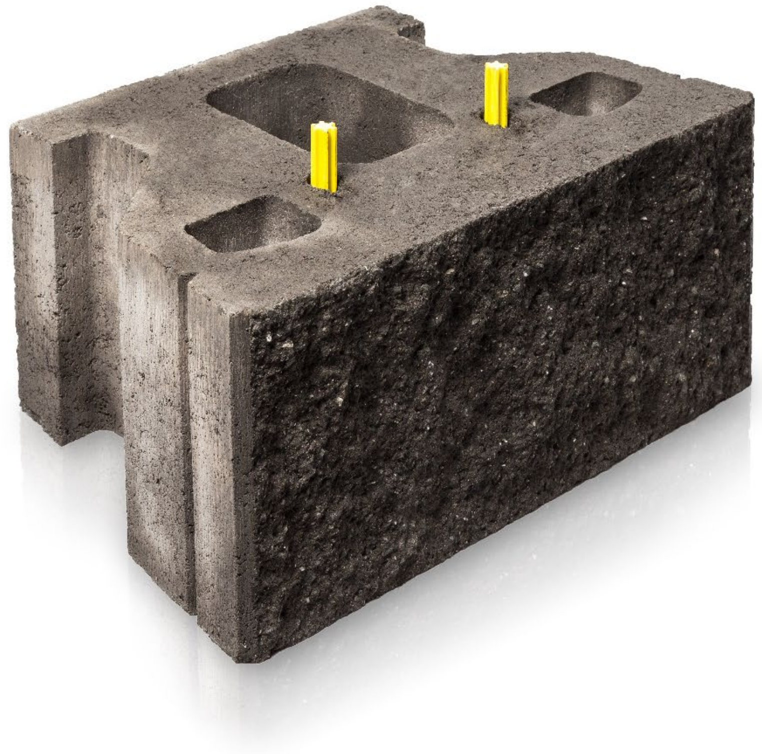


ROCKLOK

Installation Manual

August 2021 – Revision B

Contents

1. Introduction

Since the first introduction of segmental retaining walls (SRWs) in New Zealand, there has been a constant evolution and development in the understanding of SRW systems technology and performance, resulting in better materials, solutions, designs, and construction practices.

The Rocklok® SRW system is the latest SRW product in the market and the first to be 100% New Zealand made. Since 2014, the system has been developed in consultation with engineers, designers, contractors, and other construction stakeholders, with the objective of providing an attractive and economical alternative to other systems. The result is an aesthetically appealing block with a clean and smart look that provides an additional design life and superior performance.

The system has been designed following industry standards and New Zealand Transport Agency (NZTA) criteria. The Rocklok® SRW system is based on the requirements for units for use in SRWs established by the Australian/New Zealand Standard 4455.3:2008 and the design concepts and methodologies established by the American Association of State Highway and Transportation Officials (AASHTO), the National Concrete Masonry Association (NCMA), and the Federal Highway Administration (FHWA).

The Rocklok® SRW system is in constant development to improve the market offering and to fulfil increasing demand for cost-effective and convenient solutions. The Rocklok® SRW system is suitable for all sorts of applications, ranging from large infrastructure and motorway projects, commercial and residential developments, through to small landscaping designs and garden walls. The current Rocklok® SRW system allows for the installation of steel reinforcement grid, different geosynthetic soil reinforcement options, and the use of multiple pins and geogrid connectors.

This guideline, the *Rocklok® Installation Manual,* is published and maintained by Bowers Brothers Concrete Limited. The information and recommendations presented in this manual are intended to provide advice and assistance for the design and construction of safer Rocklok® retaining walls.

The objective of this manual is to provide generic construction guidelines for Rocklok® SRWs built as gravity and as geosynthetic reinforced structures.

2. Methodology

More than a few methodologies exist in reference to the design and installation of SRWs. Prior to the project commencement, a methodology should be established between the client and the engineering firms involved in it. Irrespective of the design methodology selected, if the Rocklok® SRWs are correctly designed and built, they will perform well.

Most of the available methodology options come from the United States, where SRW systems were first introduced in the 1980s. Recognised agencies and organisations such as AASHTO, NCMA, and FHWA have established the design methodology to be used. Locally, NZTA has developed the *Bridge Manual*, which sets out the criteria for the design and evaluation of retaining structures in New

Zealand. The Building Regulations 1992 and the Building Act 2004 provide for the regulation of building work and the setting of performance standards for buildings.

Where project conditions or design variables are outside the scope or provisions of these design methodologies, the design should be augmented with engineering judgement as required for the specific project application(s). Rocklok® retaining walls should be designed and built following a defined methodology, meeting or exceeding established minimum targeted design safety factors.

3. Rocklok® Retaining Wall System

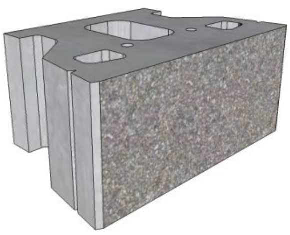
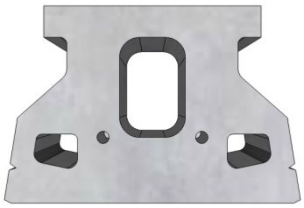
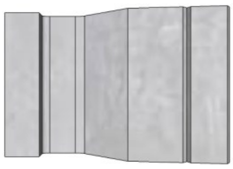
Rocklok®

The Rocklok® system comprises three types of blocks – Rocklok® Flat, Rocklok® Ladder, and Rocklok® Trench. The Rocklok® system provides engineers, architects, and contractors with solutions for different applications in both commercial and residential projects, and is designed to better serve the continually changing and demanding New Zealand market.

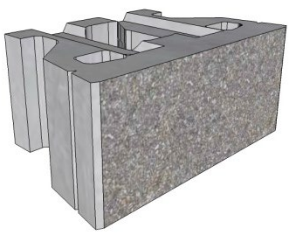
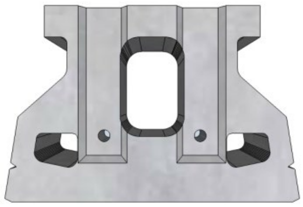
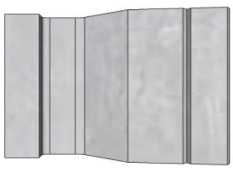
The three Rocklok® models can be distributed in two differentiated groups. The Rocklok® Flat remains the standard block to be used in most applications; private developments, landscaping, residential subdivision, and commercial development, while the Rocklok® Ladder and Rocklok® Trench are specifically designed for jobs with special requirements, such as critical surcharge loads or construction in high seismicity areas.

All Rocklok® models share the same dimensions: 450 mm (length), 300 mm (width), and 200 mm (height).

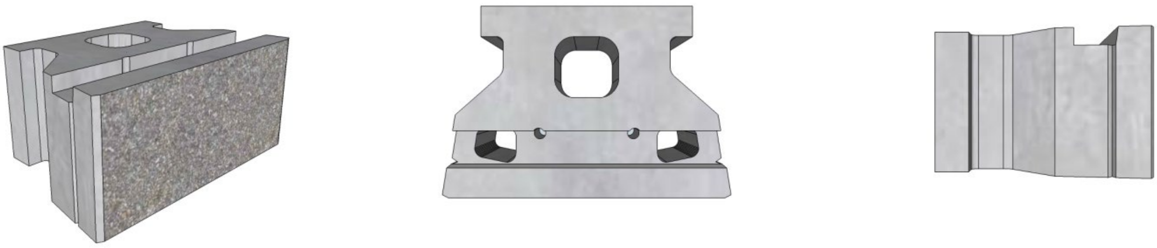
Rocklok® Flat

Rocklok® Ladder (for inextensible steel reinforcement and steel pins)

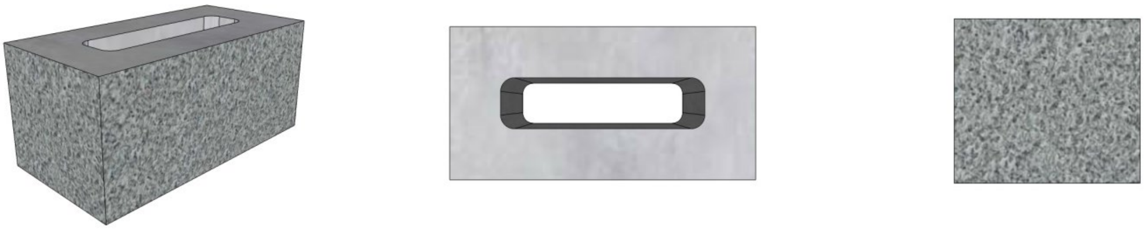




Rocklok® Trench (for Rocklok® clip and geosynthetic reinforcement)



Rocklok® Corner

Dimensions: 450 mm (length), 225 mm (width), and 200 mm (height)



Rocklok® Capping

Dimensions: 450 mm (length), 300 mm (width), and 100 mm (height)

The Rocklok® system provides multiple and significant advantages over other retaining wall systems.

- **Applications:** The Rocklok® system is an appropriate solution for a wide variety of commercial transportation and landscaping projects. SRWs are mainly suitable for:

  - Gravity walls
  - Geogrid reinforced earth walls
  - Terraced walls
  - Garden and landscape walls
  - Water applications
  - High retaining walls
  - Bridge abutments
  - Embankment protection and stabilisation
  - Wing and tunnel access walls
  - Steel ladder reinforced soil retaining structures

- **Performance:** SRWs are known for their exceptional performance during earthquakes, which is important in high seismicity countries like New Zealand. The Rocklok® retaining walls are designed to be flexible structures that allow for some minor movements without compromising the structure.

- **Economics:** The Rocklok® system is a very cost-effective solution compared to other concrete or cast-in-place systems. SRWs provide the best value when cost is compared against performance benefits.

- **Flexibility:** SRWs allow for unlimited possibilities. Rocklok® retaining walls can be built on slopes, with stairs, and with curves and corners. They can be stepped up or down, divided in two to create a terrace, and they can be used with geogrids, no-fines concrete (NFC), or steel and concrete to satisfy the project requirements.

- **Durability and design life:** Designed for New Zealand's environmental conditions, the dry-cast Rocklok® blocks are manufactured to endure for a long time. By implementing the right design procedures and using geogrid synthetics to reinforce the structure, a Rocklok® retaining wall will last 75 to 100 years.

- **Ease and speed of construction:** The Rocklok® system has been designed to facilitate the installation process, limiting the amount of machinery needed. Fast construction is achievable using a small crew of experience contractors.

- **Aesthetics:** The Rocklok® system looks sharp and elegant, and it comes with a variety of colours to provide designers with an aesthetically pleasing choice.

- **Environmentally friendly:** The Rocklok® retaining wall units are made of natural materials like water and sand or gravel, which reduces the impact it might have on the environment.

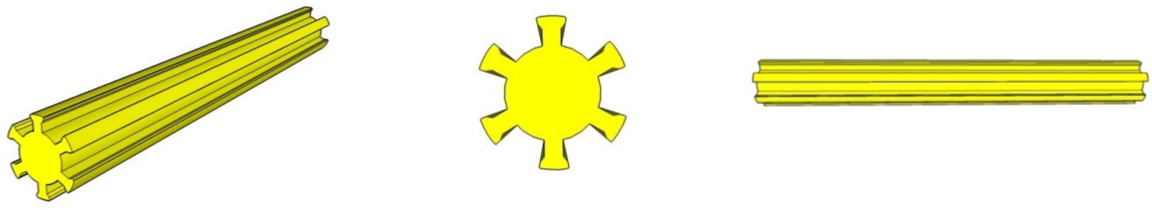
Other Elements: Pins and Connectors

Fibreglass Pins

The fibreglass pins are used to align the block courses. Each Rocklok® unit requires a pair of fluted fibreglass pins. The Rocklok® pins are 16 mm in diameter and 135 mm long.

The pins' raw material is a glass-filled resin extruded to finished size. The raw material samples are subjected to a short beam shear test in accordance with American Society for Testing and Materials (ASTM) standard ASTM D4475 to determine material longitudinal shear strength. Typical test results are:

- 38 mm span, maximum shear force is 10,445 N
- 48 mm span, maximum shear force is 9,778 N

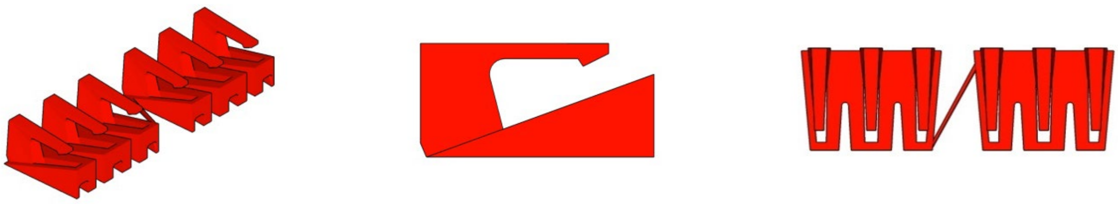


Rocklok® Clip

The plastic Rocklok® clip is used to anchor high-density polyethylene (HDPE) geogrids in the Rocklok® Trench block. This mechanical connector is a high-pressure plastic moulding made of HDPE, which is characterised by high-dimensional stability (tensile stress at yield: 23 MPa; strain at yield: 10%; strain at break: 100%; flexural modulus: 925 MPa).

The connectors are moulded in two groups of three clips with a bridge between the groups to facilitate easy separation when required. The Rocklok® clip is optimal for tall retaining walls, culvert structures, and bridge abutments. It is also ideal in seismic areas due to its capacity to create a direct mechanical connection between the clip and the geogrid at the front face. It is only suitable for the Rocklok® Trench.

The main advantage of the Rocklok® connector compared to similar products is that it does not pull out when stepping on the HDPE geogrid, keeping the direct mechanical connection at all times.

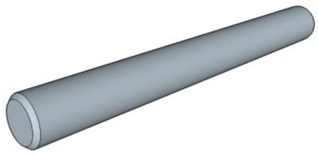


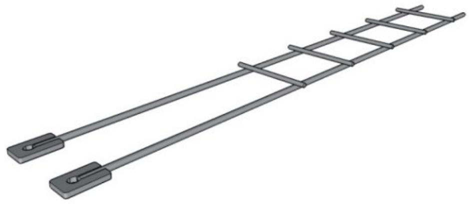
Steel Ladders and Steel Pins

The Rocklok® Ladder block allows for the connection of steel reinforcement “ladders”, which consist of two longitudinal bars arranged parallel to each other and are separated by overlapping cross bars set at defined intervals as called for by wall design soil reinforcement parameters. Steel plates (“tags”), measuring 50 mm wide × 85 mm long × 10 mm thick, are fixed to one end of the longitudinal bars.

The steel ladders are machine fabricated with cross bars welded to the longitudinal bars to ensure compliance with Australian/New Zealand Standards AS/NZS 4671, AS/NZS 3678, AS/NZS 1554:3 and AS/NZS 4680. Tags are welded to the longitudinal bars on both sides (four welds) with an effective weld length and throat thickness that ensures weld shear strength exceeds longitudinal bar tensile strength by margins greater than 2.0.

The Rocklok® parallel steel pins, 16 mm diameter × 200 mm long, are made of raw material complying with AS/NZS 4671 Grade N (i.e., a yield stress range of 500–650 MPa, an Rm/Re ratio ≥ 1.08, and a uniform elongation ≥ 5%). The pins are spun galvanised in accordance with AS/NZS 4680, with a minimum average zinc coating thickness of 55 microns.





4. Planning Considerations

Years of experience dealing with SRWs tell us about the importance of an initial meeting among the people involved in the project – owner, project manager, site engineers (civil, geotechnical or structural), architects, local council, and contractors – to understand its scope and needs.

It is imperative to discuss and establish at an early stage the project expectations, the use of the site, the design methodology, the project conditions, and the timeline of the project.

Before starting to design or plan, the SRW designer should visit the site to get a better understanding of the site conditions, existing topography, utilities and sewer pipes, surcharges, and site access, among other considerations.

It is important to keep a clear channel of communication with the owner/client and to make sure he/she is aware of the minimum building code requirements for the construction of SRWs.

The owner/client should provide a geotechnical report for the area where the Rocklok® retaining wall is going to be constructed.

5. Rocklok® Wall Construction

Rocklok® Wall Construction in 8 Steps

Step 1: Preparation and Excavation

Before starting to stack up the Rocklok® blocks, all organic soils, vegetation and unnecessary materials have to be removed from the place where the wall is going to be built. In some project earthworks, excavation and hill cutting might be necessary prior to the wall installation.

Dig the base trench in the desired location and for the required length of the wall. The excavated trench has to be wide and deep enough to allow for the installation of the levelling pad and the wall embedment.

