and construction and must be licensed to practice engineering in the Province or State that the wall is to be constructed.
B) The Engineer(s) will perform the following tasks:
   a) Produce sealed construction drawings and detailed design calculations, completed in accordance with the design requirements outlined in Part 3 of these specifications.
   b) Review the site soil and geometric conditions to ensure the designed wall is compatible with the site prior to construction.
   c) Inspect the site conditions, materials incorporated into the retaining wall, and the construction practices used during the construction.
   d) Provide the Contractor with a letter after completion, certifying the design meets the requirements of this specification, the design was compatible with the site, and the wall was constructed according to design.

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PART 2 – MATERIALS

2.01 Definitions
A) Modular concrete retaining wall units are dry-cast solid concrete units that form the external facia of a modular unit retaining wall system.
A) Coping units are the last course of concrete units used to finish the top of the wall.

B) Infill soil is specified material that is placed directly behind the drainage soil and within the reinforced zone, if applicable.

C) Retained soil is an in-situ soil or a specified soil that is placed behind the wall infill soil.

D) Foundation soil is the in-situ soil beneath the wall structure.

E) Drainage aggregate is a free draining soil with natural soil filtering capabilities, or a free draining soil encapsulated in a suitable geotextile, or a combination of free draining soil and perforated pipe all wrapped in a geotextile, placed directly behind the modular concrete units.

F) Drainage pipe is a perforated polyethylene pipe used to carry water, collected at the base of a soil retaining wall, to outlets in order to prevent pore water pressures from building up behind the wall facing modules.

G) Non-woven geotextiles are permeable synthetic fabrics formed from a random arrangement of fibers in a planar structure. They allow the passage of water from one soil medium to another while preventing the migration of fine particles that might clog a drainage medium.

H) Geogrid reinforcement is a polymer grid structure having tensile strength and durability properties that are suitable for soil reinforcement applications.

I) All values stated in metric units shall be considered as accurate. Values in parenthesis stated in imperial units are the nominal equivalents.

2.02 Products

A) Concrete Segmental Retaining Wall Units
   a) The concrete wall modules shall be 150 x 200 x 300 mm (6 x 8 x 12 inches) with a maximum tolerance of plus or minus 3 mm (1/8 in.) for each dimension.
   b) The retaining wall modules shall be solid units and have a minimum weight of 20.4kg (45 lbs.) per unit.
   c) The concrete wall modules shall have an integral shear key connection that shall be offset to permit a minimum wall batter of 1H : 8V.
   d) The concrete wall modules shall have a minimum 28-day compressive strength of 35 MPa (5000 psi) as tested in accordance with ASTM C 140. The concrete shall have a maximum moisture absorption rate of 5 percent to ensure adequate freeze-thaw protection.

B) Infill Soil
   a) The infill soil shall consist of free draining sands or gravels with less than 5% passing the #200 sieve size or as specified in the Construction Drawings.
   b) The Engineer shall review and determine the suitability of the wall infill soil at the time of construction.

C) Retained Soil
   a) The retained soil shall be on site soils unless specified otherwise in the Construction Specifications or as directed by the Owner or Owner’s Representative. If imported fill is required, it shall be examined and approved by the Engineer.

D) Foundation Soil
   a) The foundation soil shall be native undisturbed on site soils. The foundation soil shall be examined and approved by the Engineer prior to the placement of the base material.

E) Levelling Base Material
   a) The footing material shall be non-frost susceptible, well graded compacted crushed stone (GW-Unified Soil Classification System), or a concrete leveling base, or as shown on the Construction Drawings.

F) Drainage Soil
   a) The drainage soil shall be a free draining angular granular material of uniform particle size smaller than 25 mm (1 inch) separated from the infill soil or retained soil by a geotextile filter. The drainage soil shall be installed directly behind the SRW units if the infill soil is unable to provide adequate drainage capacity.

