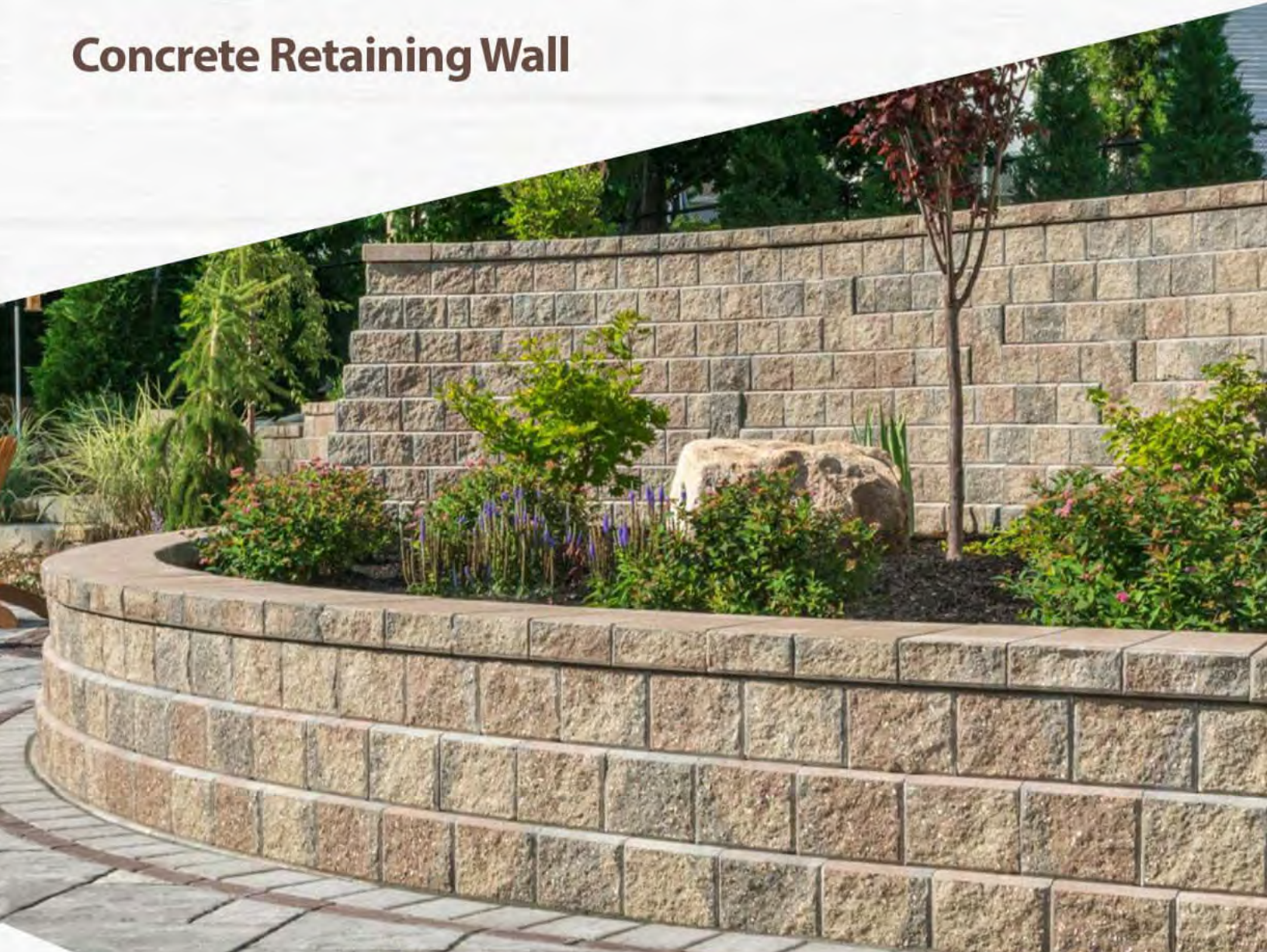


PISA 2

Concrete Retaining Wall

UNILOCK



Installation Guide

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installation

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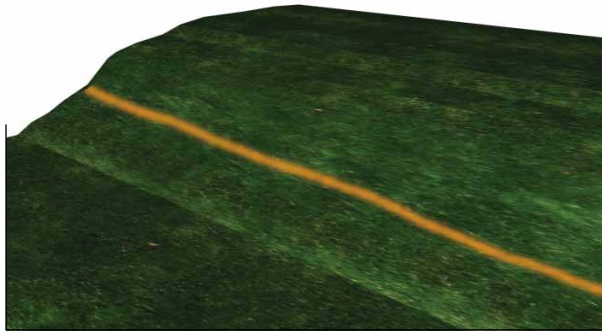


conventional srw installation procedure

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. Refer to Overview of a Successful Project before beginning.

plan

With your final design in hand, begin to establish the wall location and proposed grades. Locate all utilities and contact local utility companies before digging. Mark a line where the front of the wall will be placed, keeping in mind the 19mm (3/4 in) setback per course.

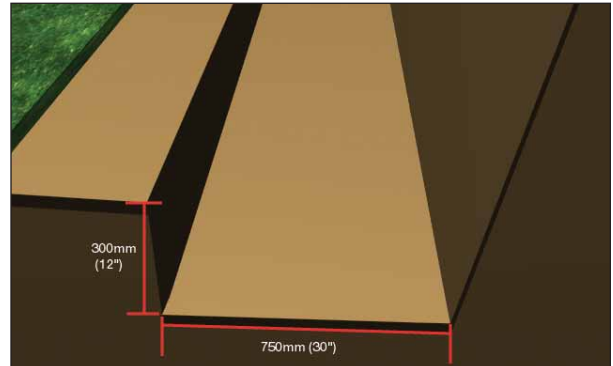


excavate

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 wall. The trench should be a minimum of 750mm (30 in) wide (front to back) and 300mm (12 in) deep. This depth assumes one unit is buried (unit height of 150mm [6 in]) plus the compacted granular base minimum depth of 150mm (6 in). As wall height increases, depth of embedment also increases, normally about 10% of the wall height. Greater embedment depths may be required to account for slopes more than 3H:1V in front of the wall, scour protection in water applications, global stability, or as specified in the design. The rear 150mm (6 in) of the trench is excavated to account for the drainage layer. Excavations should be conducted in accordance with local codes under direction of the General Review Engineer (GRE).

verify foundation subgrade

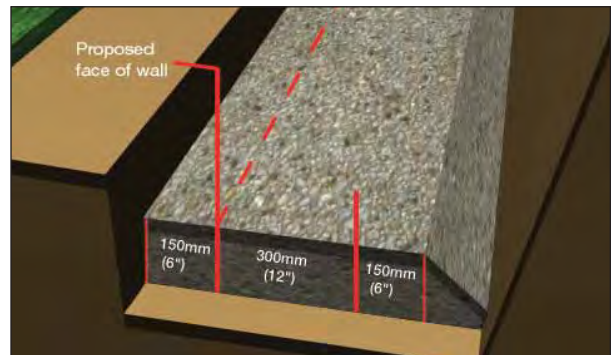
Once the foundation trench has been excavated to the specified elevations, the native foundation soil must be checked by the GRE. The foundation soil must have the required allowable bearing capacity specified in the design.



prepare the compacted granular base

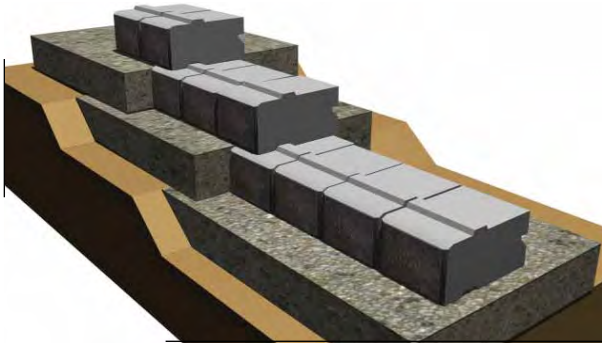
Start the base at the lowest elevation of the wall. The base should be composed of well-graded, free-draining (less than 8% fines), angular granular material, and compacted to a minimum of 98% SPD. The minimum base thickness is 150mm (6 in) or as required by the GRE to reach competent founding soil.

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



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 (6in) – the height of one course. The 19mm (¾ in) offset must be accounted for at each step.



place filter cloth

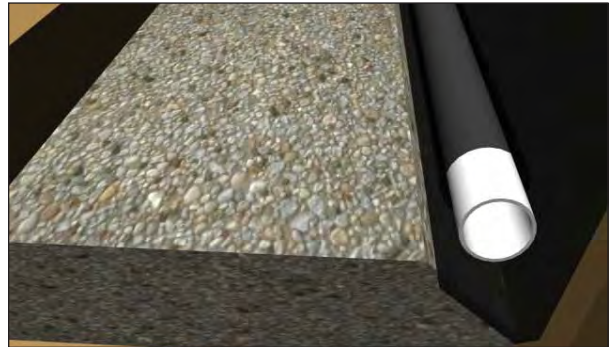
Lay the approved filter fabric (geotextile) along the bottom of the rear of the trench and extend up the exposed excavation to the proposed wall height. Leave adequate material at the top to fold back towards the wall (completely containing the drainage material). Stake the filter cloth against the slope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



place the drain

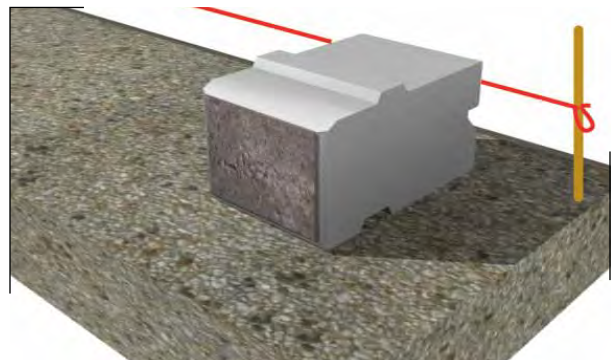
Various options for drain placement may exist, depending on how the pipe is to be outlet (refer to *Drainage*). The drain may be outlet through the wall face or connected to a positive outlet (storm drain). The drainage system is extremely important and outlets must be planned prior to construction.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