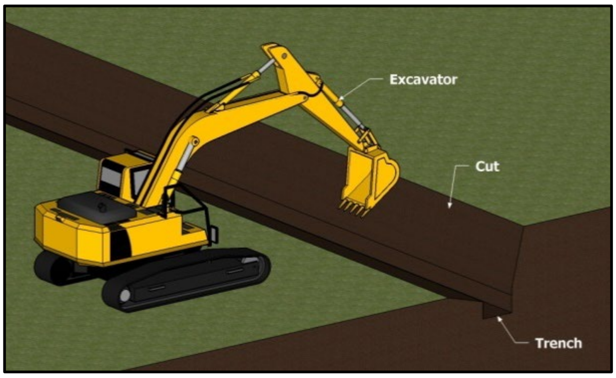


Figure 5.1.: Dig the base trench

The minimum buried block embedment depth recommended for the Rocklok® system is the height of one block (200 mm). This buried block provides extra stability and resistance to sliding. If the retaining wall is supporting high loads, toe slope is present, or the toe of the wall has signs of erosion, the minimum embedment depth of the Rocklok® wall should be augmented. If the foundation soil is formed by poor quality soil, or expansive soils such as inorganic clays, extra excavation should be carried out. Poor soil should be replaced for well-graded aggregates, and the base may need to be reinforced to provide the necessary bearing capacity.

Having this in mind, the minimum trench will be 350 mm deep and 600 mm wide. The minimum depth must be maintained on the entire length of the wall, even when there might be elevation changes at the bottom of the wall.

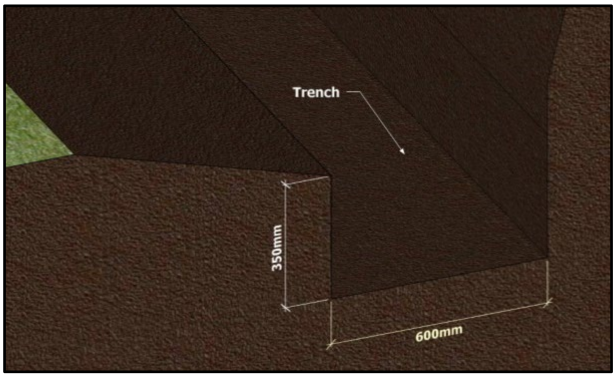


Figure 5.2.: Minimum trench dimensions

Step 2: Levelling Pad Placement

Before placing the levelling pad, it is important to compact and level the trench.

Next, place and compact a minimum of 150 mm deep and 600 mm wide of a well-graded aggregate. The suggested materials to be used in the levelling pad are General All Passing (GAP) 20 with a thin layer of sand on top. Sand may be used to help place, level and adjust the first course of Rocklok® blocks. Using larger aggregates such as GAP 65 might complicate the levelling process.

Compaction should be carried out by suitable means to achieve proper density. The compaction of the non-cohesive bedding material should be carried out to achieve a minimum relative density of 95% of standard Maximum Dry Density (MDD) of the fill material as determined by the New Zealand standard compaction test (NZS 4402.4.1.3:1986), or equivalent Clegg impact value (CIV), generally about 32 CIV.

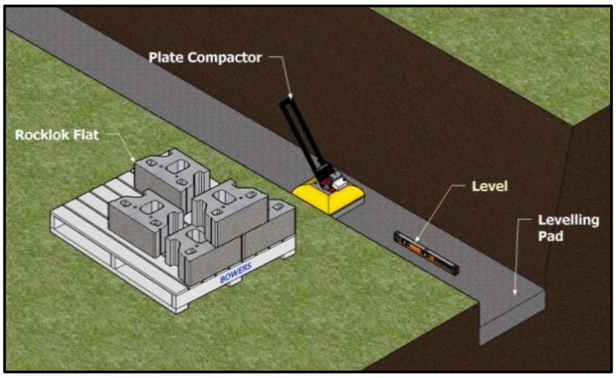


Figure 5.3.: Install levelling pad, compact

Typically, the levelling pad is installed for the entire length of the wall, except when changes in elevation exist. Check with a level tool that the levelling pad is level in its height, length, and width. Generally, concrete is not used for levelling pads. The reason is that SRWs are designed to be a flexible structure that allows for minor earth movements without compromising or damaging the wall. This also makes the Rocklok® wall construction easier and more economical. If for any reason concrete was required, unreinforced low-strength concrete may be used.

Stepping Up/Down the Base Course

A cautious approach should be taken when the construction of the Rocklok® retaining wall requires step-up or step-down in the base course. It is highly recommended to start the wall construction at the lowest elevation and to ensure that at least an entire Rocklok® unit is placed in each level.

Levels are determined by the Rocklok® unit height (200 mm), and each step-up level would require at least one Rocklok® unit per level. It is vital to guarantee that the minimum embedment at each step-up or step-down is sustained.

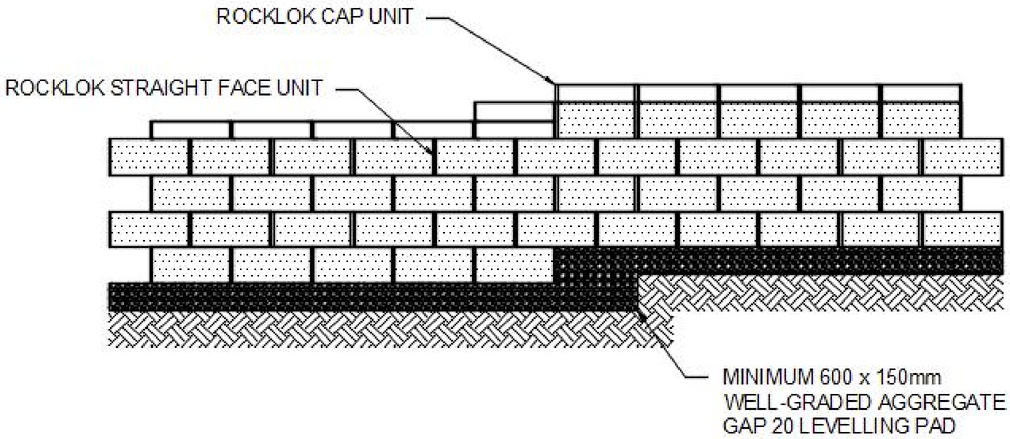


Figure 5.4: Stepping Up/Down the Base Course

Step 3: Base Course and Fibreglass Pins Installation

Once the levelling pad is placed and levelled, it is time to lay the first Rocklok® course.

Begin at the lowest wall elevation, setting a string line at the back of the Rocklok® units to keep the blocks aligned. Never use the split face because it will vary slightly from one unit to another. It is suggested to install the blocks on the centre of the levelling pad, leaving a minimum space of 150 mm in front and behind the wall. Make sure the pin holes are facing up.

Next, lay the first course of Rocklok® units for small sections of the wall, or the full length of the levelling pad if preferred. It is very important to check and even double check the level and alignment of the first Rocklok® units installed and make minor adjustments using a rubber mallet if necessary. If the levelling pad and the first course of blocks are not fully levelled and aligned, the resulting retaining wall will not be levelled and aligned. It is much easier to make modifications at the beginning rather than after the wall is completed.

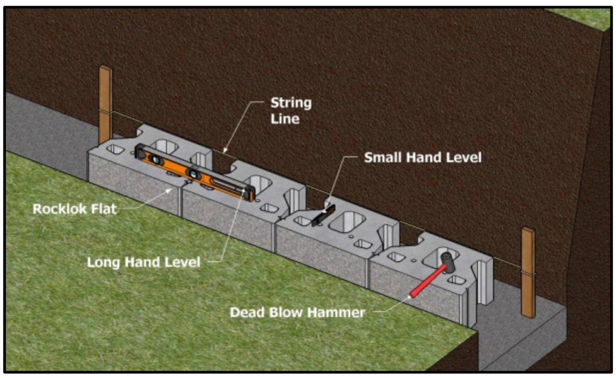


Figure 5.5: Install first course, make minor adjustments and level trench

Install two fibreglass 16 mm diameter Rocklok® pins per Rocklok® block unit. It is important to install the pins before placing any kind of drainage metal or infill material. If pins are not installed first, small rocks might get into the pins holes, blocking it and impeding the proper placement of the pins. The fibreglass pins should stick out a minimum of 25 mm from the top face of the block.

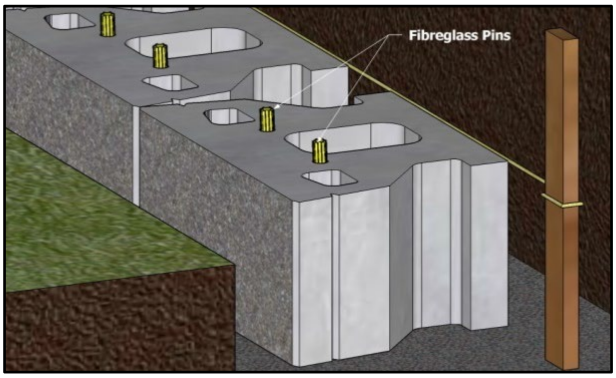


Figure 5.6.: Install Rocklok® fibreglass

Step 4: Drainage Metal and Drainpipe Installation

Fill all Rocklok® open core/cavities and spaces between units with a clean, permeable, compactible, well-graded drainage material, preferably drainage metal 25/7, 20/6 or a similar material. At the same time, place a minimum of 300 mm of the same selected material behind the Rocklok® units to create the drainage column.

Aggregates with a particle size bigger than 40 mm should not be used due to the limited size of the block voids. Particles smaller than 5 mm, such as sand, should also not be used because water filtration may wash them out through the joints between Rocklok® units, losing the system some weight and draining capacity.

The use of drainage metal has some direct benefits. It increases the weight of the system per block face, it releases hydrostatic pressure removing and filtering incidental water, and it provides a direct interlocking between Rocklok® units. When walls are reinforced with geogrids, the drainage metal will result in greater interaction, better friction and interlocking between, the block units, the geogrid, and the gravel.

A minimum 100 mm diameter drainage pipe has to be located right behind the first course of Rocklok® units and above the levelling pad. To restrict the migration of fines into the drainage metal and the pipe, a filter fabric geotextile may be used to wrap it up.

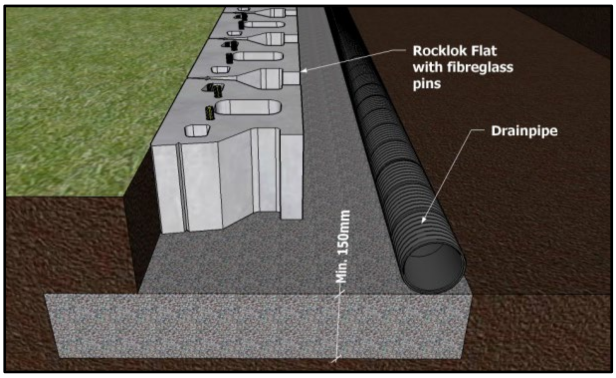


Figure 5.7.: Place drainpipe behind Rocklok® units

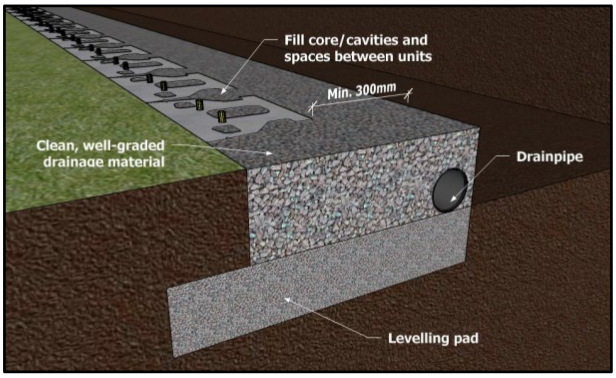


Figure 5.8.: Place clean, well-graded drainage metal

Taller walls or water applications might require increasing the size of the drainage column to a width of 600 mm.

Step 5: Infill Soil Installation and Compaction

When the Rocklok® retaining walls need to be backfilled, well-graded non-cohesive granular materials are always preferred. GAP distributions such as GAP 20, GAP 40, or GAP 65 are the ideal aggregates to be used in the Rocklok® retaining walls.

The backfill material behind the drainage column should be placed 200 mm high, coinciding with the height of the Rocklok® units and the maximum recommend soil lift for compaction. Start placement of the infill material as close as possible to the drainage column and continue moving gradually backwards to the end of the infill zone. Compaction should be carried out using a compactor in paths parallel to the Rocklok® wall face until the infill area and the drainage zone are properly compacted. The plate compactor should not be operated on top of the first Rocklok® course because it may cause unnecessary block displacement. From the second course and above, it can be operated directly on top of the Rocklok® units, taking enough care to avoid rotation on the wall, stress cracks on the block surface, and damage of the location pins.

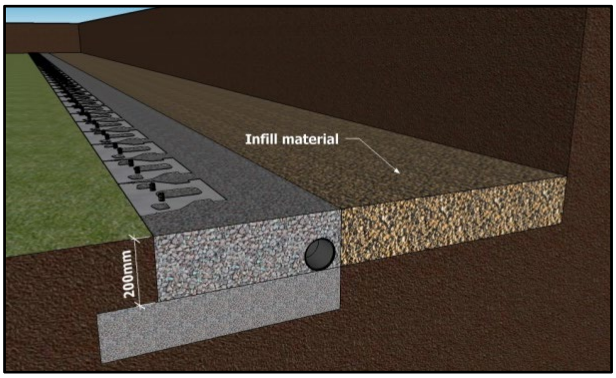


Figure 5.9.: Place infill material in lifts of 200 mm

The infill soil and drainage column should be compacted to achieve a minimum relative density of 95% of standard Maximum Dry Density (MDD) of the fill material as determined by the New Zealand standard compaction test (NZS 4402.4.1.3:1986), or equivalent Clegg impact value, generally about 32 CIV.

To not compromise the stability of the wall, it is important that road rollers and other heavy compaction machinery are not allowed in the consolidation zone, which extends 1.2 m behind the wall measured from the face of the Rocklok® units. Only small hand-operated plate compactors should be used in this area.

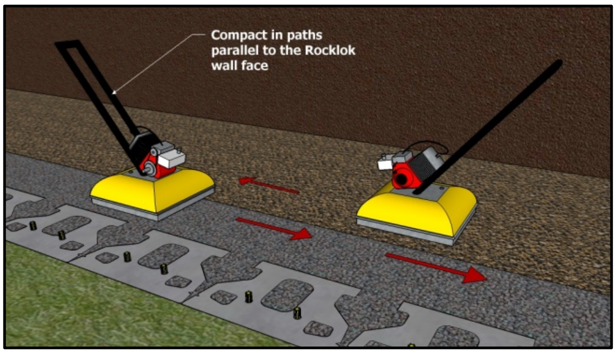


Figure 5.10.: Compact in paths parallel to the wall face

Step 6: Brush the Top of Blocks

Prior to the placement of the geogrid and the second course of blocks, it is important to clear all debris and excess material out of the top of the Rocklok® units. Drainage metal or gravel particles not cleaned from the top of the blocks can damage the wall or leave the blocks out of tolerance. The Rocklok® block units are brushed during manufacturing to eliminate excess concrete material. If for any reason the top of the Rocklok® units are not smooth, please scrape the ridge or excess material using a chisel or a similar tool before placing the next course of blocks. When possible, you can remove the slag material by sliding the next course of blocks.

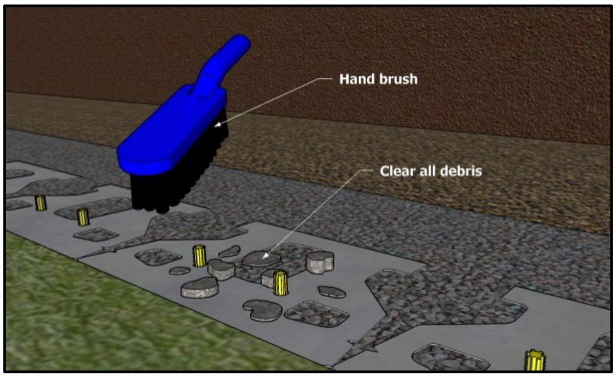


Figure 5.11.: Clear all debris and excess

Step 7: Geogrid and Additional Courses Installation

Cut and place the geosynthetic reinforcement to the specified length. The geogrid should be placed on top of the Rocklok® units around the fibreglass pins, departing from the kidney holes to the back of the infill area that has already been filled, compacted, and levelled. The geogrid must be in tension (no wrinkles) when placing the backfill soil on top of it. A temporary stake might be used to keep the geogrid in tension. Repeat the process until the top of the wall is complete, placing the backfill in lifts of 200 mm.

It is extremely important to place the geogrid in the right direction. Most geogrids are uniaxial, so their strength in only one direction (the machine direction). When installed, the strength direction of the geogrid should be perpendicular to the Rocklok® wall face. Special consideration and care should be taken when installing geogrid on retaining walls with curves and corners. Please refer to the details in pages 21, 22, 23 and 24.

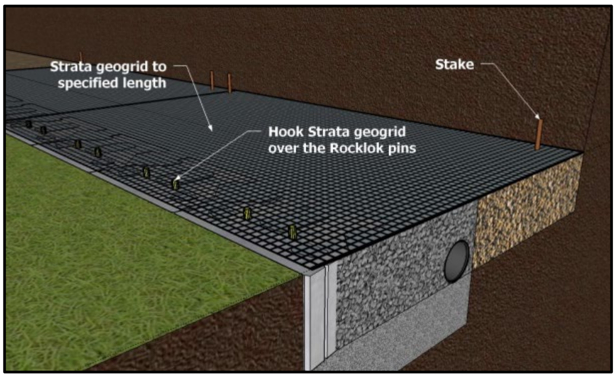


Figure 5.12.: Place the geogrid to the specified length

Lay the next course of Rocklok® blocks on top of the geogrid, stand at the face side of the wall and pull the block towards you inserting the open kidney holes over the fibreglass pins of the previously placed course, until the fibreglass pins engage the back face of the kidney holes and to create the block setback. The Rocklok® unit has to set midpoint where the two units underneath meet. Put the next pair of fibreglass pins in the recently installed course.