G) Drainage Pipe
   a) The drainage pipe shall be perforated corrugated HDPE or PVC pipe, with a minimum diameter of 100 mm (4 inches), protected by a geotextile filter to prevent the migration of soil particles into the pipe, or as specified on the construction drawings.

H) Geotextile Filter
   a) The non-woven geotextile shall be installed as specified on the construction drawings. Although selection of the appropriate geotextile specifications is site soil specific, a commonly used geotextile for filtration will have an Apparent Opening Size ranging between 0.149 and 0.210 mm (U.S. Sieve Sizes 100 to 70) and a minimum unit weight of 135 grams per square meter (5.0 oz /square yard). The coefficient of permeability will typically range between 0.1 and 0.3 cm/second.

I) Geogrid Reinforcement
   a) The Engineer shall determine the type, strength and placement location of the reinforcing geosynthetic. The design properties of the reinforcement shall be determined according to the procedures outlined in this specification. Detailed test data shall be submitted with the design calculations and shall include tensile strength (ASTM D 4595 or GGI GG-1), creep potential (ASTM D 5262), site damage and durability (GRI GG-4) and pullout resistance (GRI-GG-5 or GRI-GT-6) and connection strength (NCMA SRWU-1).

J) Concrete Adhesive
   a) The adhesive is used to permanently secure the coping stone to the top course of the wall. The adhesive must provide sufficient strength and remain flexible.

PART 3 – WALL DESIGN

3.01 Design Standard

A) The Engineer is responsible for providing a design that shall consider the external, internal, and local stability of the SRW system. It is the responsibility of the Certifying Engineer or Site Geotechnical Engineer to determine if further design considerations must be implemented to ensure adequate global/overall slope stability, and or if the foundation soils will require special treatment to control total and differential settlement. The design life of the structure shall be 75 years unless otherwise specified in the construction drawings.

B) The segmental retaining wall shall be designed in accordance with recommendations of the NCMA Design Manual for Segmental Retaining Walls, Second Edition. The following is a summary of the minimum factors of safety for the various modes of failure evaluated in the proposed design.

<table>
<thead>
<tr>
<th>External Stability</th>
<th>Internal Stability</th>
<th>Local Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Sliding</td>
<td>Tensile Overstress</td>
<td>Facing Shear</td>
</tr>
<tr>
<td>Overturning</td>
<td>Pullout</td>
<td>Connection</td>
</tr>
<tr>
<td>Bearing Capacity</td>
<td>Internal Sliding</td>
<td>1.5</td>
</tr>
<tr>
<td>Global Stabilty</td>
<td></td>
<td>1.5</td>
</tr>
</tbody>
</table>

3.02 Soil

A) Design parameters: The following soil parameters shall be assumed for the design unless otherwise shown on the plans or specified by the Engineer.
3.03 Design Geometry
A) The length, height, and overall elevations of the retaining wall must comply with the requirements of the proposed elevation detail, station information, and site grading plan.
B) The structures’ design height, H, shall be measured from the top of the leveling pad to the top of the wall where ground surface intercepts the wall facing.
C) Slopes above and below all sections of the segmental retaining wall are detailed in the site grading plan.
D) The minimum wall embedment shall be the greater of 1) the height of a SRW unit, 2) 150 mm (0.5 ft), or 3) the minimum embedment required because of the slope below the wall:

<table>
<thead>
<tr>
<th>Slope Below Wall</th>
<th>Minimum Embedment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level</td>
<td>H/10</td>
</tr>
<tr>
<td>3 : 1 (18.4º)</td>
<td></td>
</tr>
<tr>
<td>2 : 1 (26.5º)</td>
<td></td>
</tr>
</tbody>
</table>

C) The following surcharges shall be applied to the top of each design cross section based on the following proposed uses above the wall.