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

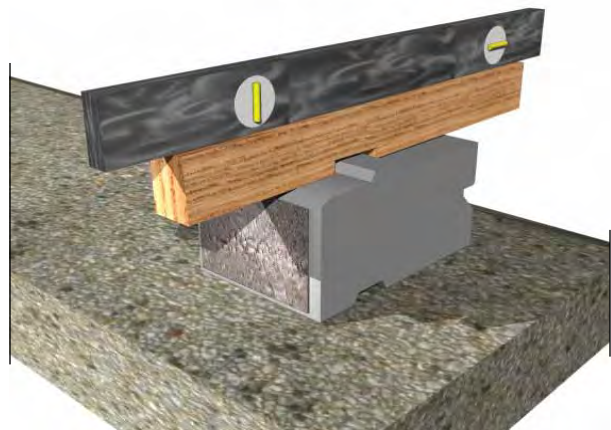


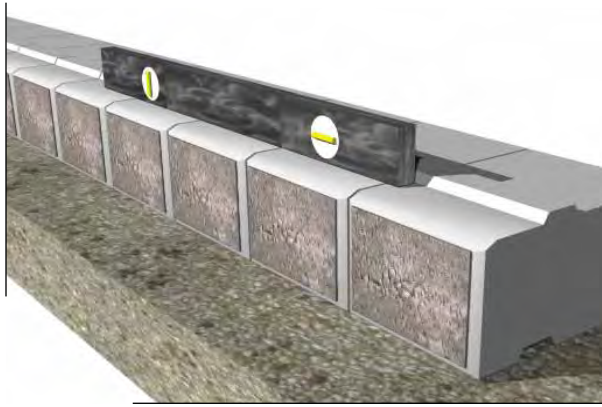
place the first course

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 [12in] 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 units below (100mm [4 in] offset). Continue stacking courses to a maximum of four courses (600mm [24 in]) before backfilling.

backfill drainage material

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

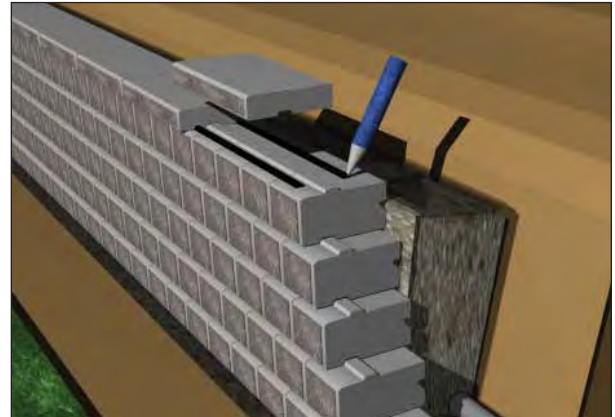
continue stacking and backfilling

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



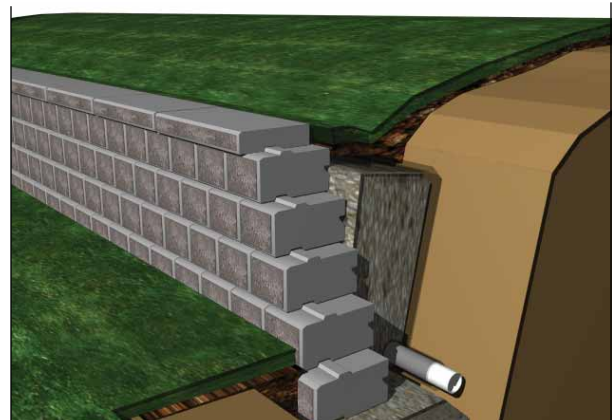
place coping unit

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



encapsulate the drainage layer and finish grading

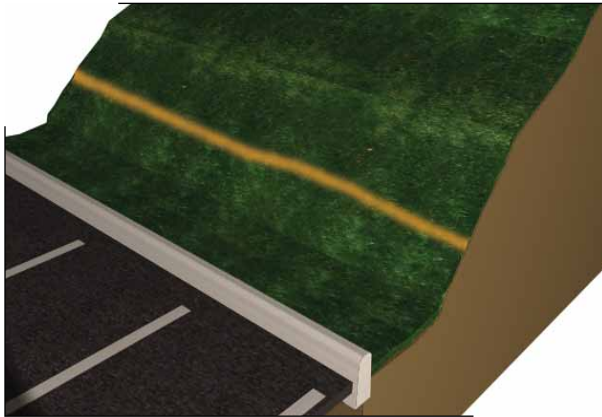
Fold the excess filter fabric over the top of the drainage layer and extend up the back face of the coping unit. Ideally, place an impervious layer of soil on top of the filter fabric and compact manually, providing for the required grading and/or swales. For other treatments such as pavers, concrete,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





plan

With your final design in hand, begin to establish the wall location and proposed grades. Locate all utilities and contact local utility companies before digging. Mark a line where the front of the wall will be placed, keeping in mind the 19mm ($\frac{3}{4}$ in) setback per course.



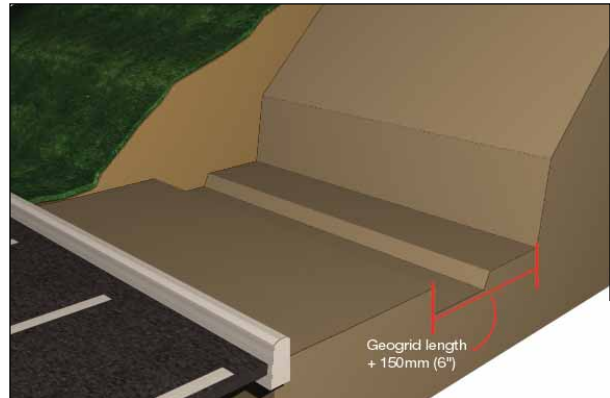
excavate reinforced zone

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

excavate granular base

Excavate a trench for the granular base. The front of the trench should be 150mm (6 in) from the planned face of the wall. The trench should be a minimum of 750mm (30 in) wide (front to back) and 300mm (12 in) deep. This depth assumes one unit is buried (unit

height of 150mm [6 in]) plus the compacted granular base minimum depth of 150mm (6 in). As wall height increases, depth of embedment also increases, normally about 10% of the wall height. Greater embedment depths may be required to account for slopes more than 3H:1V in front of the wall, scour protection in water applications, global stability, or as specified in the design. The rear 150mm (6 in) of the trench is excavated to account for the drain.

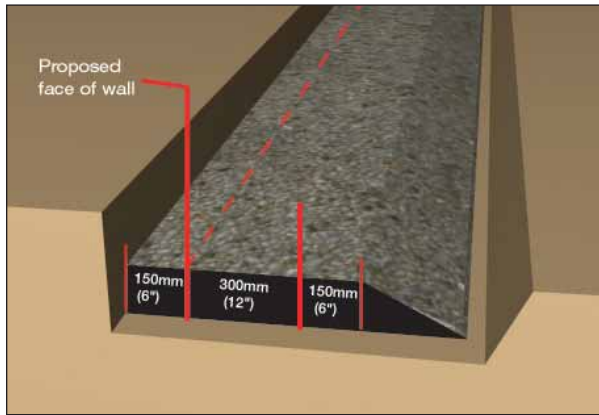


verify foundation subgrade

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

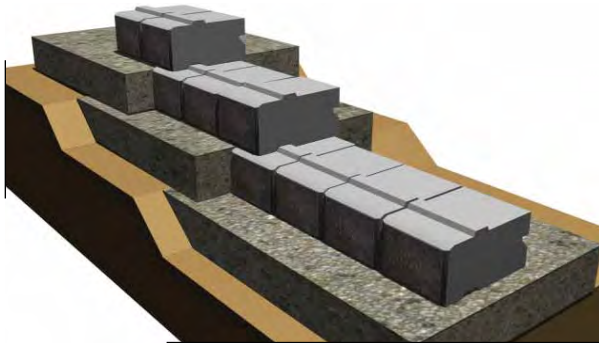
prepare the compacted granular base

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



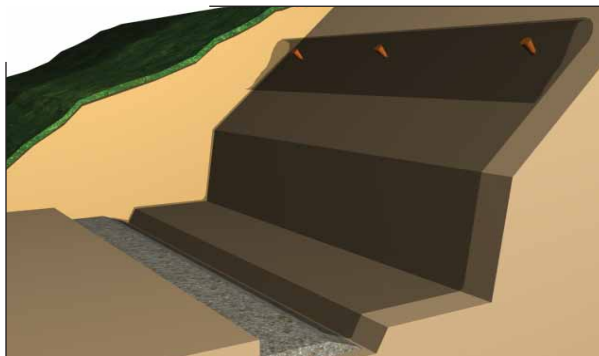
step the base

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



place filter cloth

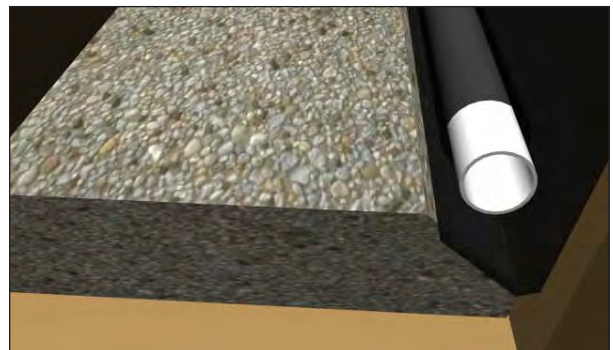
Lay the approved filter fabric (geotextile) along the bottom of the rear (150mm [6 in]) of the excavation and extend up the exposed cut face to the proposed wall height. Leave adequate material at the top to fold back towards the wall (completely containing the infill material). Stake the filter cloth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



place the drain

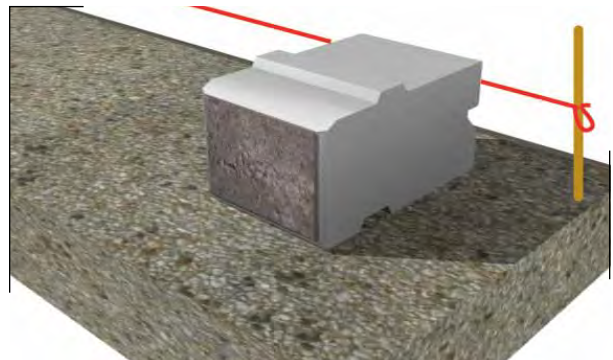
Various options for drain placement may exist, depending on how the pipe is to be outlet (refer to Drainage). The drain may be outlet through the wall face or connected to a positive outlet (storm drain).

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

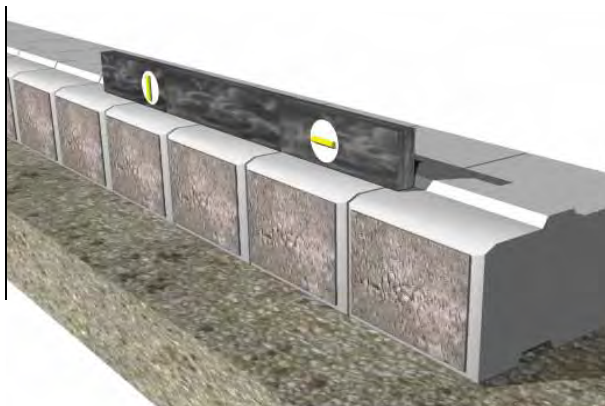
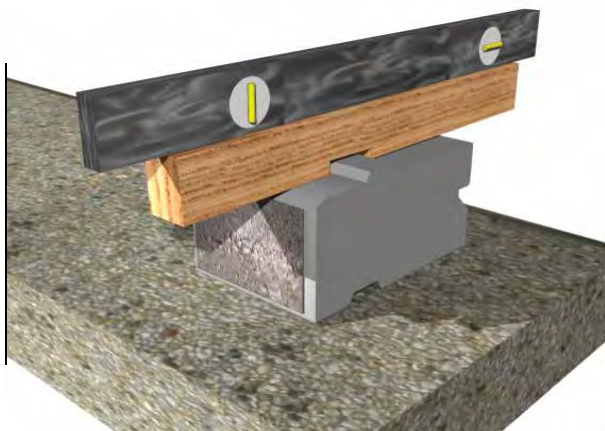


place the first course

Split units apart using a chisel and hammer if not already pre-split by manufacturer. Position a level string to mark location of first course (should be 450mm [18 in] from the front edge of the granular base). Place the first course of Pisa2 units side-by-side (touching) on the granular base.