If looking at the face of the wall, the additional Rocklok® units should be positioned to be offset from seams of the blocks below, forming a perfect running bond face pattern.

Visually check levels and make adjustment if needed. The maximum allowable tolerance per unit is a standard deviation of not more than ± 2 mm and a difference between the mean and the work size of not more than ± 3 mm according to AS/NZS 4455.3, but it is acceptable to shim using geogrid or similar shimming products under the Rocklok® units to correct for block discrepancies in height.

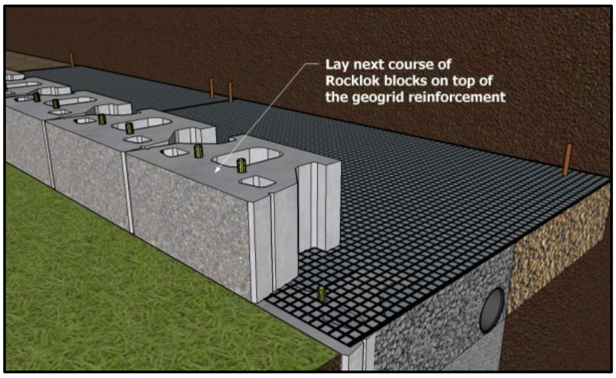


Figure 5.13.: Lay next course of Rocklok®

Step 8: Finishing the Wall

Continue with Steps 5, 6, and 7, placing the geogrid layers at the specified lengths on the correct elevations and compacting to maximum lifts of one Rocklok® course, until the last 200 or 300 mm of the specified wall height. Generally, longer geogrid layers are used at the top of the Rocklok® retaining wall.

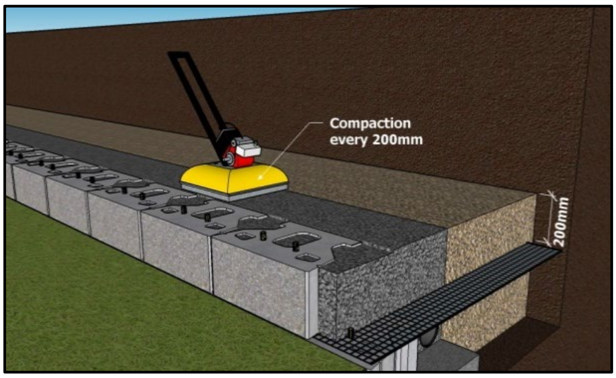


Figure 5.14.: Compaction every 200mm high

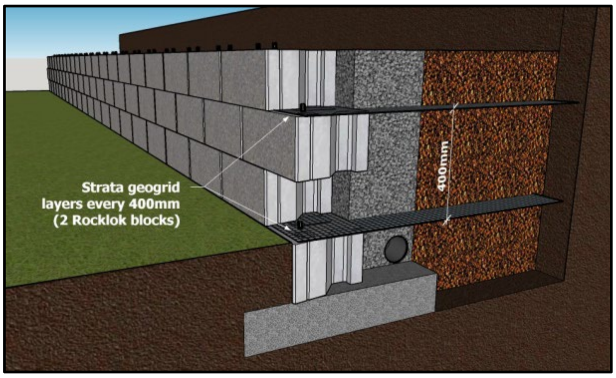


Figure 5.15.: Subsequent layers of geogrid every 400mm high

Place filter fabric on top of the drainage column to prevent the migration of fines, and place 200 mm of a low permeable soil on top of the geotextile to reduce water filtering into the reinforced zone. Install and secure the optional capping block in place at the top of the wall using a high quality, flexible, all-weather masonry adhesive.

When the Rocklok® retaining wall is completed, finish grading by adding soil or vegetation, a fence or barrier, a driveway, or other structures. The fence or barrier construction tubes should be placed on their specific locations during the retaining wall construction, and not after the Rocklok® retaining wall is completed.

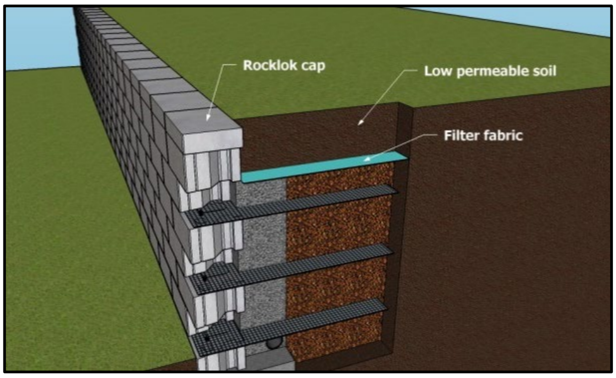


Figure 5.16.: Place filter fabric, low permeable soil and Rocklok® capping unit (optional)

Geogrid Reinforcement

Geosynthetic reinforcements have been widely used in the New Zealand construction industry for years for slopes and embankment stability, allowing for steeper, safer, and higher structures.

Those geosynthetic reinforcements or geogrids are manufactured using different type of polymers and techniques. For example, HDPE geogrids are manufactured by extruding, punching, and stretching HDPE sheets, while polyester geogrids are manufactured by woven or knitted polyester fibres.

To achieve certain heights and provide stability, Rocklok® SRWs need to be reinforced using geogrid layers. The geogrid layers are placed in the backfill generating a mass of reinforced soil, or a "mechanically stabilised earth" wall.

Although the geogrid installation process was already explained on pages 14 and 15 (Step 7: Geogrid and Additional Courses Installation), it is important to highlight several things in order to get the most out of the geogrid reinforcement when building a Rocklok® retaining wall.

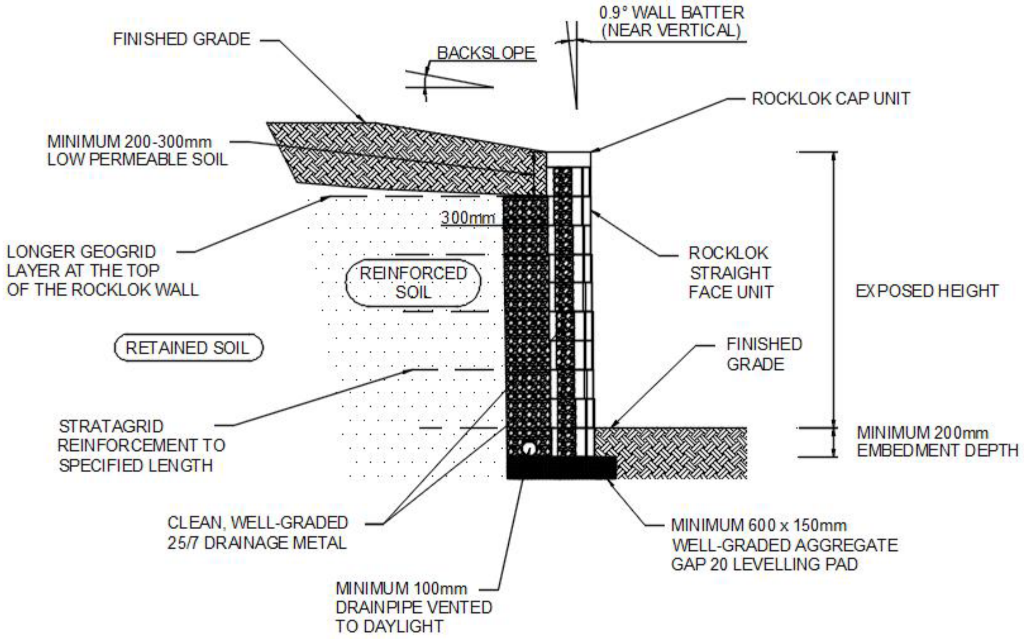


Figure 5.17.: Geogrid Reinforcement

- Before starting any Rocklok® project requiring geosynthetic reinforcement, you should verify the type of geogrid needed, its length, the elevations, and the strength direction of the geogrid. Most walls over 0.7 m will need to be reinforced.

- The first layer of geogrid should be placed at the lowest wall elevation on top of the first course of Rocklok® blocks, unless the wall design provided by a professional chartered engineer specifies a different elevation.

- Subsequent layers of geogrid will be installed every 2 courses or 400 mm from the first course. A two-course configuration provides better compaction and reduces settlement compared to a three-course configuration.

- It is critical to place the geogrid with the right orientation. To ensure the internal stability of the mass, the uniaxial geogrid should be extended following its strength direction (machine direction). Biaxial geogrids will have its strength in both directions.

- The minimum geogrid layer length should be at least 60–70% the total height of the retaining wall.

- Longer geogrid layers at the top of the retaining wall, around 90% of the total height of the wall, will provide a better pull-out resistance and will help the structure perform better under seismic conditions, bridging tension cracks from settlement between the infill and the reinforced soil.

- Use only geogrids that have been tested with the Rocklok® block. The market offers a wide variety of geogrids with similar long-term design strength and characteristics that might not be ideal. It is very important to know what materials were used for manufacturing, the country of origin, and especially the real connection capacity between the geogrid and the Rocklok® blocks. The following geogrids have been tested with the Rocklok® retaining wall system:

  - StrataGrid geogrids: SG200, SG350, SG550, and SG600.
  - Tensar geogrids: RE520, RE560, and RE580.

The need for geogrid reinforcement in a Rocklok® wall will depend on many factors, but mainly on the wall height and on the surcharges or slopes present on the wall. Geogrids are inexpensive compared to other elements of the retaining wall, so for a longer design life and performance, we highly recommend using geogrid in all Rocklok® retaining walls. To determine if geogrid reinforcement is needed, please check Table 13.1.

If you have any questions about geogrid installation, materials, and properties, please contact your local geogrid manufacturer, a Rocklok® representative, or consult a professional chartered engineer.

Alternative Solutions for Reinforcement

No-fines concrete

In recent years there has been an increasing demand for no-fines concrete (NFC) reinforced SRWs. Sometimes called pervious concrete or porous concrete, NFC is a special type of concrete containing little or no fine aggregate, such as sand.

NFC is obtained by omitting fine aggregate from conventional concrete. It is formed by cement, coarse aggregate, and water. The NFC has properties such as zero-slump, and it will exert similar pressures on the Rocklok® blocks as loosely placed aggregate.

Properties of NFC	
- Density: 1650–2100 kg/m^3	- Void ratio: 20–30%
- Aggregate size (mm): 10–20 mm	- Friction angle (ϕ): 77.2°
- Gravel/Cement ratio: 6:1	- Shear strength (MPa): 9.62 MPa
- Water/Cement ratio: 0.45–0.55	

The advantages of using NFC are ample:

- **Faster construction:** Building using NFC is faster because the concrete is vertically poured every 2 courses (400 mm). No compaction is required.

- **Less excavation:** An NFC-reinforced wall requires an excavation depth of only 40–50% of the total height of the wall, which is 20% less than conventional geogrid-reinforced retaining walls. It also means usable space maximisation.

- **Lower cost:** Less excavation and faster construction translate into lower labour costs.

- **Higher stability:** NFC increases the mass and depth of the gravity wall and thus the resistance to sliding and overturning.

- **Free-draining:** Its high permeability due to the absence of fines particles allows water to pass through, dissipating hydrostatic pressure behind the wall.

The installation process of a Rocklok®® wall using NFC is very similar to the installation using geogrid:

STEP 1: Dig the base trench in the desired location and for the required length of the wall.

STEP 2: Place and compact the levelling pad using GAP 20 or a similar aggregate.

STEP 3: Lay the first course of Rocklok® units and place the fibreglass pins (two units per Rocklok® block). Ensure the blocks are perfectly levelled.

STEP 4: Fill the Rocklok® open core/cavities and spaces between units with NFC and backfill to the specified depth. Depth is measured from the face of the block.

STEP 5: Brush the top of the Rocklok® blocks to remove any excess before the concrete gets hard.

STEP 6: Install the next course of Rocklok® blocks and continue with the same process until the last 200 mm of the specified wall height.

STEP 7: Place filter fabric on top of the NFC and place 200 mm of a low permeable soil on top of the geotextile to reduce water filtration. Install and secure the optional capping block in place using a high quality, flexible, all-weather masonry adhesive.

Some recommendations when using NFC:

- The maximum allowed vertical height of an NFC pour is 400 mm, or two Rocklok® courses.

- Brushing to remove any excess of material on top of the blocks should be carried out before the NFC hardens.

- After pouring the NFC in the first course or first two courses, additional Rocklok® blocks can be stacked up. Allow at least 2 hours for the NFC to cure before pouring concrete in the last stacked blocks.

- The filter fabric on top of the NFC structure is required to stop the settlement of fines particles and to prevent the NFC from clogging up.

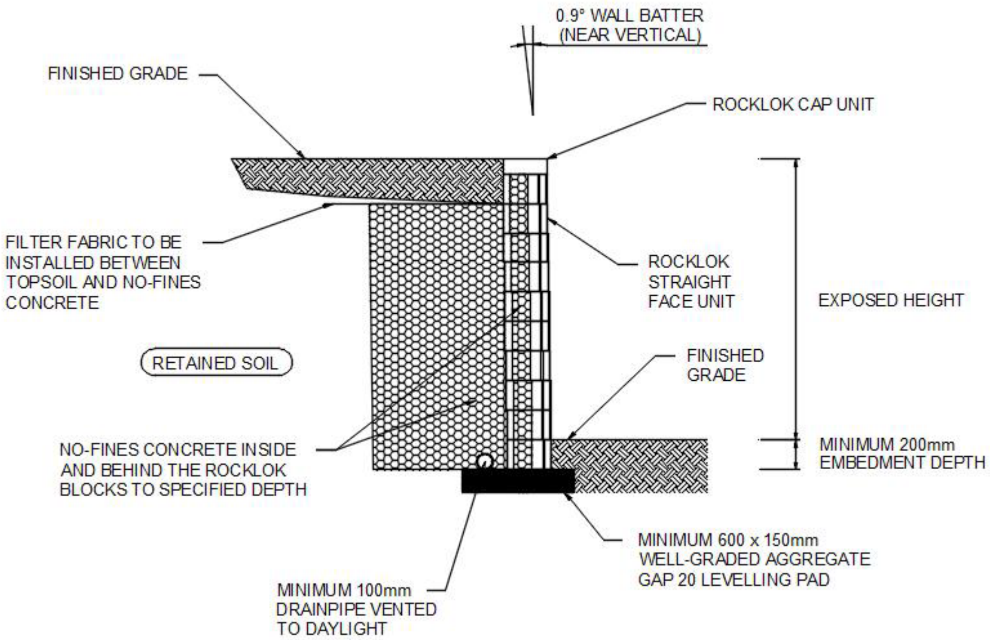


Figure 5.18.: No-Fines Concrete

Rocklok® Masonry Retaining Wall

When geogrid or NFC-reinforced Rocklok® retaining walls are not feasible because of space limitations or proximity with the boundary, the Rocklok® retaining wall system can be designed as a masonry retaining wall reinforced with steel and a concrete footing.

The Rocklok® near-vertical configuration and its hollow core allow for the placement of vertical reinforcement and the grout of concrete. Please contact a structural engineer for the design of a Rocklok® masonry retaining wall.

6. Construction Details

Corners

Returns and corners are common elements in many SRWs. Outside corners are built using the Rocklok® corner block, while inside corners require some block modification.

Outside Corner

When geogrids are used on outside corners, special considerations apply. Please refer to Figure 6.1 and 6.2.

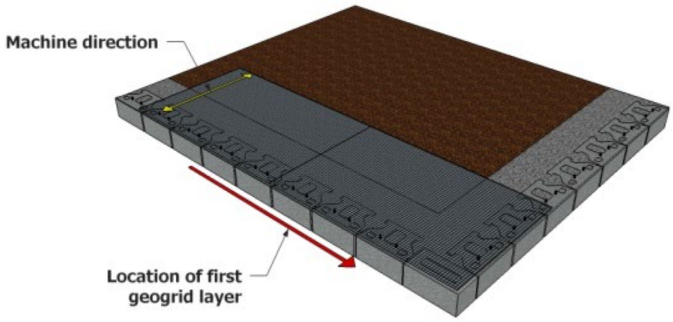


Figure 6.1.: Outside corner first geogrid layer

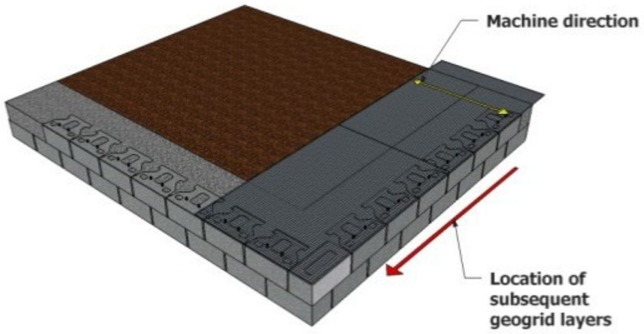


Figure 6.2.: Subsequent geogrid layers

Inside Corner

As with the outside corners, when geogrids are used on inside corners, some changes in the installation method apply. Please refer to Figure 6.3 and 6.4.