<table>
<thead>
<tr>
<th>Use Above Wall</th>
<th>Minimum Surcharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Traffic</td>
<td>0 kPa (0 lb/sq. ft)</td>
</tr>
<tr>
<td>Light Traffic</td>
<td>4.8 kPa (100 lb/sq. ft)</td>
</tr>
<tr>
<td>Heavy Traffic</td>
<td>12.0 kPa (250 lb/sq. ft)</td>
</tr>
</tbody>
</table>

3.04 State of Stress
A) The lateral earth pressure to be resisted by the reinforcements at each reinforcement layer shall be calculated using the Coulomb coefficient of earth pressure, Ka, times the vertical stress at each reinforcement layer.
B) The vertical soil stress at each reinforcement layer shall be taken equal to the unit weight of the soil times the depth to the reinforcement layer below the finished grade behind the facing units. A coefficient of active earth pressure, Ka, shall be used from the top to the bottom of the wall. The coefficient of active earth pressure, Ka, shall be assumed independent of all external loads except sloping fills. For sloping fills, the coefficient of active earth pressure, Ka, appropriate for the sloping condition, using Coulomb earth pressure shall be used in the analysis.

3.05 Inclination of Failure Surface
A) A Coulomb failure surface passing through the base of the wall at the back of the reinforced zone up to the ground surface at or above the top of wall shall be assumed in design of walls.

3.06 Geosynthetic Reinforcement
A) The allowable reinforcement tension, Ta, shall be determined in accordance with the method outlined in the NCMA Design Manual for Segmental Retaining Walls, Second Edition. This method calculates the Long Term Design Strength (LTDS) of the geosynthetic reinforcement by considering the time-temperature creep characteristics of the reinforcement, environmental degradation, construction induced damage and an overall factor of safety.

3.07 Geogrid Length
A) The minimum soil reinforcement length shall be as required to achieve a minimum width of structure, B, measured from the front face of the wall to the end of the soil reinforcements. B must be greater than or equal to 60 percent of the total height, H. The length of the reinforcements at the top of the wall may be increased beyond the minimum length required to increase pullout resistance.

3.08 Settlement Control
A) It is the responsibility of the Certifying Engineer or Site Geotechnical Engineer to determine if the foundation soils will require special treatment to control total and differential settlement.

3.09 Global Stability
A) It is the responsibility of the Certifying Engineer or Site Geotechnical Engineer to determine if further design considerations must be implemented to ensure adequate global/overall slope stability.

PART 4 – CONSTRUCTION
4.01 Inspection
A) The Engineer is responsible for verifying that the contractor meets all the requirements of the specification. This includes the use of approved materials and their proper installation.
B) The Contractor’s field construction supervisor shall have demonstrated experience and be qualified to direct all work related to the retaining wall construction.

4.02 Construction Tolerances
A) The following tolerances are the maximum allowable deviation from the planned construction:

Vertical Control: +/- 1.25 inches over a 10 ft distance, +/- 3 inches total
Horizontal Control: +/- 1.25 inches over a 10 ft distance, +/- 3 inches total
Rotation: +/- 2º from planned wall batter
Bulging: 1.0 inch over a 10 ft distance

4.03 Site Preparation
A) The foundation soil shall be excavated or filled as required to the grades and dimensions shown on the Construction Drawings or as directed by the Owner or Owner’s Representative.
4.04 Installing Drainage System
A) The approved non-woven geotextile shall be set against the back of the first retaining wall unit, over the prepared foundation, and extend towards the back of the excavation, up to the excavation face and back over the top of the infill soil to the retaining wall, or as shown in the Construction Drawings.

B) The drainage pipe shall be placed behind the leveling base, or lower course of facing units as shown in the Construction Drawings or as directed by the Engineer. The pipe shall be laid at a minimum gradient of 2% to ensure adequate drainage to free outlets.

C) T-Sections and outlet pipes shall be installed on the drainage pipe at 15 m (50 ft.) centers or as shown on the Construction Drawings.

D) The remaining length of geotextile shall be pulled taut and pinned over the face of the retained soil. Geotextile overlaps shall be a minimum of 300 mm (1 ft.) and shall be shingled down the face of the excavation in order to prevent the infiltration of retained soil into the wall infill.

