# KEYSTONE

*high performance segmental retaining walls*

australmasonry®

# KEYSTONE

## *Engineered perfection*

The Keystone retaining wall system is robust and strong, and available in standard and flushface finishes. This product is ideal for both straight and curved walls and features a patented interlocking pin connecting system that is best suited for engineered walls up to 15m in height.

**Applications**

**Maximum wall height: 1,200 mm* (15 m when engineered)**

**Straight walls**

**Curved walls**

**Corners**

**Steps**

**Please check with your local council in regards to engineering requirements.*

*Above:* Keystone Standard *Charcoal*

Natural

Almond

Silver

Charcoal

**Standard Unit**
Size: 455 L x 315 W x 200 H mm
Weight (each): 39 kg
Face area: 11 units per m²

**Flushface Unit**
Size: 455 L x 315 W x 200 H mm
Weight (each): 42 kg
Face area: 11 units per m²

**Capping Unit**
Size: 455 L x 310 W x 100 H mm
Weight (each): 30 kg
2.2 per lineal metre

**Flushface Straight Side Cap**
Size: 455 L x 310 W x 100 H mm
Weight (each): 31 kg
2.2 per lineal metre

**Corner Unit 90°**
Size: 440 L x 210 W x 200 H mm
Weight (each): 29 kg

# KEYSTONE

## *overview*

The Keystone retaining wall system is robust and strong, available in standard and flushface finishes ideal for both straight and curved walls. The patented interlocking pin connecting system is best suited for engineered walls up to 15m in height.

***Note: Information contained in this installation guide is offered as general advice only.*** *Please consult with regulating council for local design requirements prior to the commencement of any retaining wall and consult with a professional engineer prior to commencing any retaining wall project. Councils may request walls over 0.5m in height and / or where a surcharge exists (e.g. driveway, house, fence or other structure) be designed and certified by a suitably qualified engineer.*

### Benefits of Keystone

- Durable
- Allows for design creativity and flexibility
- Ease and speed of construction
- Cost effective
- Versatile
- Clean neat finish
- Strong strength to weight ratio
- Construction methodology
- Blends into environmental landscape
- RMS approved walling system
- No fines concrete walls
- Sub division walls

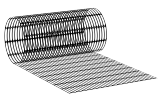
### Keystone Applications

- Low height gravity walls
- Geogrid soil reinforced up to 15m height
- Stream and drainage channels
- Wing walls
- Embankment stabilisation
- Terraced walls
- Geogrid – reinforced soil retaining structures

### Keystone Construction/Design

- Vertically with curves as tight as 1m radius (standard unit only)
- Set-back
- Straight or curved walls
- 90 degree corners
- Stairs

## Keystone System Components

| Product | Range | Description | Max Wall Height | Size | Weight | Coverage | Applications |
|---|---|---|---|---|---|---|---|
| | Keystone | Standard Unit | 15m* | 455L x 315W x 200H | 39kg | 11 Blocks per m² | Curved Walls, Straight Walls, Corners, Steps |
| | Keystone | Flushface Unit | - | 455L x 315W x 200H | 42kg | 11 Blocks per m² | Corners |
| | Keystone | Capping Unit | - | 455L x 310W x 100H | 30kg | 2.2 per lineal metre | Curved Walls, Straight Walls, Corners |
| | Keystone | Flushface Straight Side Cap | - | 455L x 310W x 100H | 31kg | 2.2 per lineal metre | Curved Walls, Straight Walls, Corners |
| | Keystone | Corner Unit 90° | - | 440L x 210W x 200H | 29kg | N/A | Curved Walls, Straight Walls, Corners |
| | Keystone | Standard Pins | - | - | - | 2 per unit | Curved Walls, Straight Walls, Corners |
|  | | Geogrid | - | Various lengths available | - | | Curved Walls, Straight Walls, Corners |

**Walls can be built to heights of 15 metres or more with appropriate engineering.*

# KEYSTEEL

## *overview*

The Keysteel retaining wall system uses a custom designed and patented interlocking top and bottom section together with steel pins to create a segmental retaining wall that has maximum resistance to lateral forces. RMS certified, the Keysteel system offers superior strength with hot tipped galvanised steel ladder soil reinforcement.