- When the angle of a corner is smaller or exceeds 90°, it is suggested to curve the wall instead. This way, gaps and weak points are not created in the retaining wall.
- Geogrid length needs to be extended by 25% the total wall height (H/4)

- Construction on a wall with corners can start from the corner and continue away from this point or can start elsewhere and work towards the corner. However, experience tells us that walls that do not start from the corner tend to look sloppy. Rocklok® retaining walls constructed from the corners reduce the amount of cutting required and make it easier to align the blocks.

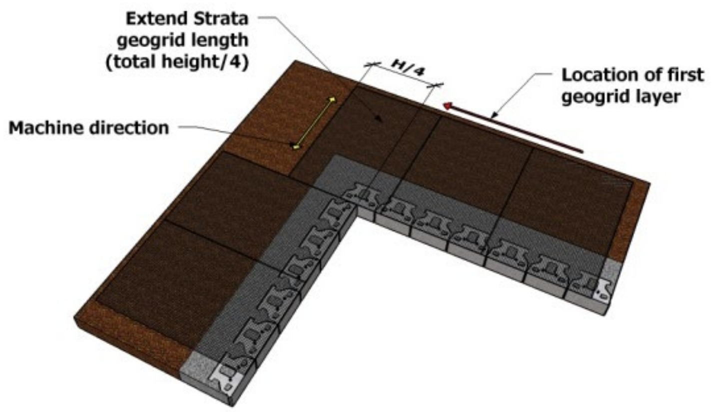


Figure 6.3.: Inside corner first geogrid layer

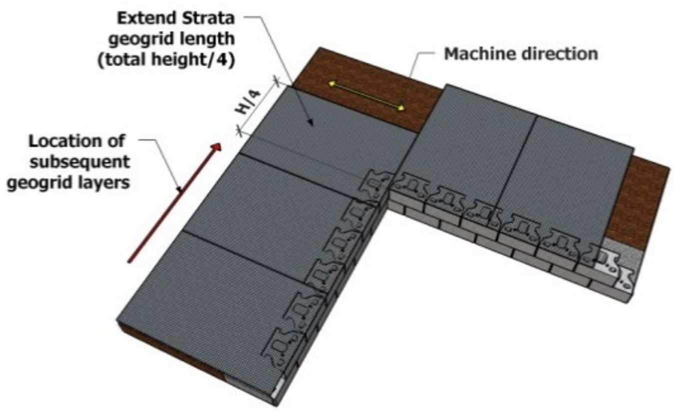


Figure 6.4.: Subsequent geogrid layers

Curves

The Rocklok® retaining wall system allows for the construction of pleasant inside/concave and outside/convex curves.

The construction methodology for curved walls remains the same as with the straight Rocklok® walls, except when geogrid reinforcement is needed. The geogrid is still positioned every two blocks starting from the top of the first course, but the suggested grid installation practices vary slightly depending if the curve is concave or convex. In either case, in curved walls the geogrid has to cover the entire surface around the curve. Please refer to Figures 6.5, 6.6, and 6.7.

The smallest external and internal construction radius in the top course of a wall is 1.0 m and 1.4 m respectively. In outside curves the radius decreases as the wall grows in height, while in inside curves the opposite tends to happen, so it is important to determine the minimum radius required on the wall before beginning its construction.

On tight curves a gap might appear between Rocklok® units. If the gap is too big for the pins to fit in their correspondent kidney holes, try to rearrange or modify the blocks by drilling a new set of pin holes with a drilling machine with 18 mm concrete drill bits.

Outside Curves

Place the geogrid as per the approved drawings and to the specified length. On the outside curves the geogrid normally overlaps. Where the geogrid is overlapping, place 75 mm of backfill material (the aggregate that is being used as infill material) between layers to separate them.

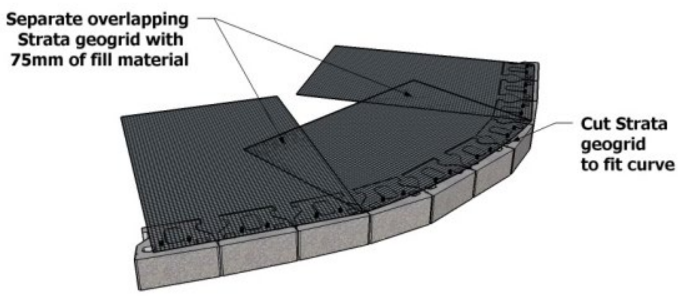


Figure 6.5.: Outside curve geogrid installation

Inside Curves

Place the geogrid as per the approved drawings and to the specified length. On the inside curves the geogrid normally creates a gap between layers, which seems to grow as the radius get tighter. Because the geogrid has to cover the entire surface around the curve, install a secondary or extra geogrid layer on the next course to cover the gap. The additional geogrid layer must have the same length as the previously installed geogrid layers.

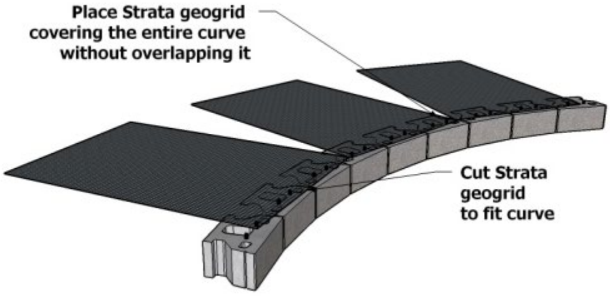


Figure 6.6.: Inside curve primary geogrid layers

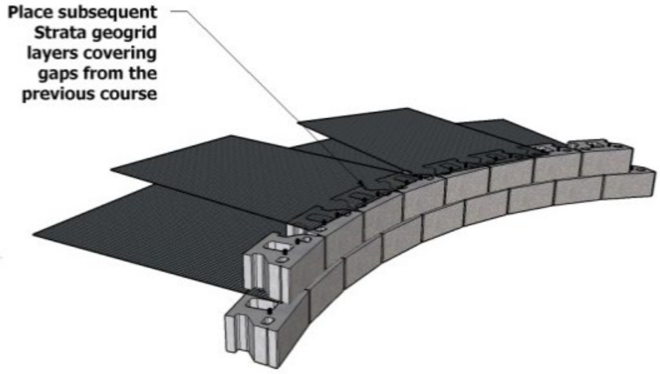


Figure 6.7.: Subsequent geogrid layers

Steps and Stairs

Steps and stairs can be integrated into the Rocklok® retaining wall construction using the standard Rocklok® unit and the capping block. The steps to build a simple tread stair are as follows:

STEP 1: Check the New Zealand Building Code requirements in reference to access routes and stairways.

STEP 2: Stipulate the width of the steps and establish the height of the riser and the run of the tread required for the construction of the stair.

STEP 3: Select the materials and the Rocklok® elements needed for the stairway construction. Remember that when using the Rocklok® blocks, the minimum width and depth will be 300 and 200 mm respectively. Play with multiples of this numbers to increase the size of the steps.

STEP 4: Once the stairway is calculated, set out the wall and stair location.

STEP 5: Excavate to the desired depth and width for each riser and compact the entire surface (all step runs) to a minimum relative density of 95% of standard Maximum Dry Density (MDD). The excavation should allow for the levelling pad and the Rocklok® units. Extra care and time should be taken during compaction when building steps in order to avoid later settlement.

STEP 6: Verify the surface is level and only then place and compact a minimum of 150 mm of a well-graded aggregate GAP 20 or similar (levelling pad).

STEP 7: Install the first Rocklok® unit. If the stairs connect to a Rocklok® retaining wall, check positioning, levels and alignment before continuing. Make corrections if necessary.

STEP 8: Fill the Rocklok® unit cores with a clean, permeable, compactible, well-graded drainage material, preferably drainage metal 25/7, and place 150 mm of the same selected material behind the Rocklok® units. At the same time, create the base for the next Rocklok® riser.

STEP 9: Compact the base and place the subsequent Rocklok® riser.

STEP 10: Repeat the same process until all the Rocklok® risers are installed. Finish the stairs by installing and securing the capping block in place.

In order to facilitate the construction of a stairway using the Rocklok® retaining wall system, and in order to achieve better compaction and reduce potential future settlement, it is recommended to carry out soil compaction every 100 mm instead of the standard 200 mm.

Mulch, stones, concrete, or paving units can be used as tread material. The Rocklok® stairs can also be built using the Rocklok® corner block. Curved Rocklok® stairs are also possible using the standard block unit, creating a smooth and more modern outline.

Terraced Walls

Terraced or tiered walls are an attractive solution for steep grades, allowing for a more usable space of land and the creation of beautiful gardens or landscaped areas. Tiered walls might also result in a more cost-effective solution because less infill material is required.

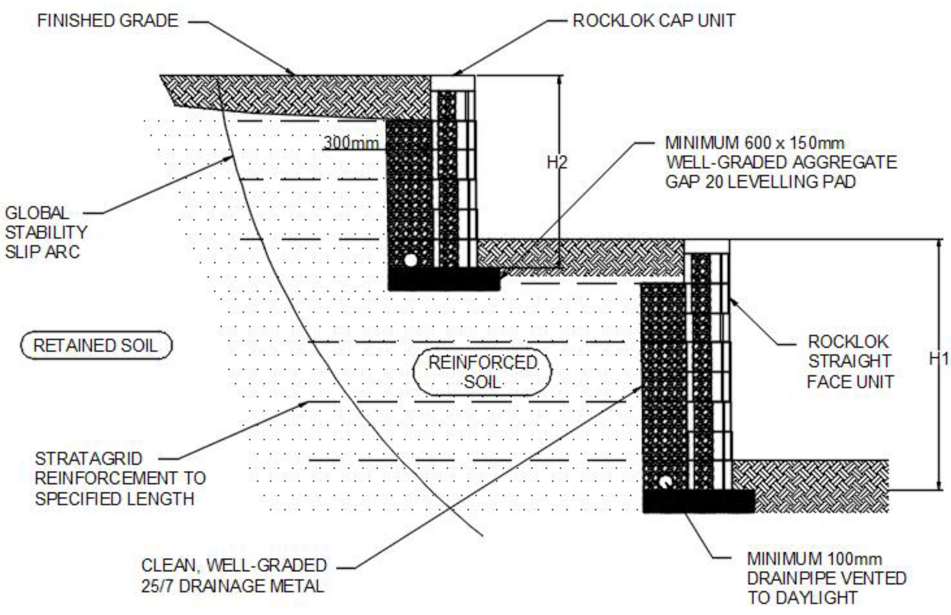


Figure 6.8.: Terraced Walls

There are basically two scenarios when building terraced walls: independent walls and dependent walls.

- **Independent walls:** Walls act as independent structures when the distance (*D*) between the lower wall and the upper wall, measured from the toe of each wall, is more than twice the height of the lower wall (H_{lower}). Moreover, the height of the upper wall (H_{upper}) should be equal or smaller than the height of the lower wall (H_{lower}).

$$Distance\ (D)\ > 2 \times H_{lower\ wall}$$

$$H_{upper\ wall} \leq H_{lower\ wall}$$

  This 2 to 1 ratio is only the general rule, but it might not apply if there are poor clay foundation soils on site or if there are slopes below, between, or above the retaining wall structures.

- **Dependent walls:** This happens when the distance between the lower and upper structure is less than two times the height (total height of the wall) of the lower wall. In this case, the upper retaining wall will apply a load to the lower retaining wall.
  It is important to consider global stability when building or designing structurally dependent walls.

Proper drainage management is very important to create long-lasting tiered walls. The upper wall drainpipe should be discharged under or around the lower wall and never above or behind the lower wall. Tiered walls with structures on top, slopes, more than two terraces, or closer than twice the height of the lower wall acting as a dependent structure need to be evaluated and designed by a chartered professional engineer.

Capping and Finish Grading

The capping unit is an optional element used to finish SRWs. The Rocklok® capping block has the same length and width as the standard Rocklok® unit, setting perfectly, and covering the top of the Rocklok® retaining wall.

The Rocklok® capping block has to be secured in place using a high-quality, flexible, all-weather masonry adhesive. Apply the concrete adhesive on top of the last Rocklok® unit, following a pattern and distributing it to cover as much area as possible. Once the glue is applied, put the capping unit firmly in place and push down slightly to ensure good adhesion. Allow the adhesive to set for a couple of hours.

The finish grading at the bottom and at the top of the retaining wall should allow for the drainage of water away from the Rocklok® SRW. The top of the Rocklok® retaining wall, approximately 200–300 mm, should be finished using a low permeable soil to minimise infiltration of surface water into the drainage column and the reinforced soil zone. A filter fabric should be horizontally placed to separate the low permeable soil from the infill material.

The capping block and the placement of low permeable soil conclude the construction of the Rocklok® SRW. It is now ready to be finished on top using mulch, top soil, or plants, or building car parks or other structures above.

Barriers and Fences

Fences are commonly placed on top of SRWs for privacy and safety.

Generally, the fence, rail, or barrier posts will be installed during the wall construction and not after the wall has been completed. When the retaining wall is being reinforced using geogrid, the geosynthetic reinforcement should be carefully trimmed as per manufacturer recommendations to allow for the rail or fence posts.

In order to apply the least amount of pressure on the top of the Rocklok® retaining wall to avoid any possibility of overturning failure, the preferred location for the fence or rail posts is 0.9 m away from the back of the blocks. If you want to place the fence or barrier closer to the wall or inside the Rocklok® block holes, professional advice should be sought to ensure the wall will resist the applied pressures.

Note: Wind loading needs to be considered for fences that will resist wind loads, for example, solid wooden fences.

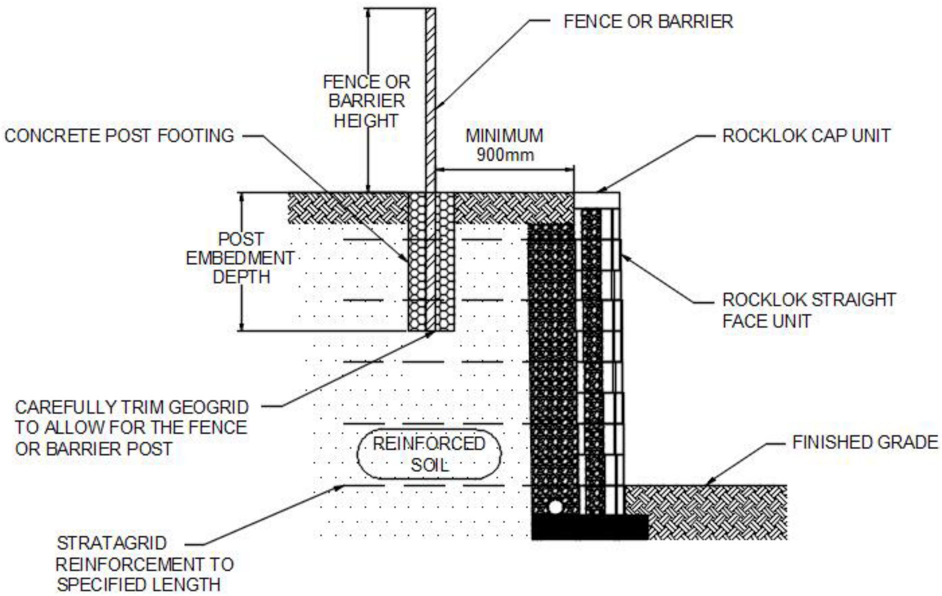


Figure 6.9.: Barrier or Fences on top of Rocklok® wall

7. Soils and Compaction

Soils have an enormous influence on retaining walls, so before starting a project it is very important to know what soils are present, what their properties are, and how those soils behave in order to construct and design the right SRW structure.

Soils can be classified in many different ways, such as using the soil particle distribution, the Atterberg limits, or other properties like soil density, cohesion, angle of friction, and shape, among others. The typical properties of common soil types are shown in Table 7.1.

Type	Coarse								Fine		Organic
			Gravel			Sand					
	Boulders	Cobbles	Course	Medium	Fine	Coarse	Medium	Fine	Silt	Clay	Organic Soil
Size Range (mm)	200	60	20	6	2	0.6	0.2	0.06	0.002		
Graphic Symbol											

Table 7.1.: Soil types and soil particle size

- **Gravel** is mainly produced by crushing rocks mechanically, and its particle size is relatively large, between 4.75 mm and 75 mm. Gravel provides a high frictional resistance and is appropriate to form a good foundation material.

- **Sand** is a highly permeable non-plastic soil with a particle size ranging from 0.075 to 4.75 mm. Sand possesses high strength in a confined state and has a significant frictional resistance.

- **Silt** is a granular material with a particle size between sand and clay, ranging from 0.005 mm to 0.075 mm.

- **Clay** is composed of flat, flaky, small particles, less than 0.005 mm in size. Clay is much more cohesive than sand, bonding the particles in the soil to one another. Clay is not recommended as infill material because of its low permeability. Clay soil retains the water that filters into it, adding weight and increasing the pressure on the retaining wall. It is also susceptible to swelling and shrinkage. Cohesion is normally taken as zero for design purposes.

Generally, a Rocklok® retaining wall constructed in clay soil would require extra compaction and reinforcement compared to a similar wall using a gravel type of soil. The ideal soil behind the Rocklok® retaining walls system is a granular material, preferably gravel or even sand, with an angle of friction between 32° and 36° or higher. Non-cohesive soils such as gravel and sand have a more predictable shear resistance and they allow water to pass through. GAP 20, GAP 40, and GAP 65 are the best materials to use in Rocklok® retaining walls.