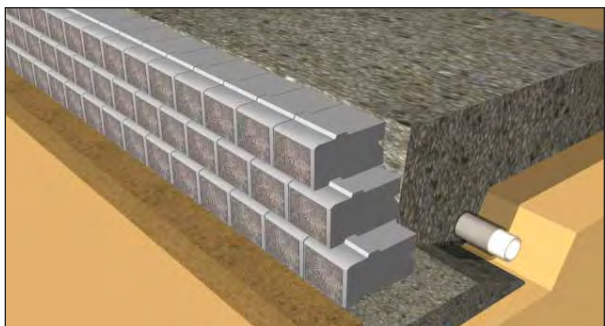


Ensure units are level front to back and left to right. Extra care should be taken at this stage as it is critical for accurate alignment.



stack the units

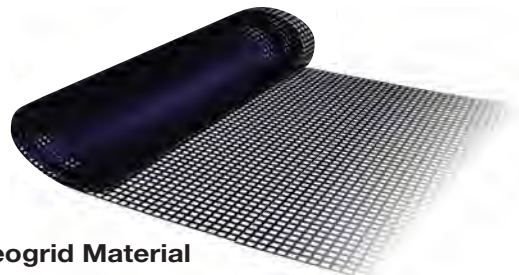
Sweep top of underlying course and stack next course in a running bond pattern so that the middle of the unit is above the joint between adjacent units below. Continue stacking courses up to the elevation of the first layer of geogrid or to a maximum of four courses (600mm [24 in]) before backfilling.



backfill

Begin backfilling the wall. Risi Stone Systems recommends using a well-graded, free-draining (less than 8% fines), angular granular material. The infill material is placed in maximum 150mm–200mm (6 in–8 in) lift

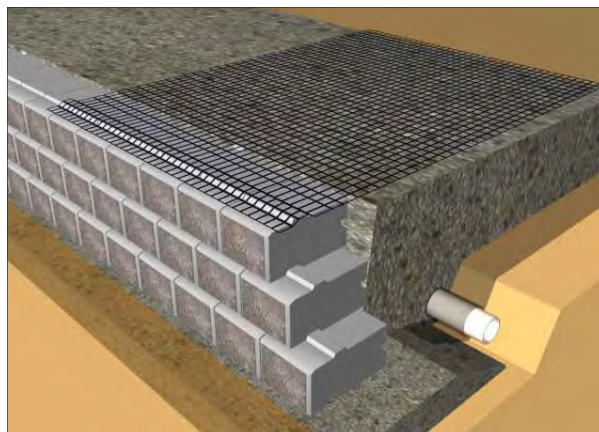
thicknesses and compacted to a minimum of 95% SPD. The compaction must be checked by the GRE at regular intervals. Continue backfilling up to the elevation of the first layer of geogrid reinforcement. Caution must be taken to ensure the allowable lift thickness is not exceeded and/or heavy compaction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



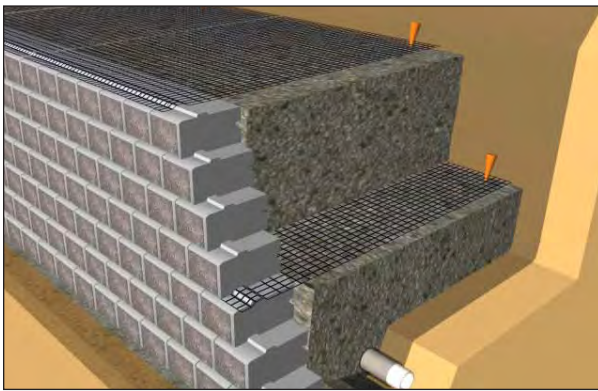
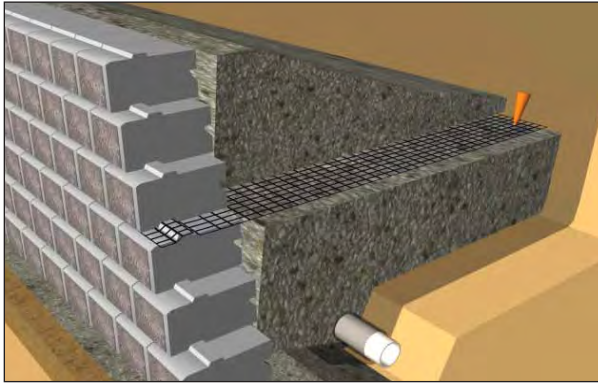
Geogrid Material

install geogrid reinforcement

Ensure the geogrid reinforcement specified in the design matches the product on site (no substitutes are acceptable without consent of design engineer). Cut the geogrid from the roll to the specified length, ensuring the geogrid is being cut perpendicular to the direction of primary strength. Ensuring the Pisa2 units are free of debris, lay the geogrid on top of the units 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



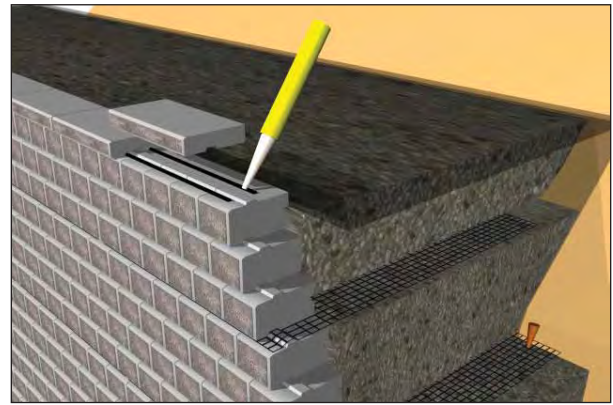
Backfill next lift of granular infill material on top of the geogrid reinforcement, placing the loose material at the front of the wall, and raking it back, away from the face (this method maintains tension in the geogrid during backfilling). Continue stacking and backfilling until the next layer of 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. Concrete adhesive must be applied to the top course in order to fix the coping units in place. Place the coping unit firmly on top of the adhesive, ensuring both surfaces are free of debris, and apply pressure to secure. Follow adhesive installation guidelines.



encapsulate the granular infill and finish grading

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





details

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**(Must be cut by installer)*



Standard



Jumbo Unit



Half Unit

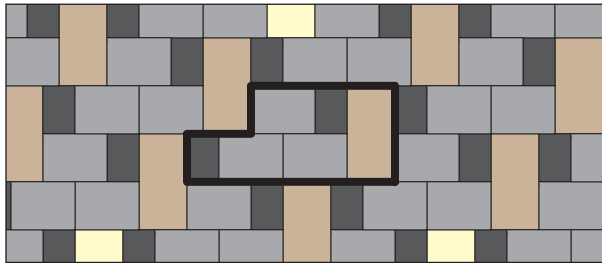


Half Jumbo Unit*

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

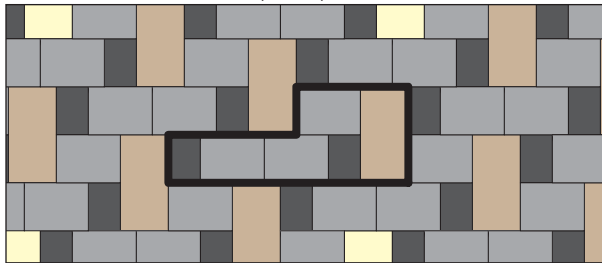
pattern one

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



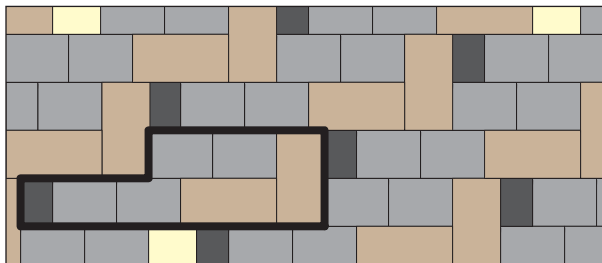
pattern two

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



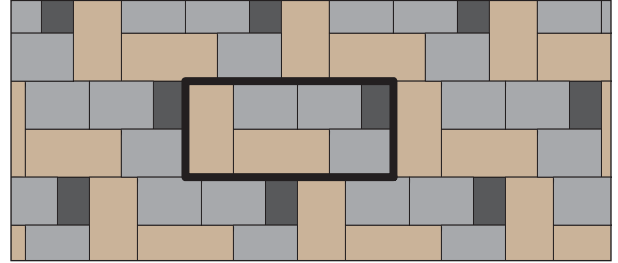
pattern three

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



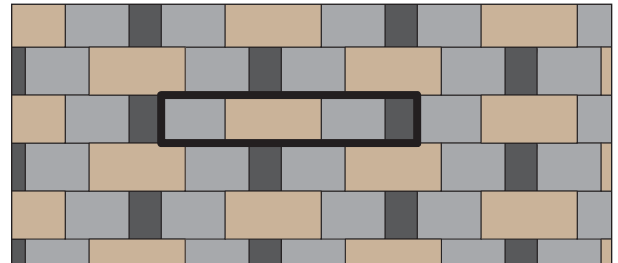
pattern four

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



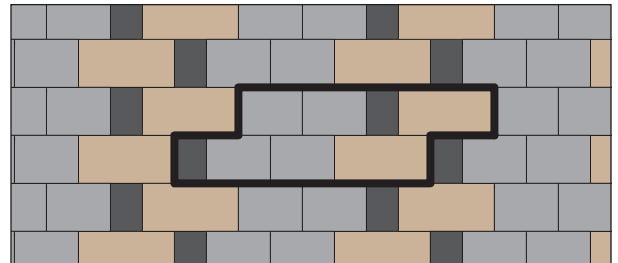
pattern five

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



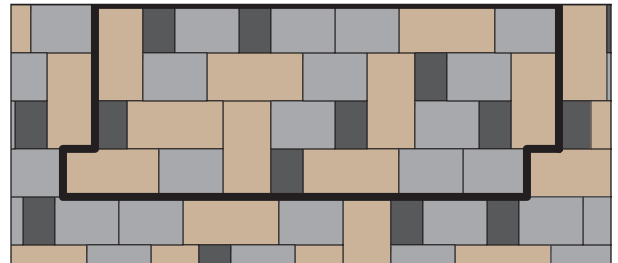
pattern six

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



creating vertical 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 (¾ in) from the rear of the base of the tongue, then split back portion off with hammer and chisel. Removal of the rear 19mm (¾ in) cancels out the offset and creates a vertical alignment.