***Note: Information contained in this installation guide is offered as general advice only.*** *Please consult with regulating council for local design requirements prior to the commencement of any retaining wall and consult with a professional engineer prior to commencing any retaining wall project. Councils may request walls over 0.5m in height and / or where a surcharge exists (e.g. driveway, house, fence or other structure) be designed and certified by a suitably qualified engineer.*

### Benefits of Keysteel

- Superior strength
- Durable
- Erosion prevention
- RMS approved walling system
- Hot-dipped galvanised steel ladder soil reinforcement

### Keysteel Applications

- Wall heights up to 25m height
- Critical surcharge loads are present
- Steel – ladder reinforced-soil retaining structures
- Bridge abutments
- Stream or drainage channels
- Tunnel access walls
- Wing walls
- Embankment stabilisation
- Terraced walls
- Seawall applications (made to order)
- Soil-anchor and rock-anchor walls

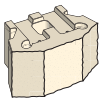
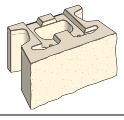
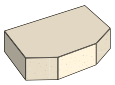
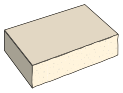
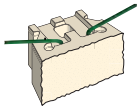
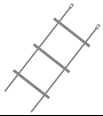
### Keysteel Construction/Design

- Vertically with curves as tight as 1m radius (standard unit only)
- Set-back
- Straight or curved walls
- 90 degree corners
- Stairs

### Keysteel Specification Table

| | |
|---|---|
| **Pins** | 2 steel pins per full unit (high strength hot dip galvanised steel) |
| **Lifting Bars** | Keystone units should be lifted by two people using the Keystone lifting bars |
| **Geogrid** | As per design requirements |

## Keysteel System Components

| Product | Range | Description | Max Wall Height | Size | Weight | Coverage | Applications |
|---|---|---|---|---|---|---|---|
|  | Keysteel | Standard Unit | 15m* | 455L x 305W x 200H | 39kg | 11 Blocks per m² | Curved Walls, Straight Walls, Corners |
|  | Keysteel | Flushface Unit | - | 455L x 305W x 200H | 42kg | 11 Blocks per m² | Curved Walls, Straight Walls, Corners |
|  | Keysteel | Capping Unit | - | 455L x 310W x 100H | 30kg | 2.2 per lineal metre | Curved Walls, Straight Walls, Corners |
|  | Keysteel | Flushface Straight Side Cap | - | 455L x 310W x 100H | 21kg | 2.2 per lineal metre | Curved Walls, Straight Walls, Corners |
| | Keysteel | Steel Pins (hot dip galvanised) | - | - | - | 2 per full Keystone unit. 2 units per ladder supplied | Curved Walls, Straight Walls |
|  | Keysteel | Lifting Bars | - | - | - | Keysteel units should be lifted by 2 people using Keysteel lifting bars | Curved Walls, Straight Walls |
|  | Keysteel | Steel Ladders (hot dip galvanised) | - | Various lengths available | - | As per design specifications | Curved Walls, Straight Walls |