Typical Soil Properties		
Soil Type	Angle of Friction (ϕ)	Unit Weight (γ)
Well-graded gravel	36°+	19–24 kN/m^3
Well-graded sand	32–36°	15–23 kN/m^3
Silty sands	28–32°	14–22 kN/m^3
Inorganic clays	24–28°	15–20 kN/m^3

Table 7.2.: Typical soil properties

It is very important that the foundation soils are adequately compacted before starting the construction of all Rocklok® retaining walls, especially if the soils underneath have previously been disturbed, dug, imported or substituted. If the foundation soil was formed by poor quality soil or expansive soils such as inorganic clays, extra excavation should be carried out. Poor soil should be replaced with well-graded aggregates, and the base may need to be reinforced to provide the necessary bearing capacity.

Compaction should be carried out to achieve a minimum relative density of 95% of standard Maximum Dry Density (MDD) of the fill material, or equivalent Clegg impact value, generally about 32

CIV. To not compromise the stability of the wall, only small hand-operated plate compactors should be used in the first 1.2 m of wall (the consolidation zone), measured from the face of the Rocklok® units. Heavy compaction machinery might be allowed in the compaction zone, which extends from 0.9 m behind the wall face to the back of the cut. Rollers and compactors must run parallel to the wall.

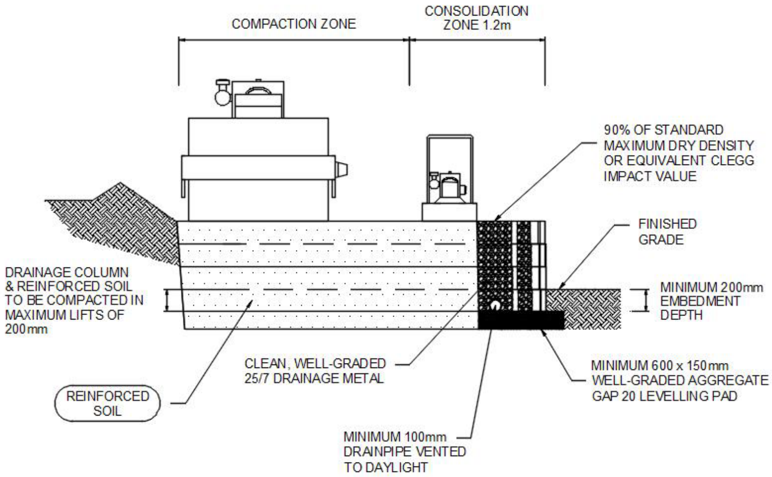


Figure 7.1.: Soil Compaction

8. Surcharges

Surcharges are external loads typically applied at the top and behind the Rocklok® retaining wall. The zone of influence of those external loads will vary depending on the site and soil conditions.

Generally, there are two types of surcharge loads: live loads and dead loads.

- **Live loads** vary considerably in magnitude and may be only temporarily present over the retaining wall. Examples of live loads are people, vehicles, and storage.

- **Dead loads** are essentially constant in magnitude and permanent during the life of the retaining wall. Examples of dead loads are fences, back slopes, building foundations, or other retaining walls.

9. Slopes and Global Stability

Slopes have an important influence on all SRWs. While a slope grading at the top or bottom of the retaining wall may be beneficial to divert water away from it, the same slope may increase the lateral earth pressures or create instability on the retaining structure.

Generally, slopes are measured using the horizontal distance (run) and the vertical distance (rise), so a four-to-one (4H:1V) back slope goes back 4 and up 1.

- **Slopes above (back slopes):** A back slope is the changing in grade that occurs on top of the retaining wall. Back slopes surcharge the wall, increasing the lateral earth pressure the Rocklok® retaining wall has to resist.

- **Slopes below (toe slopes):** A toe slope is the changing in grade that occurs in front of the retaining wall right on its toe. Toe slopes can have a substantial effect on the stability of the Rocklok® retaining wall. This decrease in the stability is directly associated with the weight of the soil stabilising the retaining wall and the decrease of shear resistance along the failure surface.

  When toe slopes are present, the retaining wall embedment must be increased. As a general rule the minimum distance between the face of the first Rocklok® block and daylight should be at least a 1.5 m (minimum bench). For example, with a 4H:1V slope in front of the wall, it would require 0.375 m (approximately 2 blocks) to create a 1.5 m horizontal bench.

Global stability is the general mass movement of an SRW and the adjacent stability of the soils above and below the retaining wall. Rocklok® retaining walls constructed on hillsides, with steep toe and back slopes, with excessive surcharges, placed on organic or high-plasticity clay soils, and tiered walls require the evaluation of the site's overall stability. This global stability analysis should be conducted by a chartered professional geotechnical engineer.

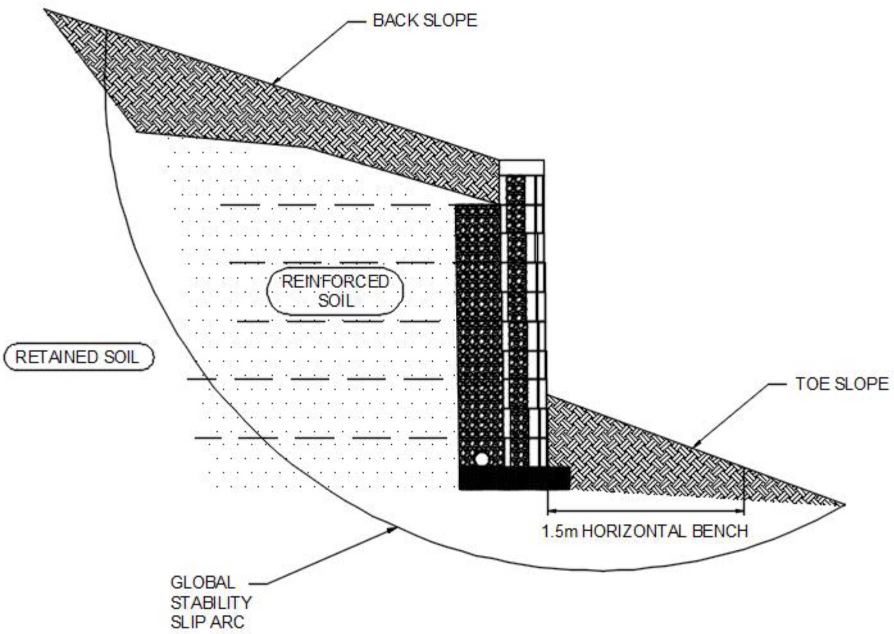


Figure 9.1.: Slopes and Global Stability

10. Seismic Performance

According to GNS Science, New Zealand has over 15,000 earthquakes a year, with 100–150 of them being large enough to be felt. The devastating earthquakes in Christchurch in 2011 and Kaikōura in 2016 caused road and bridge damage, liquefaction, and building collapse.

SRWs are known for their exceptional performance during earthquakes when designed and constructed appropriately, performing better than other retaining walls during seismic events. Rocklok® retaining walls are designed to be flexible structures that allow for some minor displacement in the case of an earthquake without compromising the structure.

As part of the Rocklok® system there are various connectors available that connect to different inextensible and extensible reinforcement. The Rocklok® clip and the Rocklok® interlocking bar provide a direct mechanical connection with the geogrids (plastics or steel) reinforcement, increasing the connection capacity at the front face of the block when designing for seismic conditions.

To improve the performance of the Rocklok® retaining wall system during seismic events, it is suggested to do the following:

- Extend the geogrid layers at the top of the retaining wall to at least 90% of the total height of the wall to bridge tension cracks from settlement between the reinforced and the retained soil.
- Increase the number of layers of geogrid in the retaining wall structure in order to reduce settlement.
- To increase soil strength, compact every 200 mm or even every 100 mm lift.
- Use a good quality infill soil such as GAP 20, GAP 40, or GAP 65.
- Use the Rocklok® Trench with the Rocklok® clips, or the Rocklok® Ladder with steel pins and steel reinforcement.

11. Water Management

The average rainfall in New Zealand is high and evenly spread throughout the year. According the National Institute of Water and Atmospheric Research (NIWA), most areas of New Zealand have between 600 and 1,600 mm of rainfall a year, which means between 600 and 1,600 litres per square metre.

These rains have effects on retaining walls all around the country, by increasing the loads on the retaining walls, through erosion, and by affecting the retaining or foundation soils, so careful water management is of vital importance to allow the structure to perform and to mitigate potential problems.

Surface Water

Localised sources of water must be considered by the site civil engineering consultant when designing any Rocklok® SRW to assure water does not filter into the infill zone.

Surface water should be diverted away from the back of the wall. Temporary berms or swales can be easily constructed and added to the site topography to provide ways to direct the water away from the retaining wall, especially during its construction. Water must not flow over the top of any Rocklok® retaining wall from a sloping backfill, so swales or U-shaped channels should be integrated in the design when back slopes are present to reduce erosion and to catch and remove the water.

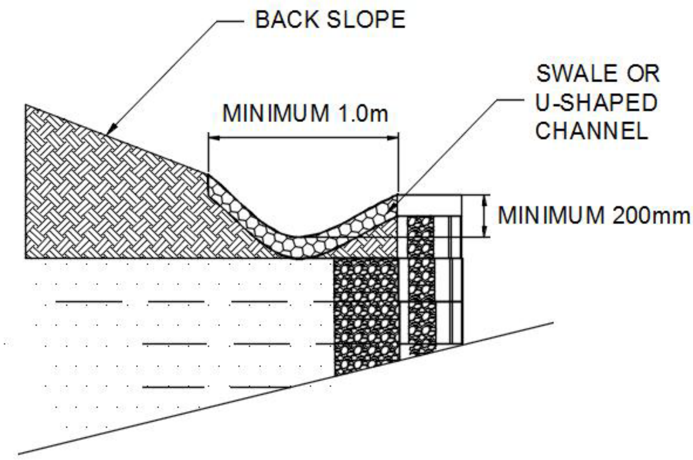


Figure 11.1.: Swale or U-shaped channel

Below Grade Water

Below grade water is the water that gets filtrated into the soils. Whenever possible, the movement of water into the reinforced soil mass, including the face of the wall, must be impeded and minimised.

- **Drainage pipe:** The toe pipe, drainage pipe, or drainpipe is an important element of the drainage system. Its main function is to remove additional water resulting from filtration and to reduce hydrostatic pressure behind the retaining wall.

  The drainpipe should be installed behind the levelling pad at the bottom of the drainage column. The minimum diameter recommended behind the Rocklok® retaining walls is a 100 mm diameter pipe, although it might be more common to find 110 mm and 160 mm diameter pipes in the New Zealand market.

  The pipes should be made of corrugated HDPE, which is flexible, or PVC, which is rigid. They should be slotted or punched, allowing the water to penetrate into the pipe. Allow for at least a 1% gradient, as gravity will pull the water downward into the underground drainage system or to an exit to daylight. Outlets should be installed every 15 or 30 m if the pipe is higher than the outlets.

Sock pipes are not recommended if they are not installed in a proper bedding. Although the sock's main function is to prevent the migration of soil and fine particles into the pipe, over time it clogs up, thus not allowing the system to perform.

- **Filter fabric:** A geotextile cloth or filter fabric should be horizontally placed on top of the drainage column to prevent the migration of fines particles from the top soil into the drainage material.

The drainpipe should provide enough capacity to gather and remove all incidental water. An extra heel drainpipe or the use of slow-draining material can be added to the system below the toe drainpipe to allow for extra removal of ground water.

Blanket and Chimney Drains

When the Rocklok® project conditions include any of the following concerns, blanket or chimney drains should be considered to reduce serious water penetration issues.

- Where groundwater is likely to rise above or just below the levelling pad.
- When there is a body of water behind the reinforced zone.
- When non-permeable soils are used in the infill area.
- When the surface water is not directed away from the reinforced and retained soil areas.
- When water flows freely from the retained soil to the reinforced soil mass.

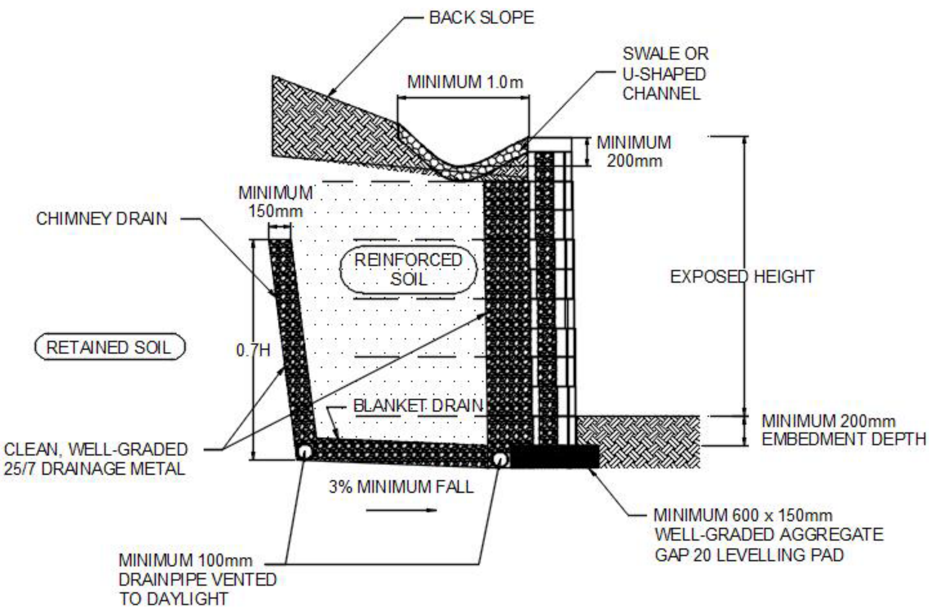


Figure 11.2.: Water Management

12. Why Retaining Walls Fail

Although the main objective of the SRW industry is to achieve *zero* wall failures, retaining walls do sometimes fail.

Failure does not essentially mean the total collapse of the retaining wall structure; it can mean cracks, displacement, or tilting, which suggest the likelihood of a future total collapse. The reasons behind a collapse are multiple, but the main cause behind retaining wall failures is improper construction.

The main reasons why SRWs fail are the following:

- **Fibreglass pins:** The Rocklok® 16 mm diameter fibreglass pins are, along with the blocks, elements of an integrated system and must be used in combination. The use of a different diameter pin or a different material can massively affect safety and the performance of the retaining wall. It is compulsory to use a pair of fluted fibreglass pins per Rocklok® block.

- **Inadequate geogrid placement and length:** Most of the reinforcement geogrids are uniaxial, which means that they have most of their strength in one direction, the machine direction. It is imperative to place the geogrids properly and extend it from the front face edge, always having their strength direction perpendicular to the face of the Rocklok® retaining wall, so they are able to resist the disturbing forces.

  It is equally important to follow the design recommendations and to install the grid to the required lengths, in the required positions, with the specified long-term design strength. The following are some common failures of geogrid:

  - **Grid pull-out** occurs when the geogrid length is not sufficient to provide the necessary anchoring capacity beyond the failure surface. The solution is to increase the grid lengths.
  - **Grid rupture** happens when excessive forces exceed the ultimate tensile strength of the geogrid. The solution is to increase the long-term design strength of the geogrid or even the number of geogrid layers.
  - **Bulging** is a rotation on the face of the retaining wall, which is usually caused by horizontal forces between layers of geogrid. The solution is to increase the number of geogrid layers and to have the geogrid tensioned when backfilling.

- **Poor water management:** Water is the number one enemy of any SRW, and it is the primary cause of failure. Localised sources of water have to be considered when designing and building any SRW, and surface water should be diverted away from the back of the wall using swales or berms.

  All Rocklok® retaining walls must incorporate a drainage column and a drainpipe to collect and divert filtrated water. The drainpipe should exit to daylight or be connected to a drainage system. Where necessary, blankets and chimney drains should be installed to reduce the filtration of water into the infill zone.

- Saturated backfill: A saturated backfill through water filtration means poor infill soils, insufficient drainage, or both. A saturated backfill increases the hydrostatic pressure behind the wall, doubling the pressure the retaining wall has to resist.

- Poor foundation and retained soils: Retaining wall failures may result from inadequate bearing capacity or ground instability. Organic soils and high-plasticity clays provide poor bearing capacity, increasing the risk of large settlements under working loads.

  Clays also change over time through consolidation, swelling, and weathering, increasing the pressure on the back of the wall. If a geotechnical report is not available, or if you are in doubt about the site soil conditions, seek advice from a geotechnical engineer.

- Unexpected loads: Is there any possible surcharge load? Is there any back slope? Make sure surcharge, slope, and the future uses of the retaining wall are considered in the design and construction. Good client–engineer–contractor communication is needed to prevent unexpected loads from happening.

  Experience tells us that retaining walls perform incredibly well and that they are extremely resistant and forgiving, but even very small garden walls, 400 or 600 mm high, might fail if they are not designed, built, or used appropriately.

- Compaction: Compaction increases the shear strength of the soil and makes it difficult for water to flow through the soil. The main reason for compacting a soil is to reduce subsequent settlement when subject to loads.