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



rock facing ReversaCap

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



creating a 45° corner unit

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



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



Score the top and bottom of the opposite side of the unit to a depth of approximately 12mm (0.5 in) at a 45° angle. The score line starts 200mm (7.87 in) from the rear of the unit. Using a chisel and hammer, break off the corner of the unit to reveal a rock-faced 45° unit.



Remove knob.



running bond pattern

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



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



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.

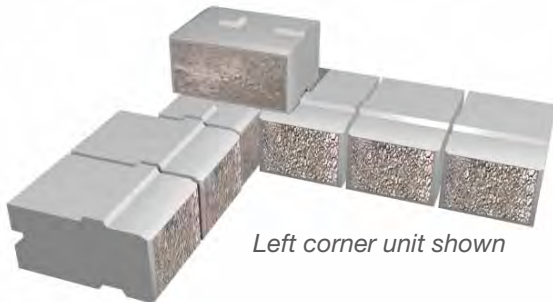


Right corner unit shown

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.

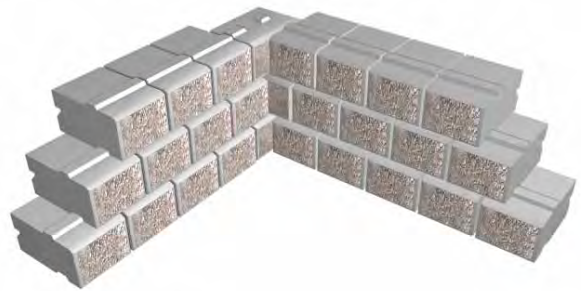


Left corner unit shown

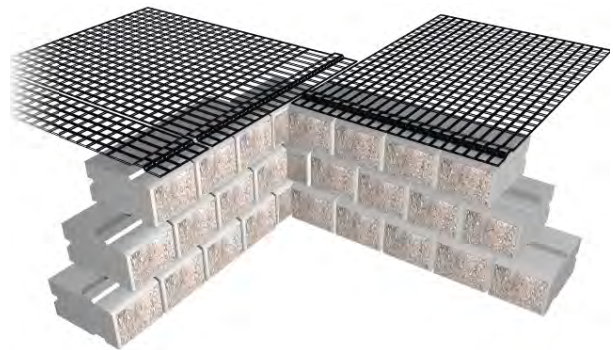
Place standard units to complete the course.



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. Cut left corner off the innermost unit at an angle equal to $\frac{1}{2}$ the desired off angle, leaving $\frac{3}{4}$ of face.



Cut right corner off adjacent unit at the same angle, leaving $\frac{1}{4}$ of the face, and continue placing base course units on adjacent wall.



Cut right corner at desired angle, leaving $\frac{3}{4}$ of the face.



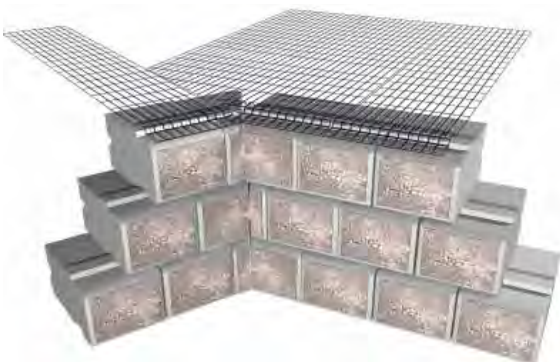
Cut left corner at desired angle, leaving $\frac{1}{4}$ of the face, and place standard units to complete the course.



Repeat until desired wall height is achieved.

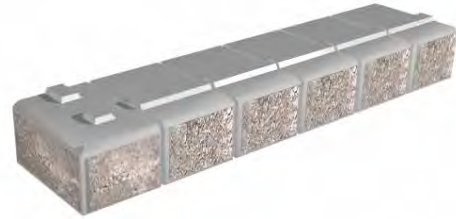


The geogrid should be placed within 25mm (1 in) of the face of the block. As it is only necessary to have geogrid extending directly away from the wall, a gap will result in the geogrid layer as shown.

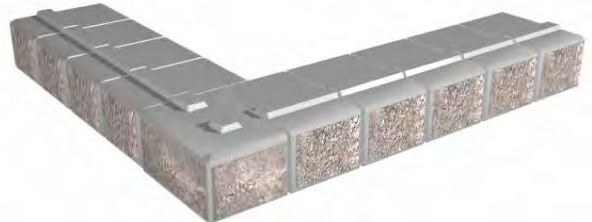


outside 90° corner

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.



outside 45° corner

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



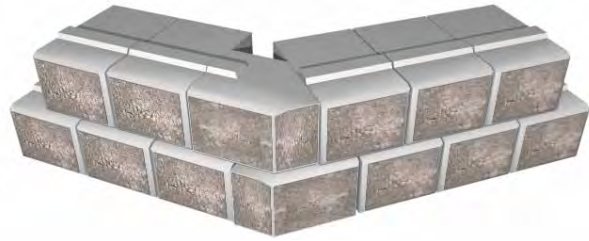
Continue placing base course units on adjacent wall.



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



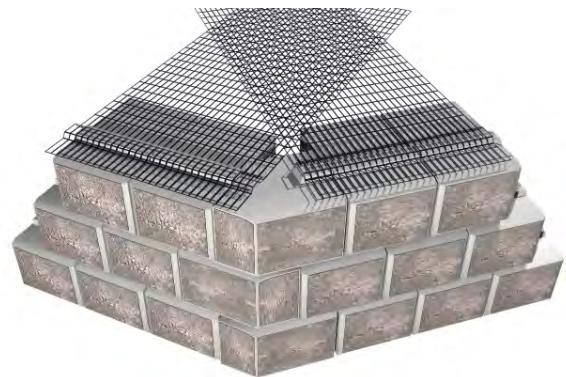
Place standard units to complete the course.



Repeat until desired wall height is achieved.



The geogrid from the two side walls will overlap and should be separated by a minimum of 75mm (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.

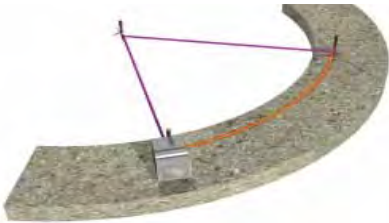




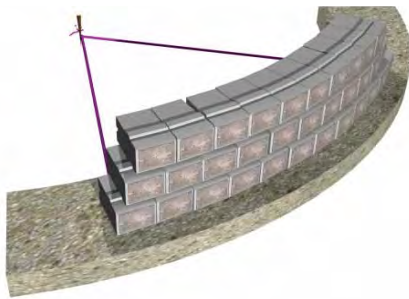
convex curve

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.

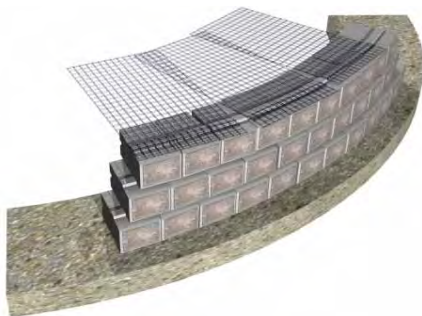
Once the radius to be used is decided upon and the necessary curve for the base course is calculated, the base can be roughly outlined with spray paint. Upon completion of the base, the starting and ending points of the curve can be staked. The curve should be marked with paint to ensure the proper radius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



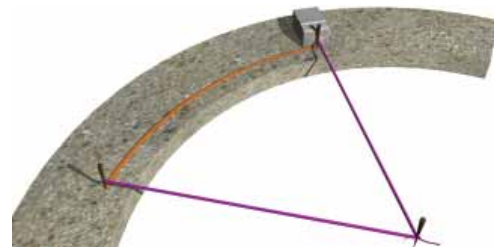
Geogrid layers should be placed within 25mm (1 in) of the front face of the block. The geogrid will overlap and should have 75mm (3 in) of compacted soil between the layers. The geogrid should be placed on the Pisa2 units so the geogrid does not overlap until it enters the soil zone.



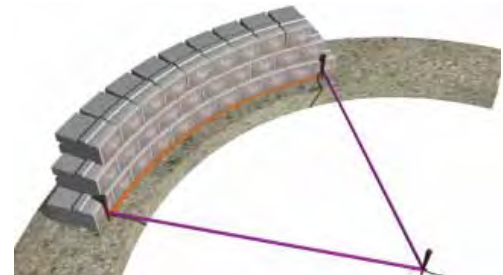
concave curve

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.

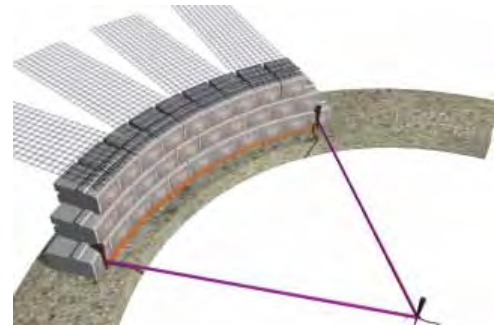
Once the radius to be used is decided upon and the necessary curve for the base course is calculated, the base can be roughly outlined with spray paint. Upon completion of the base, the starting and ending points of the curve can be staked. The curve should be marked with paint to ensure the proper radius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



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.





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.



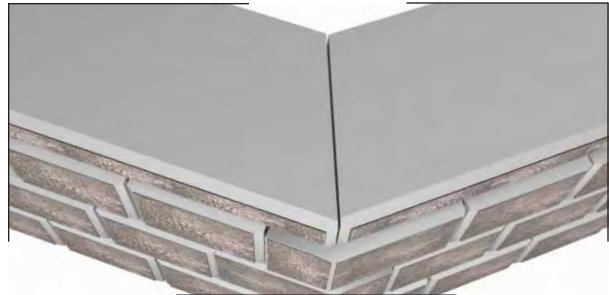
PisaStone coping unit

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.



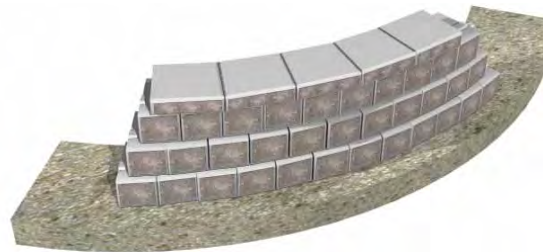
odd-angled corner

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

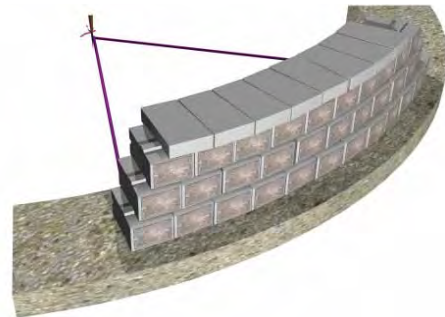


copings for curves

The PisaStone coping units can be saw cut to create a curve. Attach the PisaStone coping units to the 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.