**Walls can be built to heights of 15 metres or more with appropriate engineering.*

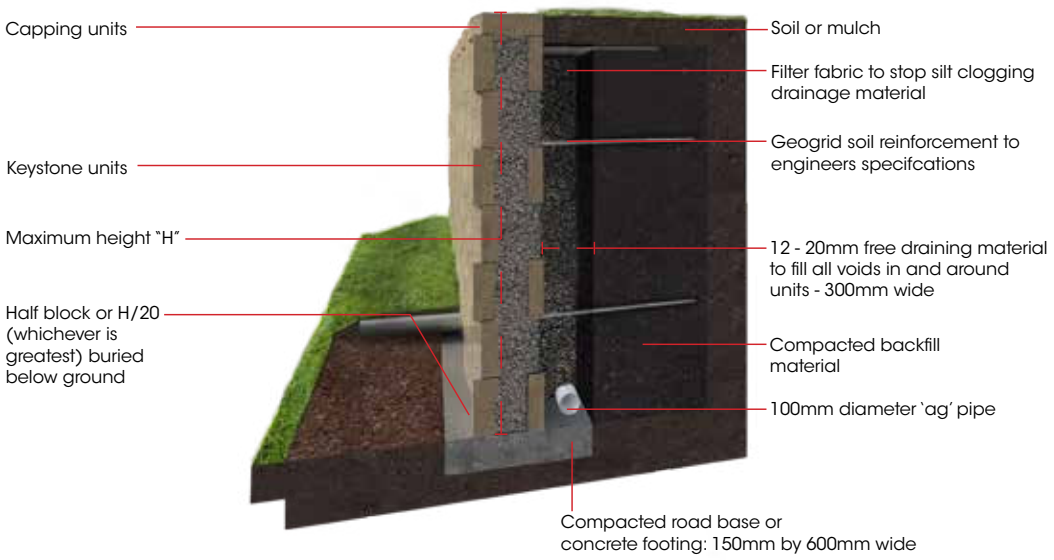
# SOIL REINFORCED WALLS WITH GEOGRID

## Overview

With use of information in these tables Keystone walls can easily be built up to 15 metres with appropriate engineering. When placed between layers of compacted soil, geogrids create a reinforced soil mass, which essentially acts as a larger gravity wall structure.

Geogrids can be used with most existing site-soils and are not affected by water, micro organisms, alkali or acidic soils. Consult with your engineer for design requirements of Keystone walls using geogrid soil reinforcement.

## Cross Section Diagram - Keystone Soil Reinforced Walls with Geogrid




## Geogrid Requirements

The length, location and grade strength of geogrid is dependent on the wall height, loading on top of the structure, and soil properties. The following table is in accordance with AS4678: 2002 - Earth Retaining Structures.

***Note:*** Please consult with appropriate council for design and construction regulations. Councils in general require walls to be designed and certified by a suitably qualified engineer where the wall is over 500mm in height or will have a surcharge load such as a road, building or hydrostatic pressure is present. The suitability of the information contained in the table must be referred to a qualified consulting engineer. These tables are provided as a guide only.

# SOIL REINFORCED WALLS WITH GEOGRID

**Table 1. Geogrid Table - Guide Only**

| | | | *Geogrid Placement above Levelling Pad (m)* | | | | | | *Geogrid Length L (m)* *Max. rear length at top most layer* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Surcharge* | *Wall Height (m)* | *Geogrid Layers* | *Number of Geogrid layers* | | | | | | *Friction Angle Ø (°)* | | |
| | | | **1** | **2** | **3** | **4** | **5** | **6** | **25** | **30** | **35** |
| *Backfill slope up to 1 in 4 slope* | 1.1 | 2 | 0.2 | 0.8 | | | | | 1.55 | 1.5 | 1.55 |
| | 1.5 | 3 | 0.2 | 0.8 | 1.2 | | | | 1.8 | 1.6 | 1.55 |
| | 1.9 | 3 | 0.4 | 1.0 | 1.6 | | | | 2.35 | 1.9 | 1.7 |
| | 2.3 | 4 | 0.2 | 0.8 | 1.4 | 2.0 | | | 3.15 | 2.4 | 1.95 |
| | 2.7 | 5 | 0.2 | 0.8 | 1.2 | 1.8 | 2.4 | | 3.95 | 2.55 | 2.25 |
| | 3.1 | 6 | 0.2 | 0.6 | 1.0 | 1.6 | 2.2 | 2.8 | 4.90 | 2.9 | 2.25 |
| *5kPa Driveway (level backfill)* | 1.1 | 2 | 0.4 | 0.8 | | | | | 1.8 | 1.5 | 1.5 |
| | 1.5 | 3 | 0.4 | 1.0 | 1.2 | | | | 1.9 | 1.55 | 1.5 |
| | 1.9 | 3 | 0.6 | 1.2 | 1.6 | | | | 2.4 | 1.9 | 1.6 |
| | 2.3 | 4 | 0.4 | 1.0 | 1.6 | 2.0 | | | 2.7 | 2.15 | 1.85 |
| | 2.7 | 5 | 0.4 | 1.0 | 1.4 | 2.0 | 2.4 | | 3.0 | 2.45 | 2.1 |
| | 3.1 | 6 | 0.2 | 0.8 | 1.2 | 1.8 | 2.4 | 2.8 | 3.85 | 2.7 | 2.3 |

**** Geogrid with Tul = 55kN/m * Geogrid lengths for 5kPa driveway are based on the load being applied a minimum of 800mm from the face of the wall.***

## Notes

Table 1 is prepared as per AS4678 : 2002. Suitability of the information contained in the table must be referred to a qualified professional engineer. These tables are supplied as a guide, and do not form any part of any contact with the user.