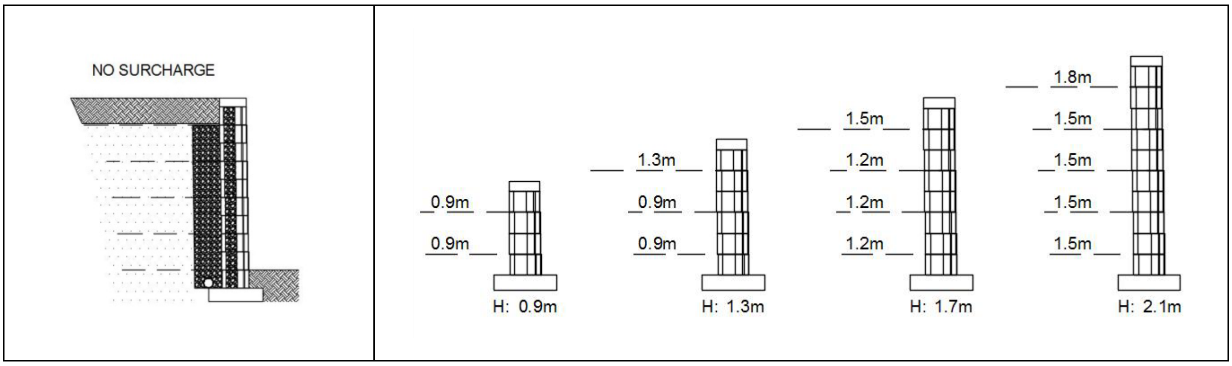
- Improper use of compaction machinery: Compaction is generally carried out by mechanical means. The proper use of compaction machines is crucial to not damage or affect the construction of the retaining wall. For instance, plate compactors should not be used directly over the geogrids, and heavy compaction machinery should be kept away from the face of the wall to avoid its rotation. They must run parallel to the face of the wall at the specified distance.

13. Design Charts and Tables

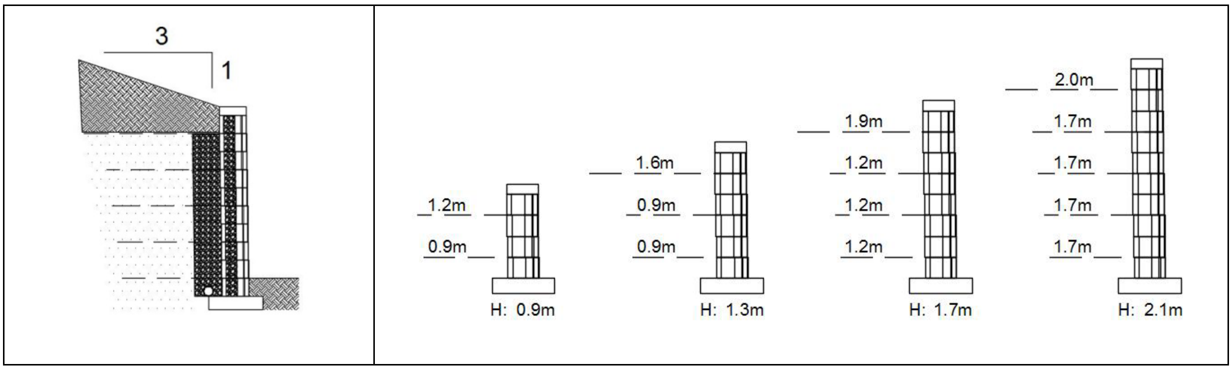
Rocklok® - Geogrid reinforcement charts

Inorganic Clay (ϕ=28°; γ=16KN/m^3); Peak ground acceleration (PGA) = 0.15g

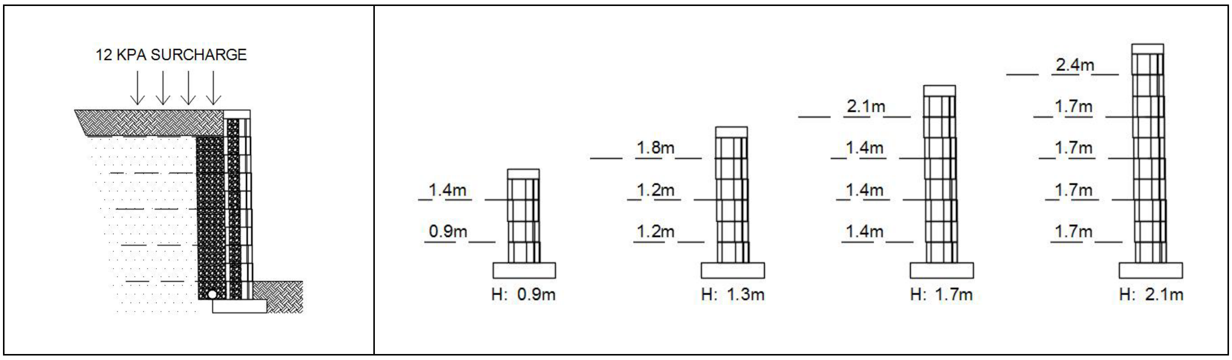
Example 1 - No surcharge



Example 2 - Slope (3H:1V)

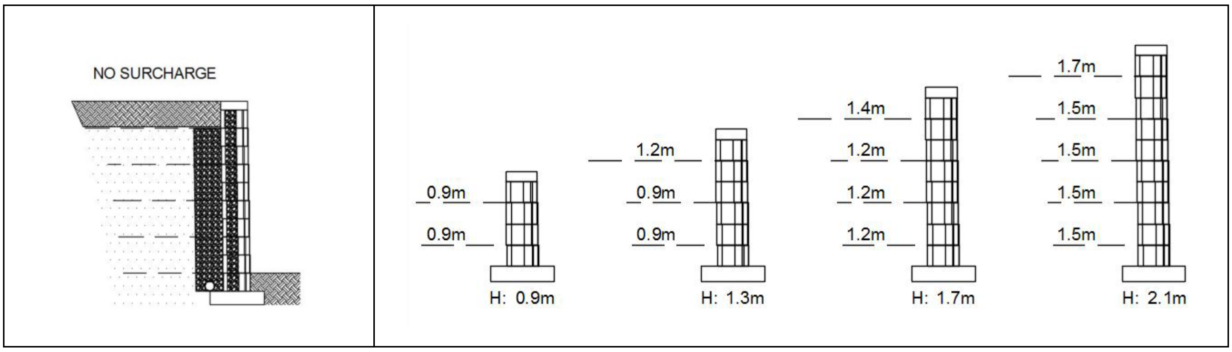


Example 3 - Surcharge (12 KPa)

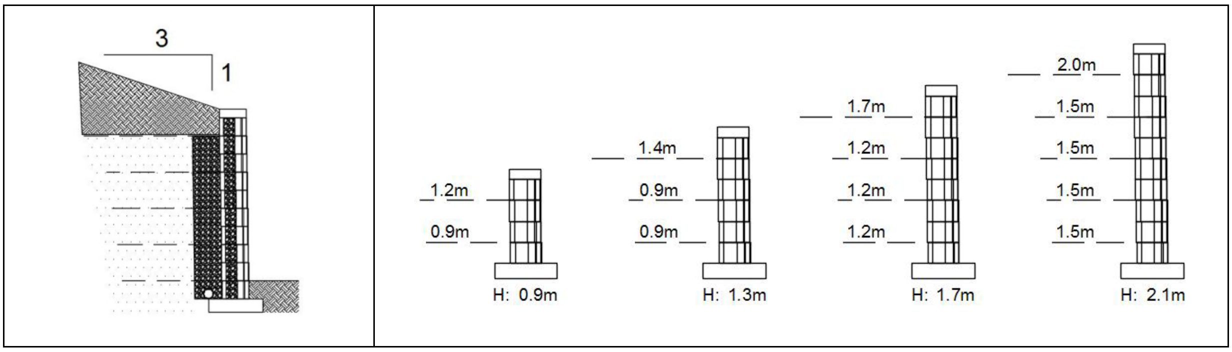


Sand (ϕ=32°; γ=19KN/m^3); Peak ground acceleration (PGA) = 0.15g

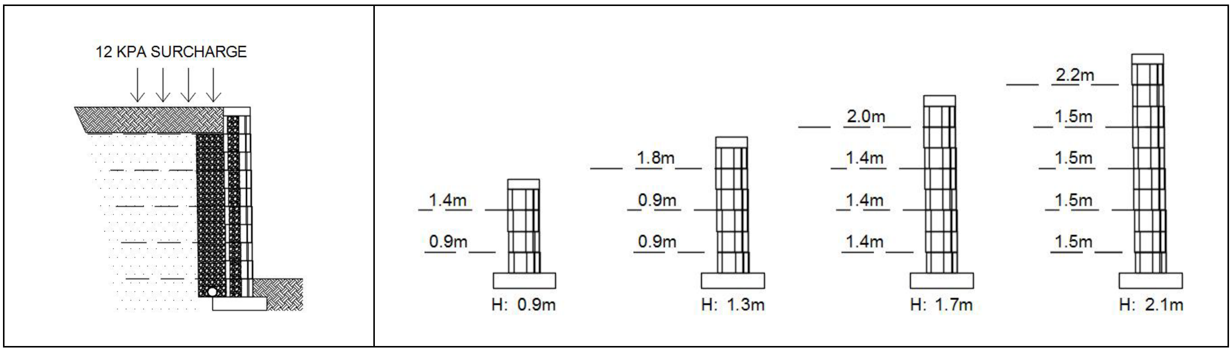
Example 1 - No surcharge



Example 2 - Slope (3H:1V)

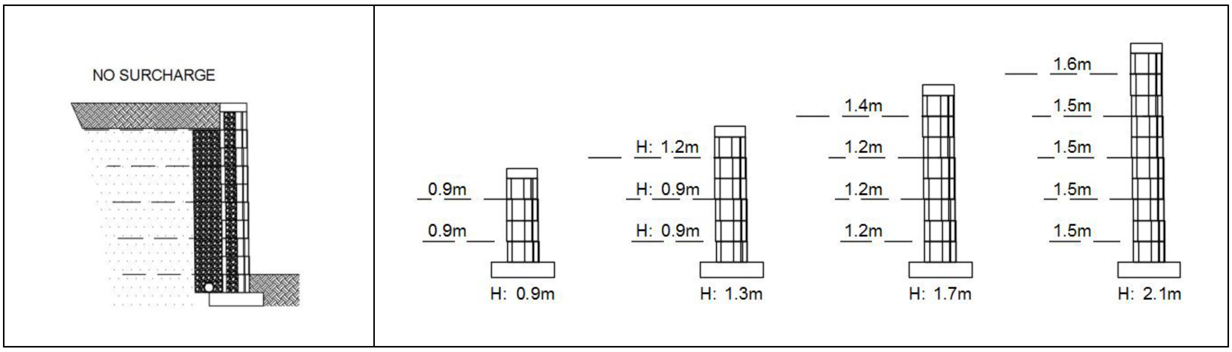


Example 3 - Surcharge (12 KPa)

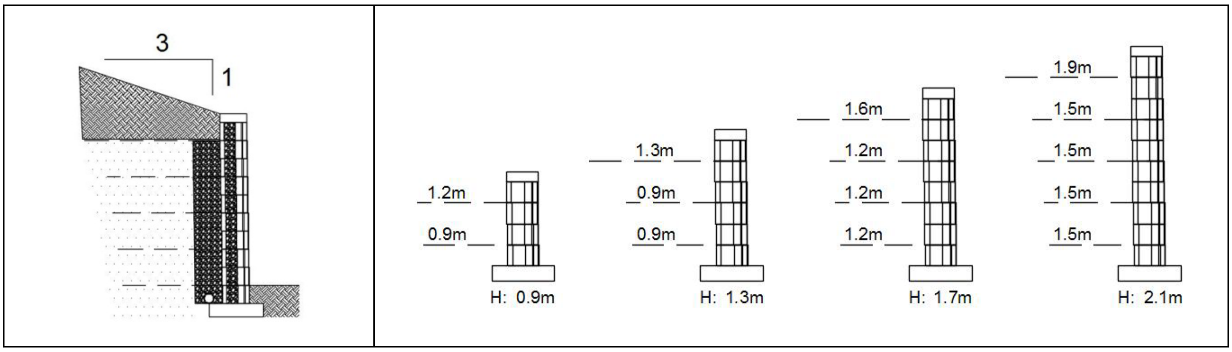


Gravel (ϕ=36°; γ=21KN/m^3); Peak ground acceleration (PGA) = 0.15g

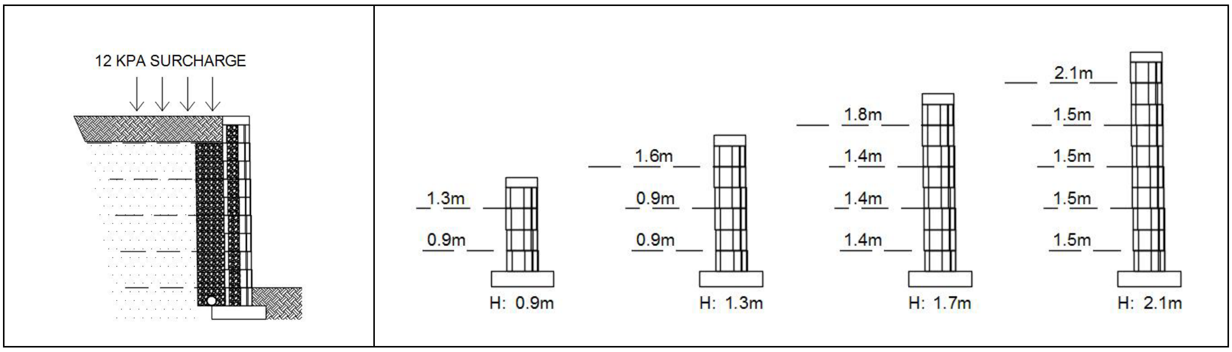
Example 1 – No surcharge



Example 2 - Slope (3H:1V)

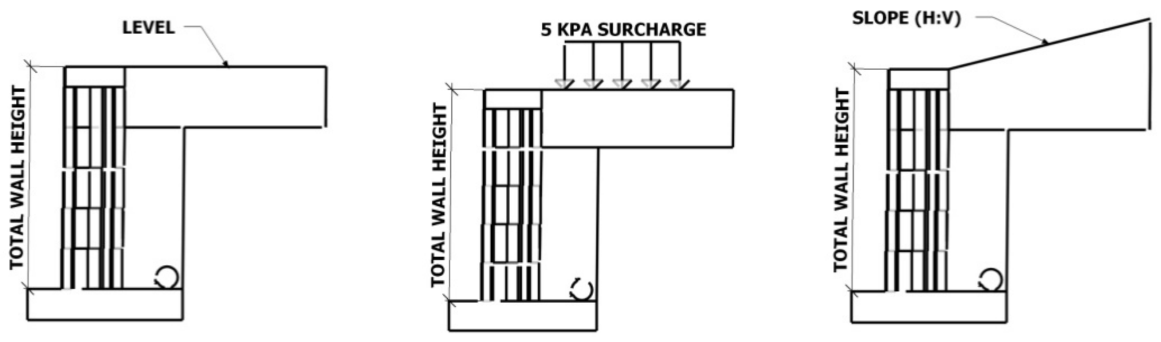


Example 3 - Surcharge (12 KPa)



Rocklok® - Gravity wall heights

Check the Rocklok® gravity wall heights table to find the maximum height that can be achieved before geogrid or NFC is needed.



Maximum gravity wall heights					
Soil Type	Level	Surcharge 5 KPa	Slope		
			4H:1V	3H:1V	2H:1V
Gravel	0.9m	0.5m	0.8m	0.8m	0.7m
Sand	0.8m	0.4m	0.7m	0.7m	0.6m
Inorganic Clays	0.7m	0.3m	0.6m	0.6m	0.5m

Table 13.1.: Maximum gravity wall heights

Note: The geogrid reinforcement chart and the gravity wall heights table assume the following soil parameters: Gravel (ϕ=36°; γ=21KN/m^3), Sand (ϕ=34°; γ=19KN/m^3) & Clay (ϕ=28°; γ=16KN/m^3). The information provided is for preliminary design use only. These charts and tables should not be used for final design or construction without the certification of a professional registered engineer. Bowers Brothers Concrete Ltd do not admit liability for the inappropriate use of these charts and tables.

14. Appendices

Appendix A Specifications Guidelines – Rocklok® Modular Masonry Retaining Wall System

General

Purpose

This specification is to describe the characteristics of Rocklok® dry masonry blocks and associated components. The work includes furnishing and installing concrete modular block retaining wall units with fibreglass shear/alignment pins to the lines and grades presented on the construction drawings and as specified herein.

Work includes:

- preparing the trench
- furnishing and installing the levelling pad, unit fill, and backfill to the lines, pins installation, and grades shown on the construction drawings
- furnishing and installing geogrid reinforcement and backfill to the lines and grades designated on the construction drawings.

Scope

This specification applies to the Rocklok® Flat dry masonry block restrained by aggregate and 16 mm diameter fluted glass reinforced polymeric pins and polymeric earth reinforcing mesh.