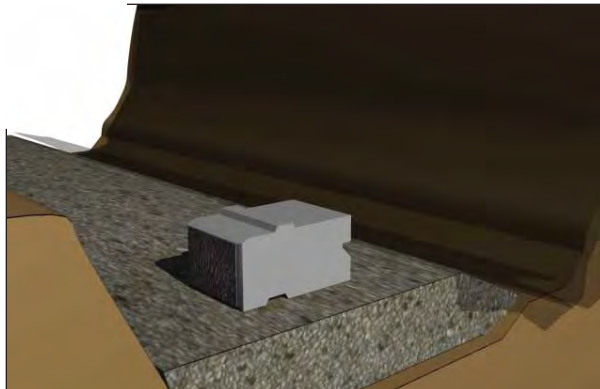


conventional SRWs

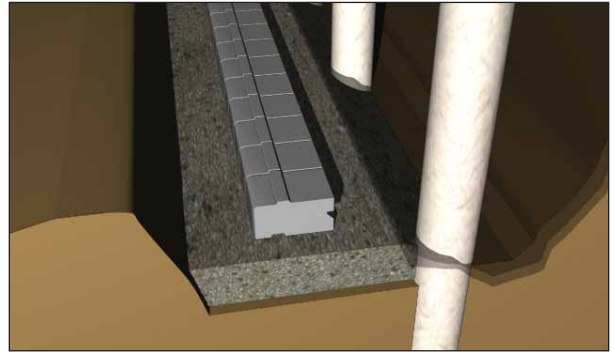
Handrails/fences are usually required for most walls over 600mm (2.0ft) in height where pedestrians have access (check with your local building code). These handrails must act to resist potential lateral pedestrian loads. *Handrails must not be secured to the Pisa2 retaining wall.*

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.

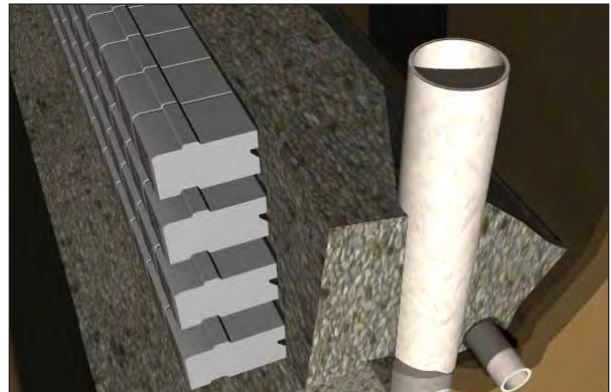
Excavate, prepare base, lay filter cloth against cut face, and define location of base course (see *Installation – Conventional SRW*).



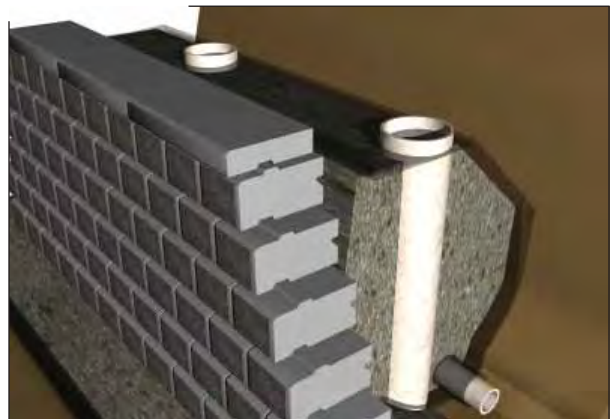
Identify the proposed location of the handrail foundations (sonotubes). Take into account the batter (setback) of the wall (19mm [¾ in] per course) and the required offset at the top. It is preferable to leave a 300mm (12 in) buffer zone between the outside of the sonotube and the back of the wall. If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



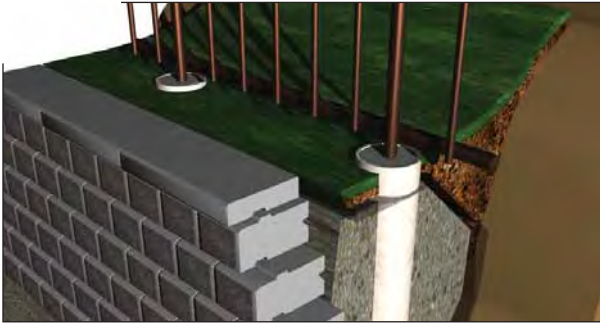
Construct the conventional SRW, stacking units and backfilling with drainage material. The recommended drainage material (¾ in clear stone) should be lightly compacted with a hand tamper, ensuring proper confinement around the sonotube.



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



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

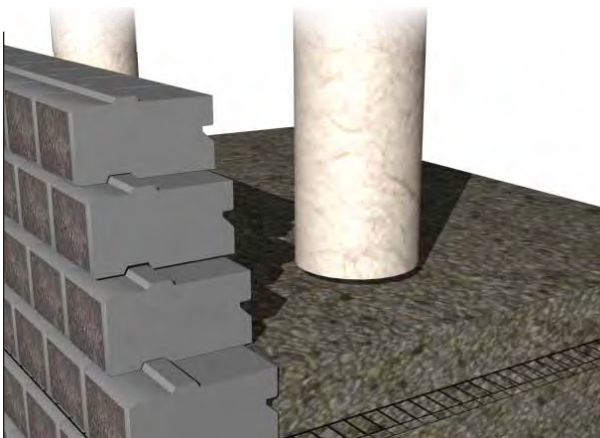


geogrid-reinforced SRWs

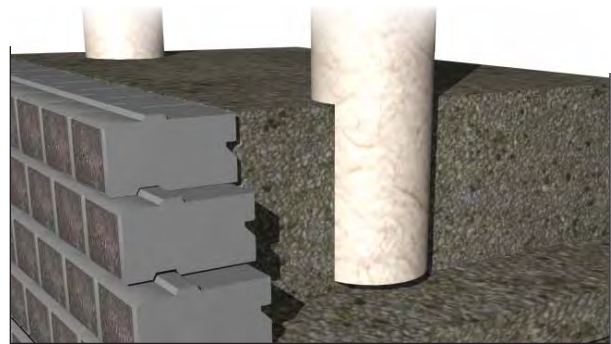
Handrails/fences are usually required for most walls over 600mm (2.0ft) in height where pedestrians have access (check with your local building code). These handrails must act to resist potential lateral pedestrian loads. Handrails must not be secured to the Pisa2 retaining wall. Concrete sonotubes, 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).

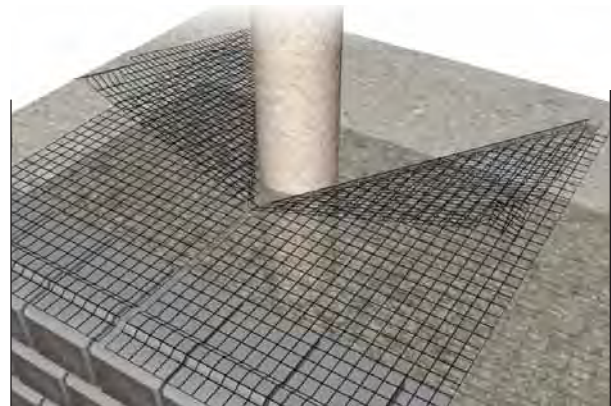
Construct the geogrid reinforced Pisa2 SRW up to the elevation corresponding to the underside of the handrail/fence foundation (concrete sonotube).



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.



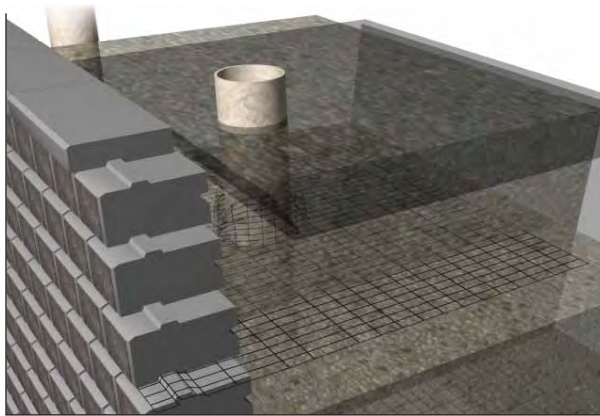
Cut the geogrid perpendicular to the wall along the centerline of the sonotube, creating two geogrid panels – one on each side of the sonotube. Lay the geogrid flat in front of the sonotube. At the intersection with the sonotube, fold the geogrid flat against vertical side of the sonotube and then around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



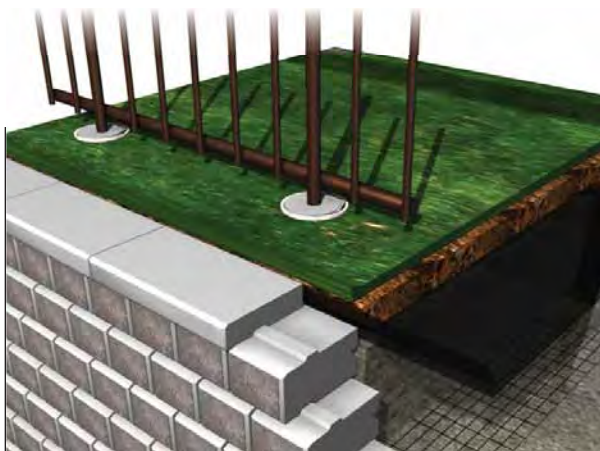
Repeat the previous step for each layer of geogrid encountered by the sonotube.

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

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

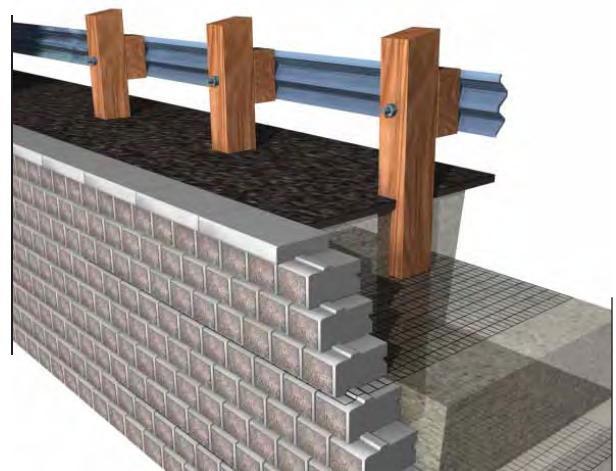


Pour concrete in foundations in accordance with fence/handrail design (reinforcing steel and/or dowels may be required). Install fence and finish grading.



guardrails

For areas adjacent to roadways and parking lots, flexible steel beam guiderails may be placed behind a geogrid reinforced 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.