Table 1 is based on foundation material with minimum 150kPa bearing capacity.

Where site conditions and loadings vary from those in the table, professional engineering advice should be obtained.

The minimum embedment of wall below ground level is assumed to be H/20 or 100mm, whichever is greater.

The length of the 1:4 backfill slope is assumed to be equal to the height of wall, H.

## Soil Types

- Poor (Ø = 25°): Soils with friction angle ≥ 25°, may include sandy clays, gravelly clays and sand. Expansive clays and organic soil MUST not be used within the soil reinforced zone.
- Average (Ø = 30°): Soils with friction angle ≥ 30°, may include gravelly sands and well graded sands.
- Good (Ø = 35°): Soils with friction angle ≥35°, may include gravels, sandy gravels, weathered sandstone and crushed sandstone.

# NO FINES CONCRETE

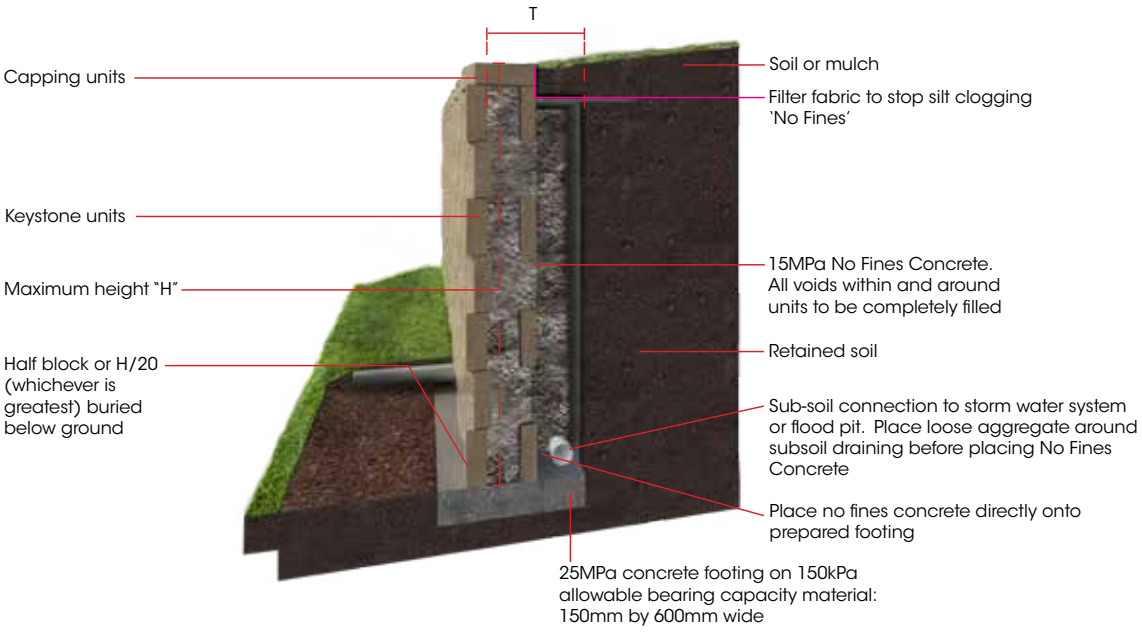
## Overview

The No-Fines Concrete backfill system increases the mass of Keystone retaining walls allowing the maximum heights in Table 3 (next page) to be exceeded without using geogrids. This is ideal for boundary walls where the geogrids would otherwise cross into the neighbouring property.

## No Fines Concrete Specification

- 15MPa No-Fines Concrete with a 7:1 ratio (Gravel : Cement).
- The density of this product will vary with the density of the aggregate used. The density range may be from 1800kg/m3 to 2100kg/m3. (Table based on density of 2100kg/m3.)
- The void ratio of the mix is expected to be between 20% and 30% and should be free draining.
- This product has no slump and exerts similar pressures on the soil and formwork, as does loosely poured aggregate.
- Global stability considerations should be checked by an engineer especially in poor clay conditions.
- Design assumes a dry excavation (i.e. water table is below bottom of footing level). If ground water appears in the excavation, the wall is to be re-designed by a suitably qualified engineer.
- No-Fines Concrete shall consist of cement, water and coarse aggregate. Cement will comply with the definitions for cement per AS3972 : 1991 - 'Portland and Blended Cements'. The quantity of cement is specified as 210kg/m3 with a total water/cement ratio of between 0.45 and 0.55.
- The particle size distribution of the aggregate shall comply with the limitations for the nominal single sized 20mm aggregate specified in AS2758.1.
- The maximum slope of the backfill behind the wall is to be 5% (1 vertical to 20 horizontal).