4.05 Levelling Base or Spread Footing Placement
A) The leveling base material shall be crushed stone compacted to 98% Standard Proctor Density, or vibrated concrete along the grades and dimensions shown on the Construction Drawings or as directed by the Engineer. The minimum thickness of the leveling base shall be 150 mm (6 inches)

4.06 Installation of Modular Concrete Retaining Wall Units
A) The bottom row of retaining wall modules shall be placed on the prepared leveling base as shown on the Construction Drawings. Care shall be taken to ensure that the wall modules are aligned properly, leveled from side to side and front to back and are in complete contact with the base material.

B) The wall modules above the bottom course shall be placed such that the tongue and groove arrangement provides the design batter (i.e. setback) of the wall face. Successive courses shall be placed to create a running bond pattern with the edge of all units being approximately aligned with the middle of the unit in the course below it.

C) The wall modules shall be swept clean before placing additional levels to ensure that no dirt, concrete or other foreign materials become lodged between successive lifts of the wall modules.

D) A maximum of 4 courses of wall units can be placed above the level of the infill soil at any time.

E) The contractor shall check the level of wall modules with each lift to ensure that no gaps are formed between successive lifts that may affect the pullout resistance of geogrid reinforcement, if applicable.

F) Care shall be taken to ensure that the wall modules and geosynthetic reinforcement are not broken or damaged during handling and placement.

4.07 Drainage Soil
A) The drainage soil will be placed behind the retaining wall modules with a minimum width of 300 mm (1 ft.) and separated from other soils using the approved non-woven geotextile.

B) Drainage soil shall be placed behind the wall facing in maximum lifts of 6 inches and compacted to a minimum density of 95% Standard Proctor.

C) No heavy compaction equipment shall be allowed within 1 metre (3 ft.) of the back of the wall facia.

4.08 Infill Soil
A) Wall infill soil shall be placed behind the first course of the wall facing units in maximum lifts of 150 mm (6 inches) and compacted to a minimum density of 95% Standard Proctor. At the specified elevations, geogrid reinforcement shall be placed, as described in section 4.09. The fill shall be placed and compacted level with the top of the wall modules at the specified geogrid elevations prior to placing the geogrid reinforcement.

B) Wall infill soil shall be placed on top of the geogrid reinforcement layers in maximum lifts of 150 mm (6 inches) and compacted to a minimum density of 95% Standard Proctor Density. Care shall be taken to ensure that the geogrid lays flat and taut during placement of the infill soil. This is best achieved by placing fill on top of the geogrid near the wall facia and spreading toward the back of the infill soil zone.

C) No tracked construction equipment shall be allowed to operate directly on top of the geogrid until a minimum thickness of 150 mm (6 inches) of fill has been placed. Rubber tired equipment may drive on top of the geogrid at slow speeds but should exercise care not to stop suddenly or make sharp turns. No heavy equipment shall be allowed within 1 meter (3 ft.) of the back of the wall.

4.09 Geogrid Soil Reinforcement
A) Pre-cut sections of geogrid reinforcement shall be placed horizontally at the specified elevations and with longitudinal axis perpendicular to the wall face (i.e. machine direction), at the elevations shown on the Construction Drawings, or as directed by the Engineer.

B) The geogrid shall be placed over the compacted infill soil and the wall facing units with the outside edge extending over the tongue of the bottom unit and to within 25 mm (1 in.) of the front facing unit. Care shall be taken to ensure that the wall modules are swept clean and the geogrid is in complete contact with the top and bottom faces of the adjacent wall modules. The next course of wall modules shall be carefully placed on top of the lower modules to ensure that no pieces of concrete are chipped off and become lodged between geotextile unit layers.

C) The geogrid shall be pulled taut away from the back the wall modules during placement of infill soil. Alternatively, suitable anchoring pins or staples can be used to ensure that there are no wrinkles or slackness prior to placement of the infill soil. The geogrid shall lay perfectly flat when pulled back perpendicular to the back of the wall facia.