Internal drainage

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

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 [$\frac{3}{4}$ in]). An approved filter cloth must be placed between the drainage layer and the infill material to prevent the migration of fines and contamination of the drainage material. At each geogrid layer, the filter cloth must be pulled back into the reinforced zone a minimum of 150mm (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

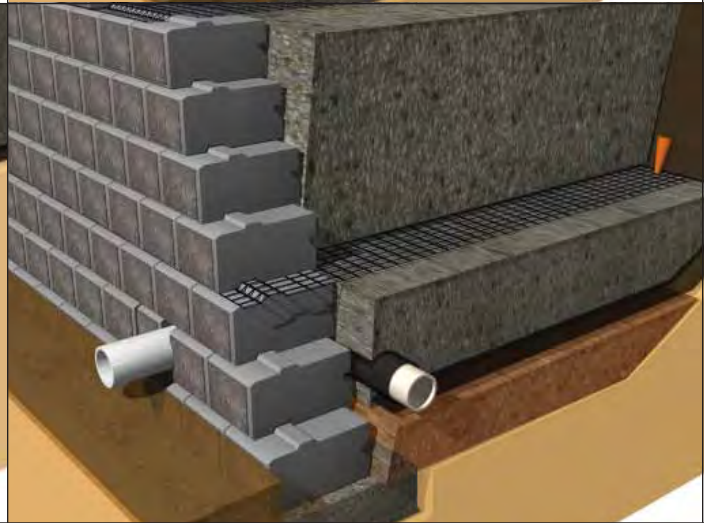
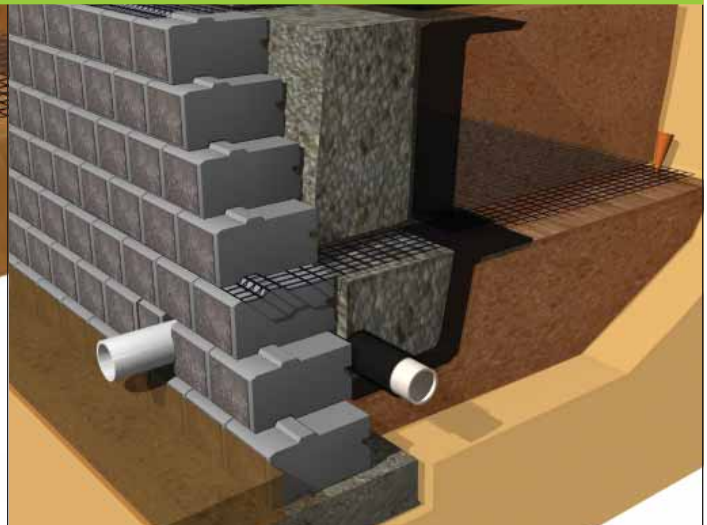
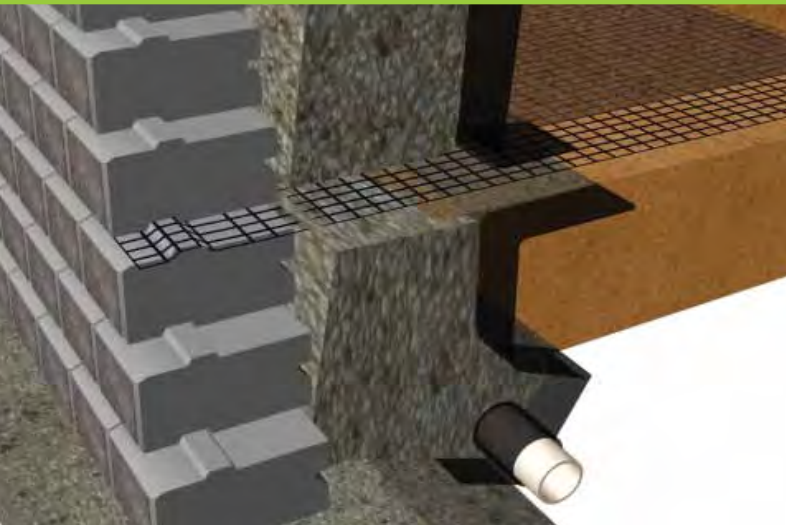
As the construction of a separate drainage layer immediately behind the facing units can be cumbersome and reduce efficiency, a popular option is to use a free-draining, granular material for the reinforced zone. It is recommended that this material be well-graded, with less than 8% fines. An approved filter cloth should be placed between the reinforced zone and retained and foundation soil to prevent the migration of fines. The use of an imported granular material in the reinforced zone has many other advantages besides its good drainage properties (see *Specifications – Soils*).

Outlet to Catch basin / Drain

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

Outlet Through Face

If the drain is being outlet through the face of the wall, it is recommended that an approved, less pervious engineered fill material be compacted under the drain up to the grade in front of the wall. This measure collects water percolating through the reinforced zone and directs it to the drain, rather than allowing the base to become saturated. The outlet pipe should be a non-perforated PVC (connected through a T-joint) placed a minimum of 15m (45ft) on centre (or as required by the design). Cutting a half 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.

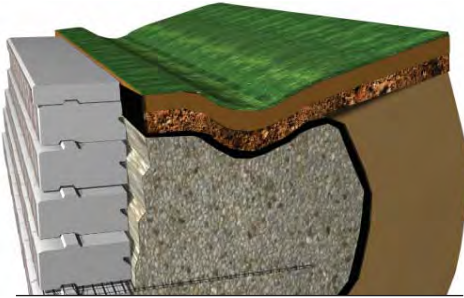


external drainage

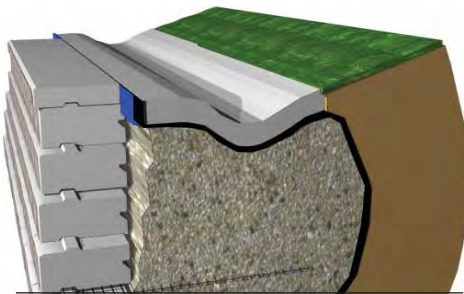
Swales

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). The swale must be designed (dimensioned) by the Civil Engineer as part of the overall site drainage plan.

Clay Swale

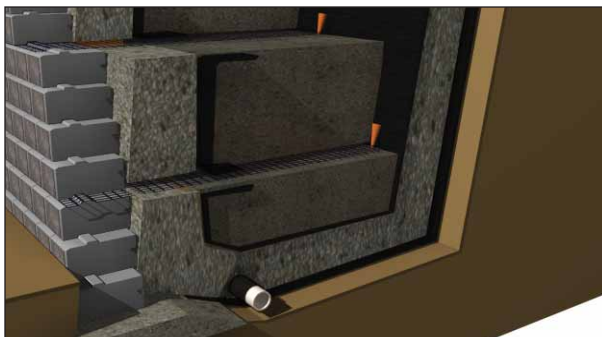


Concrete Swale



Blanket / Chimney Drains

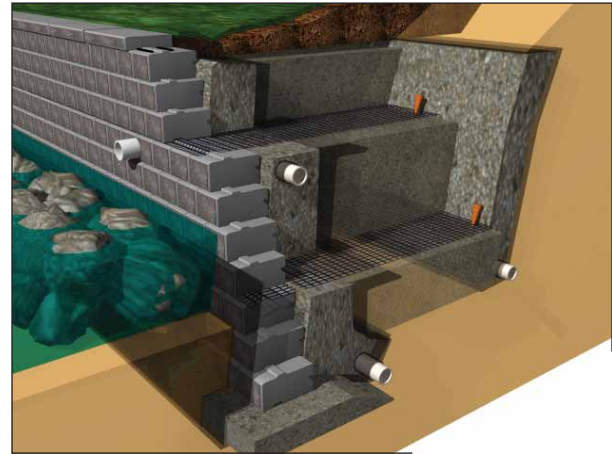
Where high groundwater flows are anticipated, the use of blanket drains (drainage layer extended horizontally along the base of the wall) or chimney drains (drainage layer extended up the back of the infill zone to intercept groundwater flows) prevent infiltration in the Pisa2 structure. Refer to the NCMA manual for drainage options under various groundwater conditions.



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, and ice effects.

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.



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

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

wall around box culvert

The key point in building this wall is to structurally separate the concrete headwall plus the above Pisa2 units from the other part of the walls by a 25mm asphalt-impregnated fibreboard expansion joint.

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

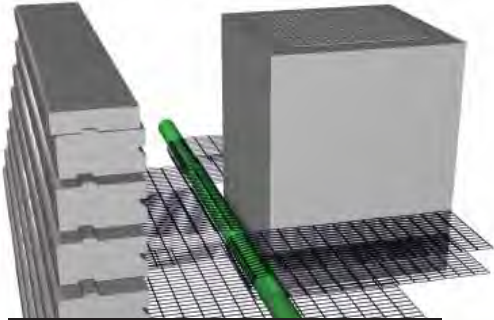
A culvert may be outlet through the face of the wall, providing the pipe has been designed to withstand the load of the wall above it and no excessive settlement is anticipated which may alter the alignment of the pipe. Once these issues have been addressed, the Pisa2 units can be cut to fit on site. 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.