Reference Standards

- ASTM C1372-04 – Standard Specification for Segmental Retaining Wall Units
- ASTM C1262 – Standard Test Method for Evaluating the Freeze Thaw Durability of Dry-Cast Segmental Retaining Wall Units and Related Concrete Units
- ASTM C90 – Standard Specification for Loadbearing Concrete Masonry Units
- ASTM D3916-08 – Standard Test Method for Tensile Properties of Pultruded Glass-Fiber-Reinforced Plastic Rods
- ASTM D3917-15a – Standard Specification for Dimensional Tolerance of Thermosetting Glass Reinforced Plastic Pultruded Shapes
- ASTM D4318 – Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- ASTM D4475-02 – Standard Test Method for Horizontal Shear (Short-Beam Method) of Pultruded Reinforced Plastic Rods
- ASTM D4476/D4476M – Standard Test Method for Flexural Properties of Fiber Reinforced Pultruded Plastic Rods.
- ASTM D4595 – Standard Test Method for Tensile Properties of Geotextiles by the Wide Strip Method

- ASTM D570-98 – Standard Test Method for Water Absorption of Plastics
- ASTM D5262 – Standard Test Method for Evaluating the Unconfined Tension Creep Behavior of Geosynthetics
- ASTM D5874-16 – Standard Test Methods for Determination of the Impact Value (IV) of a Soil
- ASTM D6638 – Standard Test Method for Determining the Connection Strength Between Geosynthetics Reinforcement and Segmental Concrete Units
- ASTM D6706-06 – Standard Test Method for Measuring Geosynthetic Pullout Resistance of Soil
- ASTM D6916 – Standard Test Method for Determining the Shear Strength Between Segmental Concrete Units
- ASTM D698 – Standard Method of Laboratory Compaction Characteristics of Soil Using Standard Effort (600kN-m/m^3)
- ASTM F405 – Standard Specification for Corrugated Polyethylene (PE) Pipe and Fittings
- ASTM F758 – Standard Specification for Smooth-Wall Poly(Vinyl Chloride) (PVC) Plastic Underdrain Systems for Highway, Airport, and Similar Drainage
- AS/NZS 4455.3 – Masonry units, pavers, flags and segmental retaining walls unit – segmental retaining wall units
- AS/NZS 4456 – Masonry units and segmental pavers – Methods of test
- GRI-GG4 – Determination of Long-Term Design Strengths of Geogrids; Geosynthetic Research Institute
- GRI-GG5 – Determination of Geogrid (Soil) Pullout
- NCMA SRWU-1 – Test Method for Determining Connection Strength of SRW; National Concrete Masonry Association
- NZS 4402.4.1.3:1986 – Methods of testing soils for civil engineering purposes – Soil compaction tests – Determination of the dry density/water content relationship – Test 4.1.3 New Zealand vibrating hammer compaction test

Delivery, Storage and Handling

- Contractors should examine materials upon delivery to ensure the right materials, grades, finish, and colours have been delivered.

- Contractors should put materials in storage and protect them from being affected by temperature, humidity, chemicals, deterioration, and breaking.

- Contractors should look after the materials and preserve them from damage. Damaged or affected material should not be integrated into Rocklok® SRWs.

Contractor Certification

- Contractors should be instructed and certified by Bowers Brothers Concrete. Contractors should make available a list of projects they have successfully finished.

Materials

Modular Concrete Block Units

The block units should be Rocklok® retaining wall system units produced by Bowers Brothers Concrete or another licensed manufacturer. The Rocklok® system is formed by three types of blocks: Rocklok® Flat, Rocklok® Ladder, and Rocklok® Trench. All Rocklok® blocks comply with ASTM C1372 and AS/NZS 4455.3.

- Dimensions: Common to all Rocklok® types and units:
  - Length: 450 mm
  - Height: 200 mm
  - Depth: 300 mm
- Exterior face finish: Straight split face
- Bond alignment: Bonds positioned to be offset from seams of the blocks below, midpoint, forming a perfect vertical running bond face pattern in both curved and straight walls
- Minimum 28 days compressive strength: 20.7 MPa
- Pins: Two 16 mm diameter and 135mm (+ or - 5mm) long fibreglass pins per block unit
- Setback: System designed to provide a minimum wall setback of 1 in 60 per course
- External surfaces: Uniform and consistent, free of cracks, chips and imperfections viewed from a distance of not less than 6.1 m in diffused light as applied in other concrete products stated at ASTM C90
- Block units shall provide a minimum total weight of 623 kg per square metre of wall face area.
- Tolerances: Maximum standard deviation of no more than ±2 mm and a difference between the mean and the work size of no more than ±3 mm, not including the rough split face in plan as established in AS/NZS 4455.3.

Drainage Fill

Drainage fill should be a non-cohesive, compactible, draining clean gravel between 6mm and 25 mm with less than 5% passing the #200 sieve. Drainage material is to be placed inside blocks facing and immediately behind block units.

Drainage Fill	
Sieve Size	Percent Passing
25 mm	100
19 mm	75–100
4.75 mm	0–10
0.075 mm (75µm)	0–5

Table A.: Drainage Fill

Reinforced Soils

Well-graded non-cohesive granular materials such as GAP 20, GAP 40, or GAP 65 are always preferred.

Sieve Size	Percent Passing		
	GAP 65	GAP 40	GAP 20
65 mm	100	–	–
37.5 mm	80–90	100	–
19 mm	50–70	63–81	100
9.5 mm	30–55	40–60	52–76
4.75 mm	20–40	25–45	33–57
2.36 mm	15–30	16–35	20–44
1.18 mm	10–22	9–27	12–35
0.6 mm (600 µm)	6–18	5–20	7–25
0.3 mm (300 µm)	4–14	1–15	4–20
0.15 mm (150 µm)	2–10	0–10	0–12
0.075 mm (75 µm)	0–10	0–7	0–8

Table B.: Reinforced Soils

The reinforced soil must be free of debris and it has to meet or exceed the design grading, friction angle and durability indicated on the project drawings. The soil should have a plasticity index (PI) of no more than 10 and a liquid limit (LL) of no more than 40.

Soils with relatively low plastic fines that do not meet the 300 µm to 75 µm size distribution (PI <20 and LL <40) might be used for low retaining walls only when an appropriate drainage system (drainpipe, drainage column, blanket and chimney) is installed and a geotechnical engineer has approved it. In tall retaining walls (more than 3 m), use the specified soil gradation and PI of no more than 6. Organic soils, top soils, and high-plasticity clays should not be used as infill soil in the construction of the wall.

Soil parameters have to be provided by a chartered geotechnical engineer. The geotechnical engineer should be engaged in the project to ensure compliance with local regulations, to certify proper retaining wall design and installation, and to certify the use of on-site soils.

Geosynthetic Reinforcement

- Geogrid reinforcement should be manufactured using HDPE or polyester fibres.

- Geogrid reinforcement should always be extended along its strength direction (machine direction).

- The minimum geogrid layer length should be at least 60–70% the total height of the retaining wall.

- The geogrids tested with the Rocklok® system are:
    - Strata geogrids: SG200, SG350, SG550, SG600 and SG1200
    - Tensar geogrids: RE520, RE560, and RE580

Drainage Pipe

- The drainpipe should be rigid or flexible, manufactured in corrugated HDPE or PVC, and slotted or punched.

- The drainpipe should have a minimum diameter of 100 mm and should comply with ASTM F405 and ASTM F758.

Filter Fabric

- The filter fabric should be a highly porous non-woven geotextile that allows water to flow through the geotextile but impedes soil migration.

Wall Construction

Excavation

- Engage with the project engineers and/or architect to review the retaining wall construction prior to the start of the job. Before excavation, call and check the locations of utilities (pipes and cables) or other infrastructure.

- Dig to the lines and grades shown on the construction drawings and check that the excavation limits are sufficient to allow for the reinforcement, drainage, and soil placement. The contractor should pay attention to not over-excavate or disrupt foundation soils or grades beyond the limits shown on the drawings/design.

Foundation Soil

- The foundation soil is the soil underneath the SRW system that supports the levelling pad and the reinforced soil. Before construction begins, a geotechnical engineer should verify that the foundation soils meet or exceed the required bearing capacity. If those soils do not meet the minimum bearing capacity, the soils should be substituted with a more suitable material.

- The foundation soil and base trench should be dug to the grade specified on the drawings, and compaction should be carried out to achieve a minimum relative density of 95% of standard Maximum Dry Density (MDD) of the fill material as determined by the New Zealand standard compaction test (NZS 4402.4.1.3:1986), or equivalent Clegg impact value, generally about 32 CIV.

- The trench dimension should include the wall embedment (buried block) and the levelling pad.

Levelling Pad

- Place, compact, and level GAP 20, or another well-graded aggregate to the grades and requirements shown on the construction drawings.

- The minimum levelling pad depth and width should be 150 mm deep and 600 mm wide for all retaining walls. A thin layer of sand (10–15 mm) on top of the levelling pad can be placed to facilitate and guarantee the right placement of the dry concrete units.

- Compaction should be carried out to achieve a minimum relative density of 95% of standard Maximum Dry Density (MDD) of the fill material, or equivalent Clegg impact value, generally about 32 CIV.

Rocklok® Block Units

- Place the first course on top of the levelling pad, and verify levels using a level tool and alignment using a string line set using the back of the block. Do not place chipped, stained, or damaged Rocklok® units.

- Confirm the concrete block units are accurately seated and in full contact with the levelling pad.

- The concrete block units should be side by side for the entire length of the wall. The gaps between contiguous block units should not be bigger than 5 mm.

- Insert two fibreglass pins per block in the right pin holes to ensure shear connection and alignment, and to provide the right setback as designated in the drawings.

- Follow the curves and corners suggested in the drawings and the manufacturer recommendations.

Gravel Drainage Placement

- Insert clean drainage gravel inside the Rocklok® units and place a minimum of 300 mm behind the blocks, forming a drainage column. Lay the clean drainage gravel in lifts 200 mm high.

- Place the drainage pipe behind the levelling pad at the bottom of the drainage column.

Backfill Placement

- Lay and spread backfill material in lifts 200 mm high behind the drainage gravel.
- Compact both the drainage gravel and the backfill to maximum lifts of one Rocklok® course (200 mm high). To get better compaction results, reduce the compaction lift depth.
- Compact infill material to a minimum relative density of 95% of standard Maximum Dry Density (MDD) as determined by the New Zealand heavy compaction test (NZS 4402.4.1.3:1986).
- Only small plate compactors should be used within 1.2 m from the face of the Rocklok® units.

Geosynthetic Reinforcement

- Install geosynthetic reinforcement with its strength direction perpendicular to the Rocklok® wall face. Begin at the lowest elevation.
- Place geogrid under tension at the specified elevations with the specified length. Keep tensions using staples or stakes.
- Install geogrid over the fibreglass pins up to the front face and extend it over the compacted clean gravel and backfill towards the embankment.
- Geogrid reinforcement should not overlap in its design strength orientation.
- To avoid geogrid damage, do not operate machinery directly on top of geogrid reinforcement.

Capping Unit Installation

- Bind the capping unit in place using a high-quality, flexible, all-weather masonry adhesive.
- The capping adhesive should meet the Rocklok® manufacturer requirements.

Appendix B Construction Details

1. Standard Gravity Wall
2. Geogrid Reinforced Wall
3. No-Fines Concrete Reinforced Wall
4. Inside & Outside Corners
5. Inside & Outside Curves
6. Fence on Top of Wall
7. Terraced Wall
8. Levelling Pad & Steps-Up/Down
9. Toe and Back Slopes
10. Soil Compaction
11. Water Management

Note: Details are available at the end of the manual

Appendix C Frequently Asked Questions

Trench and Levelling Pad

What is the least possible base trench depth?

The minimum trench depth should consider the depth of the levelling pad (150 mm) plus at least one buried Rocklok® block (200 mm). Trench depth = 150 + 200 = 350 mm (0.35 m).

What is the minimum recommended width of the base trench?

The minimum recommended width is 600 mm.

What is the minimum size for the levelling pad?

The minimum size is a 600 mm width and 150 mm depth levelling pad.

What materials are recommended for the levelling pad?

GAP 20 or GAP 40 are probably the best options. Otherwise, a non-cohesive compactible gravel with less than 10% passing the #200 sieve and a particle size of no more than 40 mm may be used.

Can I use concrete instead of aggregates as material for the levelling pad?

Yes, SRWs are normally designed with aggregate to allow for movements and settlement without compromising the wall, but unreinforced concrete can be used instead.

First Course (Embedment)

I have problems levelling the first course of Rocklok® block on top of the levelling pad after compacting it. What can I do?

Adding 12–15 mm of sand of top of the levelling pad may help to level and place the first course of Rocklok® blocks.

How many Rocklok® blocks should be buried as embedment?

The minimum embedment is 150 mm. However, it is easier when constructing to use a minimum of 200 mm, which is the height of the Rocklok® units. This minimum embedment applies to retaining walls with a total wall height of 1.8 m. For retaining walls over a 1.8 m, the following formula should be used:

$$Embedment\ (m) = Total\ wall\ height\ (m)/8$$

For example, the embedment depth of a 3 m high retaining wall would be: 3.0/8 = 0.375 m.

Note: Unless specified by a chartered professional engineer, the embedment depth is to a maximum of 0.6 m (three blocks). Poor soils, toe slopes, or seismically active areas may require extra embedment.

I am building on a slope. Can I use the standard embedment depth?

No. Normally walls built on slopes or with toe slopes require additional buried blocks. It is suggested that the minimum distance between the face of the first Rocklok® block and daylight should be at least a 1.5 m (minimum bench). For example, the necessary embedment of a Rocklok® retaining wall with a 3H:1V (Run:Rise) slope in front of the wall would require 0.5 m (2.5 blocks).

$$Total\ embedment\ depth\ (m) = \frac{Minimum\ bench\ (m)}{Run\ of\ slope\ (m)} + Levelling\ pad\ (m)$$

$$Total\ embedment\ depth\ (m) = \frac{1.5}{3} + 0.150 = 0.65\ \mathrm{m}$$

Note: When toe slopes are present, you should contact a chartered professional engineer to carry out a global stability analysis and to evaluate the site's overall stability.

Fibreglass Pins

Can I replace the Rocklok® fibreglass pins for other pins or equivalent products?

No. The pins and the Rocklok® blocks are part of a system and they must be used in combination. Pins are not interchangeable with similar products or components from other retaining systems. Cost, performance, and safety may be affected by the use of elements not certified by Bowers Brothers Concrete Limited.

What advantage do the Rocklok® pins have compared to the pins used in other systems?

The Rocklok® fibreglass pins have a bigger diameter than other common pins, which normally are 12 or 14 mm. The 16 mm diameter pins provide extra shear strength compared to smaller diameter pins.

Infill and Aggregates

What kind of soils should be used in the infill zone?

Well-graded non-cohesive granular materials are always preferred. GAP 20, GAP 40, and GAP 65 are the ideal aggregates because they provide the necessary shear strength and interlocking. They also contain fine particles that help compact the soil. Other granular material such as sand may also be appropriate. Cohesive soils such as clays would require extra care and compaction. They tend to change with moisture and retained water, so they should be avoided when possible.

What type of soil should be used inside the Rocklok® blocks and in the drainage column?

Non-cohesive well-graded clean gravels such as drainage metal 25/7, 20/6, or similar aggregates are the suggested materials to be placed inside the Rocklok® open cavities, in the gaps between units, behind the units, and in the drainage column. These coarse gravels will:

- provide extra draining capacity
- release hydrostatic pressure
- increase the weight of the Rocklok® units
- provide direct interlocking between the Rocklok® units and the reinforcement geogrid.

Some contractors might prefer to use scoria. Scoria is a suitable material that provides the drainage capacity. However, it is a very light aggregate and it does not help to increase the structural stability of the Rocklok® units by increasing the system weight the way drainage metal does.

Note: It is recommended to avoid the use of rounded rocks like pebbles.

What is the size of the drainage column?

The drainage column should be 300 mm behind the Rocklok® units. Taller walls or water applications might require a wider drainage column.

How many courses can I lay before placing the drainage metal and the backfill material?

Just one course should be installed before filling the blocks with the drainage material and placing the infill soil.

How high can the Rocklok® units be stacked before filling the blocks with NFC?

If NFC was selected as reinforcement and placed in the cores behind the block units, it is suggested to stack a maximum height of two Rocklok® units (400 mm) before pouring the NFC.

Compaction

What are the recommended lifts for soil compaction?

The infill soil should be placed and compacted in lifts 200 mm high.

Can over-compaction occur on the soils behind the wall?

Yes. Too much compaction can rotate the wall, damage the reinforcement geogrid, and displace the block units.

What is the minimum compaction requirement?

The minimum compaction requirement is a minimum relative density of 95% of standard Maximum Dry Density (MDD) of the fill material as determined by the New Zealand standard compaction test (NZS 4402.4.1.3:1986), or equivalent Clegg impact value, generally about 32 CIV.

Geogrid

When do I start placing the geogrid reinforcement?

The geogrid reinforcement placement should begin on top of the first course (buried block) and continue every 400 mm high (two blocks) until the top of the wall.

What is the recommended length of the geogrid?

The geogrid should be a minimum of 60–70% of the total height of the wall. To improve wall performance, it is suggested to extend the top layer of geogrid to 90% the total height of the wall.

Curves

What is the smallest external construction radius in the top course of a Rocklok® retaining wall?

The smallest external radius is 1.0 m.

What is the smallest internal construction radius in the top course of a Rocklok® retaining wall?

The smallest internal radius is 1.4 m.

How can I calculate the number of Rocklok® units needed for a full circle?