4.10 Retained Soil
A) Retained soils shall be placed and undisturbed native material or engineered fill compacted to a minimum density of 95% Standard Proctor.

B) No heavy compaction equipment shall be allowed within 1 m (3 ft.) of the back of the wall modules.

4.11 Finishing Wall
A) Items 4.05 to 4.10 shall be repeated until the grades indicated on the Construction Drawings are achieved.

B) Coping units shall be secured to the top of the wall with two 10 mm (3/8 inch) beads of the approved flexible concrete adhesive positioned 50mm (2 inches) in front and behind the tongue of the last course of retaining wall units.

C) Finish grading above the wall to direct surface run off water away from the segmental retaining wall. Use a soil with a low permeability to restrict the rate of water infiltration into the retaining wall structure.
**Glossary**

**Aggregate**
Materials such as sand gravel and crushed stone used with cement to make concrete.

**Batter**
Apparent inclinations, from vertical, of the retaining wall face due to the units’ setback.

**Certifying Engineer (CE)**
The Professional Engineer retained to verify site conditions, inspect construction, and ultimately provide a letter to the owner certifying the design is compatible with the site and the wall was constructed according to the design. The CE may sub-contract out the soils testing and/or compaction testing to a geotechnical testing firm.

**Compaction**
The process of reducing the voids in newly placed soils by vibration, kneading, or tamping to ensure the maximum density and strength in the soil.

**Coping**
Top course of units on a wall. Provides a finished appearance and ties the wall together.

**Convex Curve**
The surface of the wall is curved like the exterior of a sphere or circle.

**Cut Bank**
The embankment of site soil created before the retaining wall is installed.

**Density**
Measure of the quantity of mass per unit volume. Dimensions are kg/cu.m or lb/cu.ft.

**Drainage Conditions**
Varying groundwater/soil conditions require different treatments to ensure proper drainage. The steps in our Installation section illustrate a typical situation where no excessive groundwater flow is anticipated. For other options, refer to Details – Drainage.

**Drainage Fill**
A poorly graded aggregate material with a high permeability and porosity (e.g. clear stone).

**Facade/Facade**
The assembled modular concrete units that form the exterior face of the retaining wall.

**Concave Curve**
The surface of the wall is curved like the interior of a sphere or circle.

**Conventional Segmental Retaining Wall System**
An earth retaining structure that uses its mass to resist the movement of the soil mass behind the structure.

**Filter Cloth**
A continuous sheet of flexible, permeable fabric used to separate, filtrate, and reinforce.

**Foundation Soil**
The soil upon which the base of the retaining wall is placed.
**Geogrid**
A synthetic material that has an open, thin sheet, grid-like structure that is used to reinforce soil.

**Infill Soil**
Soil material placed and compacted around the geogrids. Ideally free-draining granular material.

**Reinforced Segmental Retaining Wall System**
An earth retaining structure that incorporates synthetic materials used to reinforce the soil mass behind the structure.

**Retained Soil**
Site soil in a cut bank or soil material placed and compacted behind the wall structure.

**Running Bond**
Pattern created by stacking units so the vertical joints are offset one half unit from the course below.

**Setback**
The horizontal distance that units in successive course are offset.

**Side Wall**
Return wall at the edge of the steps running perpendicular to the risers.

**Slope**
A surface that inclines up or down (i.e. is not horizontal).

**SPD**
Standard Proctor Density

**SRW**
Segmental Retaining Wall

**Surcharge**
Loads or extra weight placed on the soil above and behind the retaining wall (e.g. traffic).

**Wall Embedment**
Depth of retaining wall that is buried. Distance from top of base to lower surface grade.

**Weight**
Measure of gravity force on an object.
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• Cdn. Pat. 2,017,578 • Ind. Des. 83,773 • Ind. Des. 78,184. Other domestic and foreign patents and designs are pending.