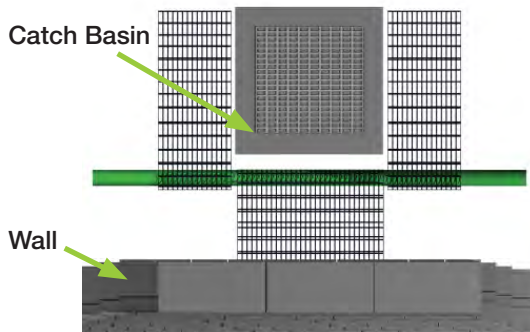


catch basin

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



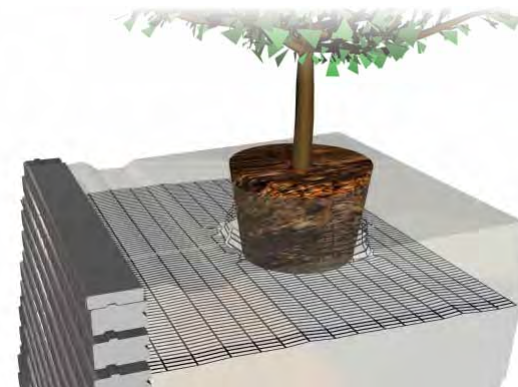
Select an appropriately sized steel pipe with a length of at least twice the width of the catch basin. Extend the geogrid from the specified layer and wrap it around the pipe back to the course below. Place a width of geogrid reinforcement (half the catch basin width) on either side of the catch basin,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



trees

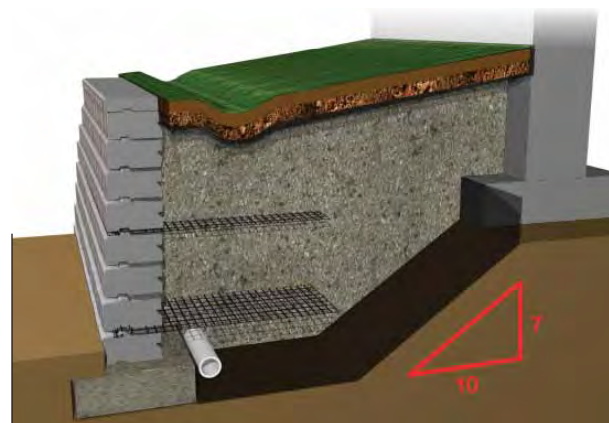
When planting trees or shrubs behind Pisa2 walls, a few steps must be taken to ensure the stability of the wall. The root ball should only impact the top two layers of the geogrid reinforcement. The geogrid should be cut perpendicular to the wall along the centerline of the root ball and placed flat. 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 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 units and to reduce the wind loading effects caused by the trees. Note that if multiple trees are to be planted, a qualified Engineer should be contacted to assess the impact of the geogrid cuts. A root barrier may also be required to avoid root growth towards the Pisa2 wall and drainage layer.



structures

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

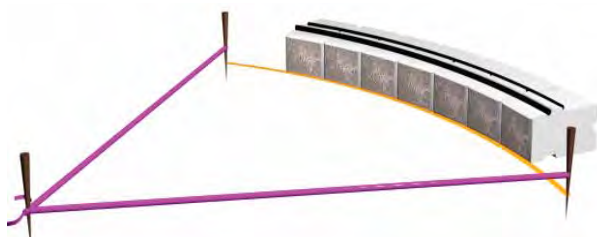




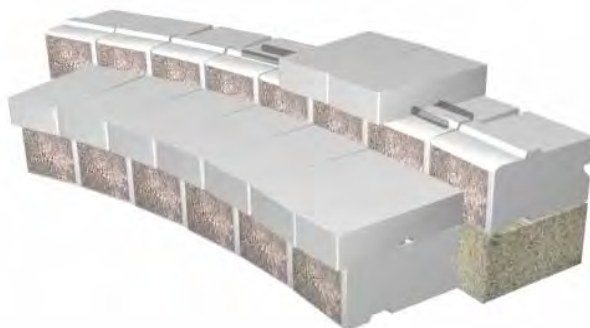
The Pisa2 system offers the flexibility to create a wide variety of step configurations and designs. As with any SRW structure, proper base preparation is critical to success when constructing steps. We recommend that only a free-draining, well-graded, granular material be used for the 150 mm (6 in) base at each riser. Compaction at each step (to 98% SPD) is crucial to resisting settlement due to continuous pedestrian loading.

concave

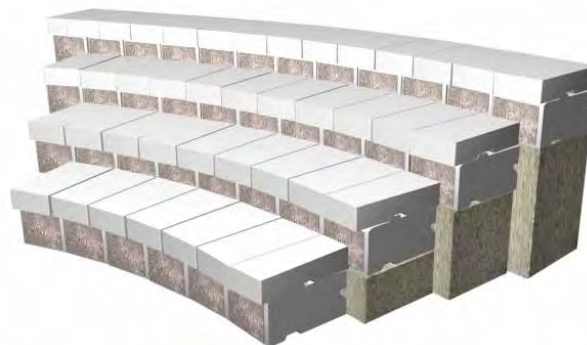
Locate the centre of the curve and lay out the curve on site. (Minimum radius for a Pisa2 wall is 2.44m [8ft]). Build the first riser with Pisa2 standard units along the marked line. See the section on Curves for instructions on laying the first course.



Position the ReversaCap coping units and secure with adhesive. Backfill the first course with the granular base material and compact to 98% SPD. The top elevation of the base should be flush with the top elevation of lower units. The face of riser units must be in contact with the back of the coping units on the lower course. Make sure the new curve is parallel to the curve of lower riser. Position the coping units on top and secure with adhesive. Some trimming and chipping of coping units might be necessary.

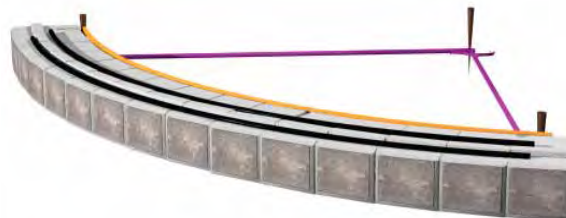


Repeat the previous stage to continue the risers to finish the steps.



convex

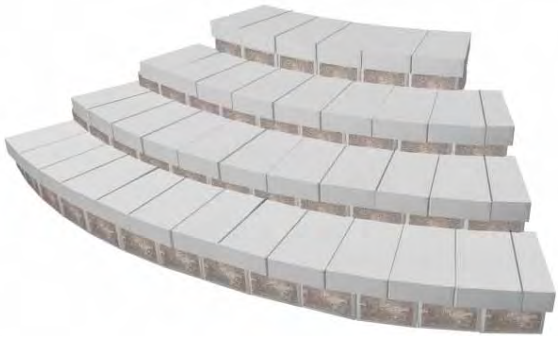
Locate the center of the curve and mark the curve on site. (Minimum radius for Pisa2 wall is 2.44m [8ft]). Build the first riser with Pisa2 Tapered Units along the marked line. See the section on curves for instructions on laying the first course.



Position the ReversaCap coping units and secure with adhesive. Backfill the first course with the granular base material and compact to 98% SPD. The top elevation of the base should be flush with the top elevation of lower units. The face of riser units must be in contact with the back of the coping units on the lower course. Make sure the new curve is parallel to the curve of lower riser. Position the coping units on top and secure with adhesive. Some trimming and chipping of coping units might be necessary.



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



perpendicular

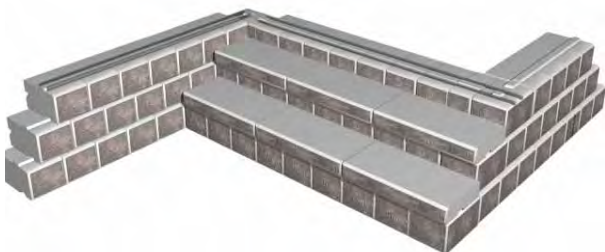
Start the wall with 90° inside and outside corners. At the inside corner, the wall is extended with two units to support the units that will be placed above.



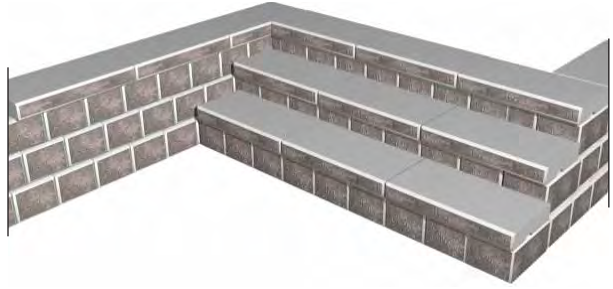
Position the coping units and secure with adhesive to finish the first course of riser. Backfill and compact to 98% SPD. The second riser is then positioned on the base so the face of the unit is in contact with the back of the coping unit at the first riser. Some trimming or chipping of the tongues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



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

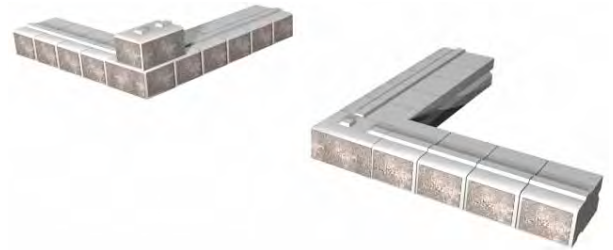


Finish the wall by placing the coping units with adhesive.



inset

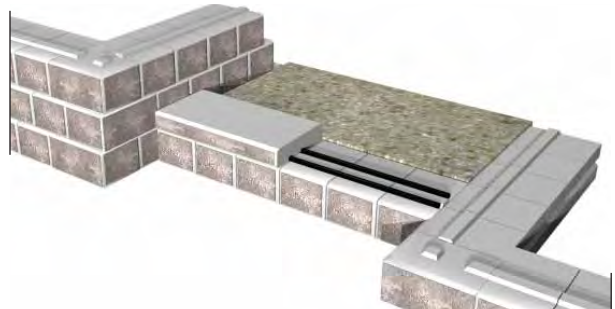
Start with two outside corner walls with a distance of one riser length in between.



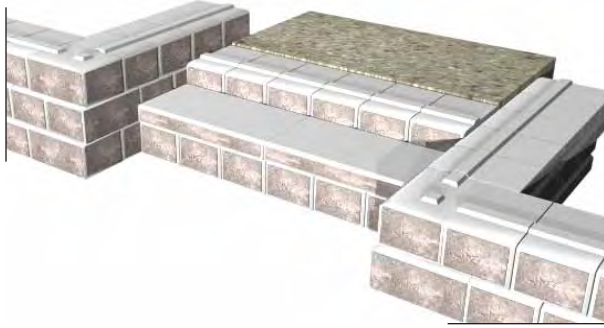
Build each wall up. The side walls can be built in either battered or vertical arrangement, as specified in the design. The side walls can be stepped up following the steps, but the side of riser (step) units must be in contact with the face of units in the side wall.



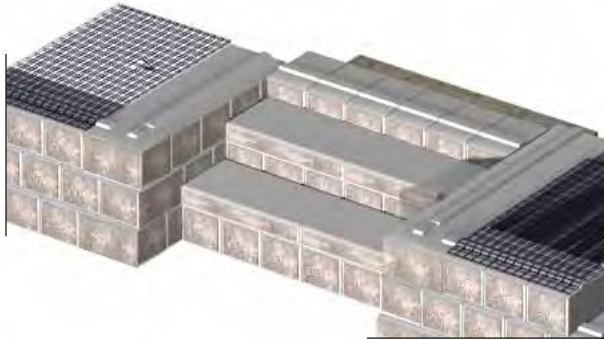
Place the first course of step units on the same foundation elevation as the side walls. A unit may have to be cut to make the riser fit between the side walls. Fill in base materials at the back of the riser and make it even with the top of the first course. The coping is then cut (if necessary), positioned,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



Repeat the previous two stages to finish the steps.