The number of Rocklok® blocks needed is equal to the diameter of the circle times *pi* (π) divided by the length of the Rocklok® unit.

$$Number\ of\ Rocklok\ blocks = \frac{Diameter\ (m) \times \pi}{Rocklok\ block\ length\ (m)}$$

For example, for a 3.6 m diameter circle, 26 Rocklok® units are required.

$$Number\ of\ Rocklok\ blocks = \frac{3.6 \times 3.1416}{0.45} = 25.13\ (26\ \text{units})$$

Note: If the number of blocks is not a whole number, please round the number up.

Corners

How much should be trimmed away in the first Rocklok® course when building a 90° inside corner?

Ideally, half of the Rocklok® block should be trimmed away to create the inside corner.

Note: It is recommended to start the retaining wall construction from the corners.

Terraced Walls

What is the suggested distance between terraced gravity walls to act as independent structures?

As a rule of thumb, for the gravity walls to act as independent structures the recommended distance (wall face to wall face) has to be at least a distance twice the height of the lower retaining wall.

$$Distance\ (D)\ > 2 \times H\ (lower\ wall)$$

Note: This rule assumes the walls do not have back or toe slopes and that they are built in good ground as defined in NZS 3604:2011. Terraced walls closer than twice the height of the first wall should be evaluated by a chartered professional engineer.

Does the previously explained rule of thumb apply to three walls or more?

Yes, it applies to all subsequent terraces.

Note: All terraced walls have to take into account a global stability analysis of the overall structure. Please contact a chartered professional engineer for advice and assistance.

I am planning to build a terraced wall; however, I do not have enough space to keep the walls as independent structures. Can I still construct the walls?

Yes, the retaining wall can be built. However, the upper retaining wall will apply a load to the lower retaining wall, so it will have to be evaluated and designed by a chartered professional engineer.

Steps and Stairs

I would like to build some stairs in the retaining wall using the Rocklok® blocks. How many steps do I need for a 2.4 m hill?

The number of steps should be equal to the total hill height divided by the Rocklok® block height.

$$Number\ of\ steps = \frac{Hill\ height\ (m)}{0.2}$$

For example, Number of step = 2.4/0.2 = 12 steps (treads)

Note: If the number of steps is not a whole number, please round the number up.

What is the run length of a 12-tread stair?

The run length is equal to the Rocklok® block width times the number of treads.

$$Run\ length\ (m) = Rocklok\ width\ (m) \times Number\ of\ treads$$

For example, run length = 0.3 × 12 = 3.6 m.

Capping

Do I have to secure the optional capping block?

Yes. The capping block has to be bound in place using a high-quality, flexible, all-weather masonry adhesive.

Note: Expansive foams are not recommended to adhere and bind the capping block.

Do you manufacture a capping corner block?

No, but you can cut two standard capping blocks with a 45° angle to make a capping corner.

Building Consent and Surcharges

I would like to build a retaining wall that is 1.4 m high, but it will have a slight slope on top. Do I need a building consent?

Generally, the slopes above the wall add weight and pressure to the retaining structure, but not all back slopes have the same influence on the retaining wall. Some moderate slopes may not be considered as surcharge. In that case, the retaining wall might be exempt from needing a building consent.

Please contact a chartered professional engineer to get qualified advice and evaluate your case. It might save you money.

Are all barriers considered surcharges?

No. Some light barriers may not be considered surcharges. Please contact a chartered professional engineer to evaluate your barrier and determine if it is a surcharge or not.

Other Questions

What is the maximum allowed variation from unit to unit?

The height between two contiguous units should not be more than 3 mm.

I started building the wall and I realised that some Rocklok® blocks were not level. What can I do to correct it?

If the back of the Rocklok® block is lower than the front of the block, the Rocklok® wall will lean back towards the slope, which increases stability. If the front of the Rocklok® block is lower than the back of the block, the inclination will push the block forward and away from the embankment, which is a problem that has to be solved immediately.

This a bigger issue in taller walls than in smaller walls because the variation will accumulate from course to course. To maintain the right level and alignment, asphalt shingles or geogrid may be used to shim the block courses.

Appendix D Glossary of Terms

The following glossary of terms includes common words and expressions used in SRW design and construction.

Adhesive	High quality, flexible, all-weather masonry adhesive used to secure the capping blocks in place.
Angle of friction	A measure of the ability of a unit of soil to withstand a shear stress (ϕ). It is the single most important value for determining the lateral pressure and bearing capacity of a specific soil.
Atterberg limits	A measure to establish the moisture content at which soil changes from a liquid to a plastic state.
Barrier	Anything that prevents or obstructs passage or access. Fences and railings are types of barriers.
Batter	The facing angle created by the Rocklok® unit setback, measured from a vertical line drawn from the toe of the wall. The Rocklok® system batter angle is 0.9° from vertical, sloping towards the infill soil.
Batter wall	A wall that slopes backward.
Bearing capacity	The capacity of a soil to support the loads applied to the ground.
Building consent	A consent to carry out building work granted by a territorial authority.
Bulging	Outward curve or localised rotation on the face of the retaining wall. It is usually caused by horizontal forces between layers of geogrid.
Capping block	Optional block used to cap or finish the top of a retaining wall.
Clay	Very fine-grained soil in which particles range in size from 0.002 to 0.005 mm. Clay is plastic when wet and hardens when heated. Clay consists primarily of hydrated silicates of aluminium and is widely used for a variety of building materials such as bricks, tiles, and pipes.
Clegg impact value (CIV)	Soil impact tester used to control soil strength and confirm compaction.
Cohesion	The force of attraction that holds molecules of a given substance together.
Cohesive soil	Soil that tends to hold together in a comparatively stable clump or mass. Cohesive soils include clayey silt, sandy clay, silt clay, clay, and organic clay.
Compaction	The densification of soil by removal of air. The degree of compaction of a soil is measured in terms of its dry unit weight.

Compaction test	A test for determining the degree of compaction of filled soil.
Compaction zone	The zone that starts at the end of the consolidation zone and finishes at the cut or hill that needs to be retained.
Compressive strength	The measured maximum resistance of a concrete specimen to compressive loading expressed in megapascals (MPa).
Concrete	A composite material that consists mainly of aggregate, water, and Portland cement, normally weighing between 2300 and 2400 kg/m^3.
Consolidation zone	The zone that extends from the back of the Rocklok® unit to 0.9 m into the backfill area.
Cut	The elimination or removal of part of a bank, hill, or slope.
Drainage column	A minimum thickness of 300 mm of drainage metal (less than 5% fines) placed immediately behind the Rocklok® system units.
Drainage metal	Clean gravel placed within and immediately behind the Rocklok® facing units and in other areas for drainage purposes.
Drainpipe	HDPE or PVC pipe installed in the back of the retaining wall under the drainage column to allow the removal of filtrated water and to reduce hydrostatic pressure. The pipe is normally punched with a minimum diameter of 100 mm.
Dry density	The dry mass of soil per unit of volume. It is expressed in kilonewtons per cubic metre (kN/m^3).
Embedment depth	The block depth or buried block(s) required to provide additional stability to the retaining wall.
Erosion	The wearing away of rocks and other deposits on the earth's surface by the action of water, ice or wind.
Excavation	The process of removing earth or soil by digging.
Expansive soil	Soils that experience an appreciable volume change when the moisture content is altered.
Fibreglass	A plastic material reinforced with glass fibre. It usually refers to the material used to manufacture the fibreglass pins.
Filter fabric	A layer of filter cloth used to separate the drainage material from the soil behind or on top of the retaining wall.
Footing	A foundation unit constructed in masonry or concrete under the base of a wall for the purpose of distributing the load over a large area.
Foundation soil	The soil underneath the SRW system that supports the levelling pad and the reinforced soil.
General All Passing (GAP)	An aggregate size distribution with both fine and coarse materials limited to a narrow range. Common GAP distributions are GAP 20, GAP 40, and GAP 65.
Geogrid reinforcement	Geosynthetic material used to reinforce the soil mass behind the retaining wall. It is usually composed of polypropylene, polyester, and polyethylene.

Global stability	The general mass movement of an SRW and the adjacent stability of the soils above and below the retaining wall. It may be a problem of terraced walls, walls with slopes at the top or bottom, and retaining walls with weak foundations.
Grade	The surface of the ground at a specific location.
Gravel	A loose aggregation of rock fragments ranging from 4.75 mm to 75 mm.
Gravity wall	A type of retaining wall that relies purely on its own weight to retain soil and prevent failure.
Grid rupture	A rupture that happens when excessive forces exceed the ultimate tensile strength of the geogrid.
HDPE	High-density polyethylene. It normally denotes the material used to manufacture the drainpipe, geogrids, or the Rocklok® clip connectors.
Hydrostatic pressure	The pressure exerted by a fluid at equilibrium at a given point within the fluid, due to the force of gravity.
Infill	Soil replaced or put back behind a retaining wall after having been excavated. It may be reinforced with soil reinforcement.
Levelling pad	Densely compacted gravel or unreinforced, low-strength concrete used to distribute the weight of the dry-stacked column of Rocklok® units over a wider foundation area and to provide working surface during construction. The levelling pad is generally built with GAP 20 or GAP 40.
Liquefaction	Phenomenon in which the strength of a soil is reduced by an earthquake shaking or other rapid loading. Liquefaction occurs in saturated soils and it can cause serious settlement or failure of foundations.
Liquid limit (LL)	The moisture content at which soil starts to behave as a fluid material.
Long-term design strength (LTDS)	The strength in the geogrid reinforcement at the completion of the service life of a reinforced soil.
Maximum Dry Density (MDD)	The dry density achieved by the compaction of soil at its optimum water content. For SRWs, maximum dry density is generally 95%.
Mechanically stabilised earth (MSE)	See *Reinforced Soil.*
No-fines concrete (NFC)	A special type of concrete containing little or no fine aggregate. It is commonly used as reinforcement in SRWs.
Non-cohesive soil	Soil in which particles tend to lie side by side without bonding. Non-cohesive soils include gravel and sand.
Overturning	This external stability failure is a result of excessive lateral earth pressure with relation to the retaining wall resistance thereby causing the retaining wall system to topple or rotate (overturn).
Plasticity index	The numerical difference in water content between the liquid limit and the plastic limit of a soil.
Permeable	The ability of a material to allow liquids or gases to pass through.

PVC	Polyvinyl chloride. It normally refers to the material used to manufacture the drainpipe.
Reinforced soil	(Also known as mechanically stabilised earth.) A technique where tensile elements are placed in the soil to improve stability and control deformation.
Retained soil	Soil that is being held or retained by an SRW.
Retaining wall	Any wall supporting the ground where there is a slope or change of grade. A retaining wall has to withstand the load of the soil, water content, back slopes, and any surcharge.
Rocklok® SRW	Patented segmental retaining wall system.
Sand	Granular material composed of finely divided rock and mineral particles ranging in size from 0.075 mm to 4.75 mm.
Segmental retaining walls (SRWs)	Systems that consist of modular concrete blocks that interlock with each other. They are typically battered.
Settlement	The downward movement of a foundation due to consolidation of the underlying soil mass.
Silt	Granular material with a particle size between sand and clay, ranging from 0.005 mm to 0.075 mm.
Sliding	This external stability failure is a result of excessive lateral earth pressure with relation to the retaining wall resistance thereby causing the retaining wall system to move away (slide) from the soil it retains.
Soil	The top layer of the earth's surface, consisting of rock and mineral particles mixed. There are three basic types of soil: rock/sand, silt, and clay.
Soil lift	The maximum recommended lift to fill and compact a soil. It is generally 200 mm.
Surcharge load	External load, typically applied at the top of the retaining wall. Vehicles, fences, back slopes, building foundations, or other walls are common surcharge loads.
Swale	A shallow trough-like depression formed on top and behind the retaining wall that collects and carries water away.
Terraced walls	(Also known as tiered walls.) A series of two or more stacked walls.
Top soil	Generally 200 or 300 mm of low permeable soil used to finish the top of the wall.
Total wall height	(Also known as design height.) The height of the wall measured from the top of the levelling pad to the top of the wall, including the optional capping block.

Table C.: Glossary of Terms

Appendix E Building Act Requirements

Bowers Brothers Concrete are committed to ensuring that all the retaining walls built with our products are healthy, safe, and durable for everyone who may construct or be affected by them.

All projects that require a building consent must comply with the New Zealand Building Act 2004, the New Zealand Building Code, and any relevant local council regulations, legislation, and requirements.

The need of a building consent and the necessity of a barrier on top of the retaining wall represent two areas of uncertainty that generate doubts for many people when referring to the construction of SRWs.

When Is Building Consent Needed?

According to the Building Amendment Act 2013 – Schedule 1, the following work does not require a building consent:

- *Exemption 20:* "building consent is not required for the construction or alteration of any retaining wall that retains not more than 1.5 metres depth of ground and does not support any surcharge or any load additional to the load of that ground (for example, the load of vehicles on a road)".

Retaining wall – urban	Is a building consent required?
Retaining wall < 1.5 m / no surcharge	No
Retaining wall < 1.5 m / with surcharge	Yes
Retaining wall > 1.5 m / with or without surcharge	Yes

Table D.: Exemption 20

- *Exemption 41:* Building work for which design is carried out or reviewed by chartered professional engineer

1. Building work in connection with a retaining wall in a rural zone, if:—

    a. The wall retains not more than 3 metres depth of ground
    b. The distance between the wall and any legal boundary or existing building is at least the height of the wall

2. In sub clause (1), **rural zone** means any zone or area (other than a rural residential area) that, in the district plan of the territorial authority in whose district the building work is to be undertaken, is described as a rural zone, rural resource area, or rural environment, or by words of similar meaning.

When Is a Barrier Needed?

As required and highlighted in the Building Code clause F4.3.1 – Safety from falling: “A barrier to be constructed to safeguard people from falling, where the height of the retaining wall exceeds 1 metre and the area is associated with the use of a building.”

Examples of areas associated with the use of a building are in respect to retaining walls:—

1. On the edge of driveways
2. Near pedestrian access routes to and from buildings
3. Amenity areas used in conjunction with the use of a dwelling

This does not preclude the design of landscaping and gardens to separate amenity areas or an access route from the edge of a retaining wall without a barrier.

15. References

Articles, Books, Codes, and Standards

Auckland Council, AC2231 (v.2) “Construction of Retaining Walls”, 2014

Allan Block Corporation, “AB Engineering Manual Allan Block Retaining Walls”, 2014

Allan Block Corporation, “Commercial Installation Manual for Allan Block Retaining Walls”, 2014

AS/NZS 1554.3:2014 – “Structural steel welding – Part 3: Welding of reinforcing steel”

AS/NZS 3678:2016 – “Structural steel – Hot-rolled plates, floorplates and slabs”

AS/NZS 4671:2001 – “Steel reinforcing materials”

AS/NZS 4680:2006 – “Hot-dip galvanized (zinc) coatings on fabricated ferrous articles”

Braja M. Das, “Principles of Geotechnical Engineering”, Seventh Edition, 2010

BRANZ, *Build* 152, “Low Retaining Walls”, February/March 2016

Building Act 2004, “Building work that does not require a building consent”, Third Edition, 2014

Building Regulations 1992, “Schedule 1: New Zealand Building Code”

Hugh Brooks and John P. Nielsen, “Basics of Retaining Wall Design: A design guide for earth retaining structures”, Tenth Edition, 2013

J. Michael Duncan, Stephen G. Wright, Thomas L. Brandon, "Soil Strength and Slope Stability", Second Edition, 2014

Keystone Retaining Wall Systems, "Keystone Design Manual & Keywall Operating Guide", 2001

National Concrete Masonry Association, "Design Manual for Segmental Retaining Walls", Third Edition, 2009

National Concrete Masonry Association, "Design Manual for Segmental Retaining Walls", Third Edition, 2009

National Concrete Masonry Association, "Segmental Retaining Walls Best Practices Guide for the Specification, Design, Construction and Inspection of SRW Systems", 2016

National Concrete Masonry Association, "SRW History Article Series", 2016

New Zealand Building Code, "Clause F4: Safety from Falling", Third Edition, 2006

New Zealand Concrete Masonry Association Inc., "New Zealand Concrete Masonry Manual – Chapter 6: Masonry Retaining Walls", 2012

New Zealand Standard 4402.4.1.3, "Methods of testing soils for civil engineering purposes – Soil compaction tests – Determination of the dry density/water content relationship – Test 4.1.3 New Zealand vibrating hammer compaction test", 1986

New Zealand Transport Agency, "Bridge Manual", Third Edition, 2013

NZS 3604:2011 – "Timber-framed buildings"

NZS 4210:2001 – "Masonry construction: materials and workmanship"

NZS 4229:2013 – "Concrete masonry buildings not requiring specific engineering design"

NZS 4230:2004 - Design of reinforced concrete masonry structures"

Strata Systems Inc., "StrataGrid Product Line Overview and Summary", 2015
R. C. Hibbeler, "Mechanics of Materials", Ninth Edition, 2014

Tensar, "Tensar Re500 series geogrids – Product specifications design temperature 20°C", 2018

Websites

GNS Science, www.gns.cri.nz

National Institute of Water and Atmospheric Research (NIWA), www.niwa.co.nz

Auckland Council, www.aucklandcouncil.govt.nz/building-and-consents/building-renovation-projects/build-retaining-wall/Pages/check-need-consent-build-retaining-wall.aspx