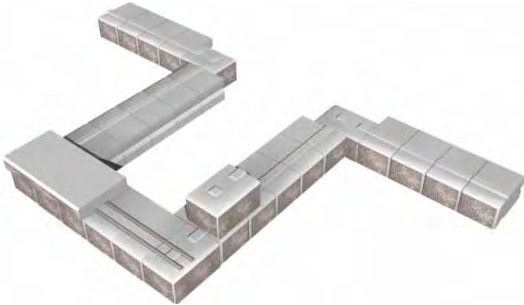


Place geogrid if required by design.



protruding

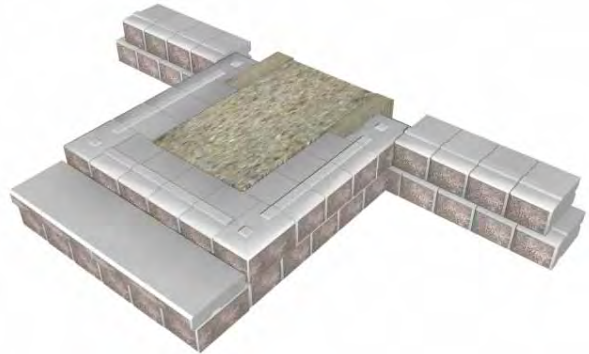
Start the wall with two inside 90° corners and two outside 90° corners. At the two outside corners, chop part of tongues off corner units and position the coping units with adhesive to form the first riser.



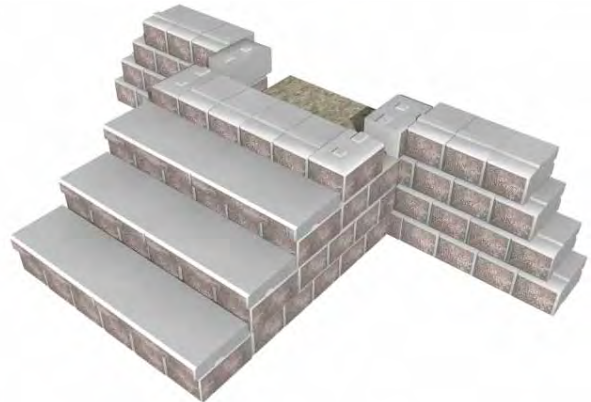
Place the next riser on the base with the face of units in contact with the back of the coping units at the first riser. Some chopping will be necessary for the positioning of left and right corner units.



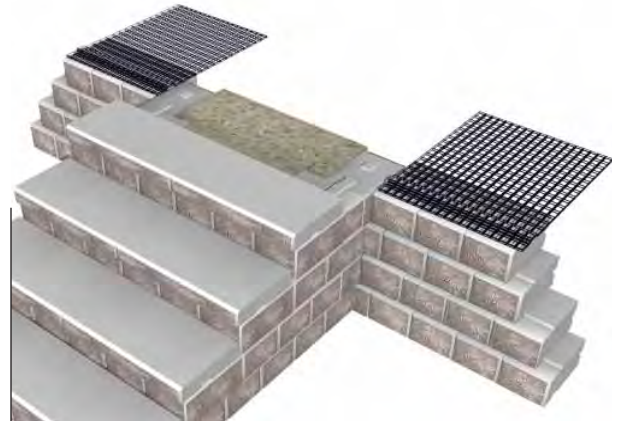
Continue to finish the second course of the wall. The side walls can be built in either battered or vertical arrangement as specified in the design. If the side walls are designed to be battered, each riser will be 38mm (1.5in) narrower than the course below.



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



If required, place geogrids to reinforce the wall.

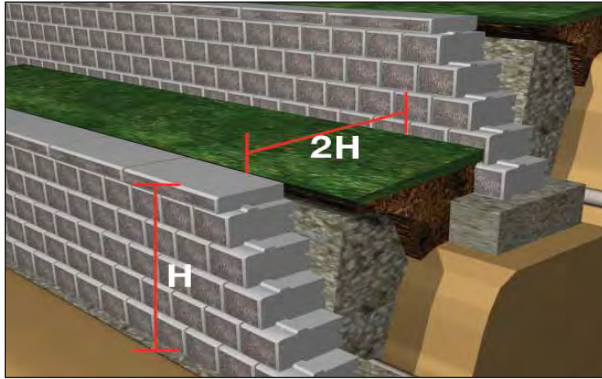




conventional SRWs

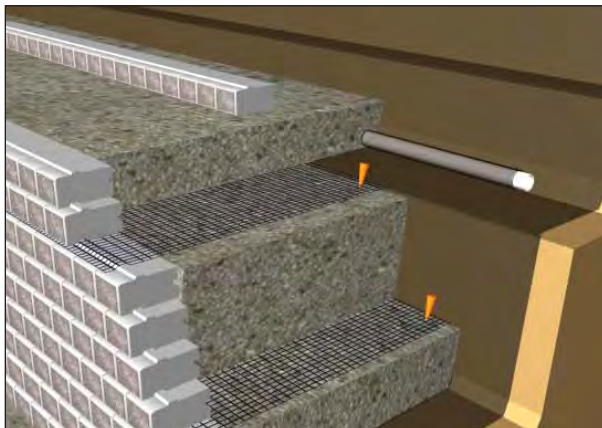
If done correctly, terracing can be an effective way to reduce loading and gain greater overall height, while still maintaining an aesthetic appearance.

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



reinforced SRWs

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



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

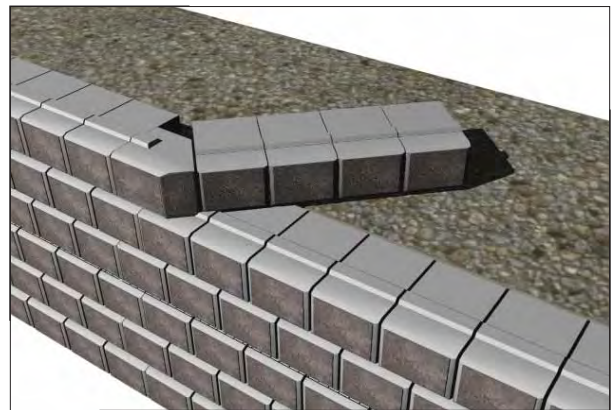
depth of the upper wall. Wherever possible, the lower wall should be higher than the upper wall.

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



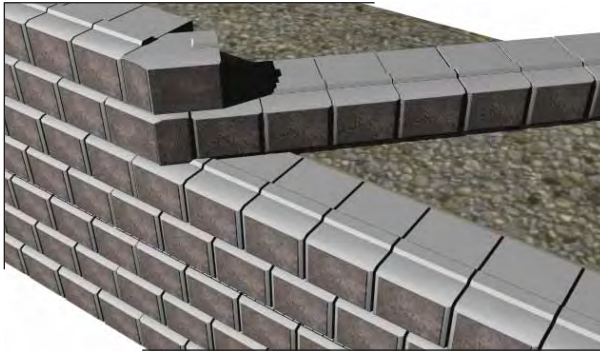
converging walls

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

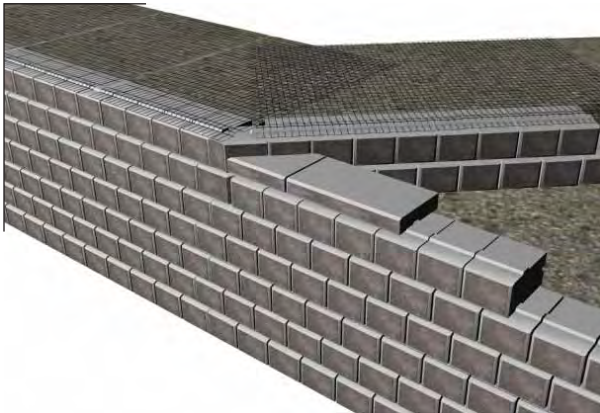


The low wall (Wall 1) must be designed based on the maximum height required. As Wall 1 splits into an upper (Wall 2) and lower wall, the lower wall must still be designed for the additional loading until the point where the upper wall has diverged far enough back to reduce the effect.

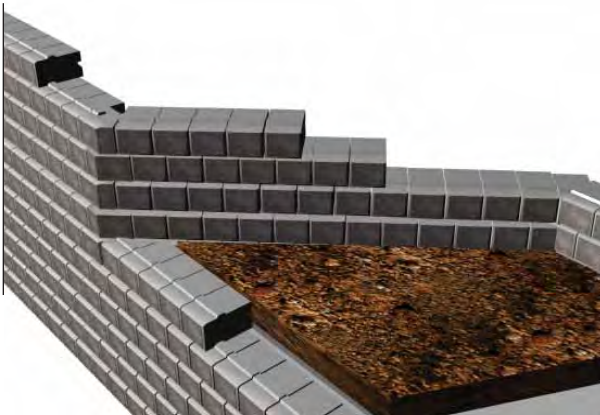
Construct the lower wall up to the transition height (height where the wall diverges into two). Based on the plan, determine the location along the top of the lower wall where the upper wall will diverge. This split may be achieved using an outside corner (90°, 45°, etc.) or outside curve.



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



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



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





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 with a precast cap.



large pillars

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

Base Course

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



Remaining Courses

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





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

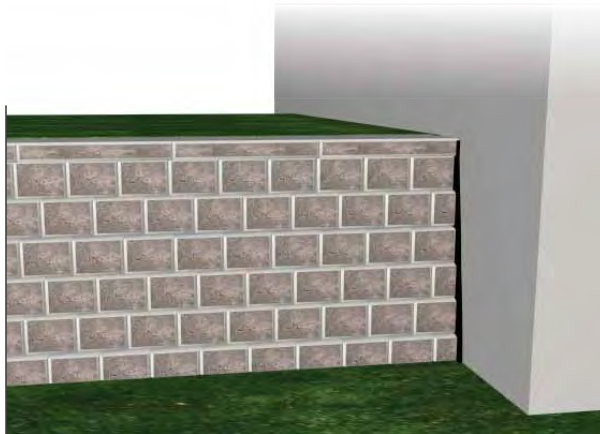
90° return end

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



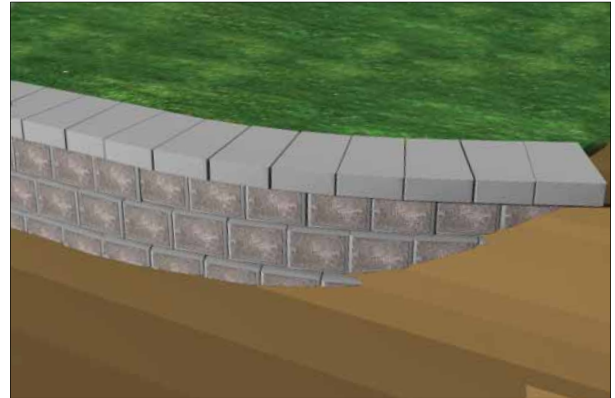
abut existing structure

The wall could be abutted to an existing structure. This would involve cutting the retaining wall units in order to maintain the running-bond pattern. An expansion joint (25mm asphalt-impregnated fibreboard) should be constructed between the retaining wall and the structure. This will allow the wall to move slightly while still containing the granular material. Note that if the existing structure's footing extends under the retaining wall for a short distance, this could lead to differential settlement and in turn, cracking or separation between the units.



curved return

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





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