## Cross Section Diagram - Keystone with No Fines Concrete



# NO FINES CONCRETE

**Design Considerations**

• The 'No Fines' concrete maximum wall heights table is based on a 5 kPa surcharge load acting on top of the wall as per AS4678: 2002. This table is supplied as a guide only.

• For higher walls the use of geogrid soil reinforcement is recommended. Contact Austral Masonry for further details.

• This product has zero slump exerting similar pressures on the soil and formwork, as loosely poured aggregate.

• The vertical height of any pour of 'No Fines' concrete is to be limited to 3 blocks high (approx. 600mm). The concrete must be allowed to harden before pouring the next lift.

• Global stability should be checked by a suitably qualified engineer. The design assumes no ground water to be present. For site conditions where ground water exists, the wall must be re-designed by a suitably qualified engineer.

**Table 2 - Maximum Wall Height for No Fines Concrete Construction - 5kPa surcharge Level Backfill**

| *Wall Height H (mm)* | *Retained Soil CLAY = 26° (POOR) T (mm)* | *Retained Soil SAND=30° (AVERAGE) T (mm)* | *Retained Soil GRAVEL = 34° (GOOD) T (mm)* |
|---|---|---|---|
| 1000 | 500 | 500 | 450 |
| 1200 | 550 | 500 | 500 |
| 1600 | 800 | 750 | 750 |
| 2000 | N/A | 1000 | 990 |
| 2400 | N/A | 1150 | 1100 |
| 2800 | N/A | 1250 | 1200 |

Table 2 is prepared as per AS4678 : 2002, and is based on a 5kPa surcharge loading at the top of the wall. This table is supplied as a guide, and does not form any part of any contract with the user.

Max slope of backfill behind wall to be 3° (1:20)

**Table 3 - Maximum Wall Height for No Fines Concrete Construction with Sloping Backfill up to 1 in 4 backslope with no surcharge**

| *Wall Height H (mm)* | *Retained Soil CLAY = 26° (POOR) T (mm)* | *Retained Soil SAND=30° (AVERAGE) T (mm)* | *Retained Soil GRAVEL = 34° (GOOD) T (mm)* |
|---|---|---|---|
| 1000 | 450 | 400 | 400 |
| 1200 | 550 | 500 | 450 |
| 1600 | 750 | 700 | 700 |
| 2000 | N/A | 900 | 850 |
| 2400 | N/A | 1050 | 1000 |
| 2800 | N/A | 1200 | 1150 |

Table 3 is prepared as per AS4678 : 2002, and is based on structural classification '5' and a 5kPa surcharge loading at the top of the wall. This table is supplied as a guide, and does not form any part of any contract with the user.

Max slope of backfill behind wall to be 14° (1:4)

# NO FINES CONCRETE

**Construction Steps**

***Step 1: Excavation/Preparation of Levelling Pad***

Excavate a trench 600mm wide and sufficiently deep to allow a levelling base of 150mm +25mm height for each course. Place 25MPa concrete (non-reinforced) to form the footing.

***Step 2: Installing the first course***

Half block or H/20 (whichever is greatest) of the block should be buried below ground. Lay the first course of units side to side over the prepared base, with the 12mm pinholes on top. Maintain the 305mm distance between pinhole centres of adjacent units. In straight walls, units will touch. In concave or convex curves, the units will overlap or require spacing to maintain the 305mm pin distance.

***Step 3: Installing the pins***

Place two Keystone fibreglass connecting pins into each unit. Use the front holes for a vertical wall (corners and curved walls). Use the rear holes for a 1 in 8 setback (i.e. for every course the wall will set back 25mm). For straight walls only.

***Step 4: No Fines Concrete Backfill***

Backfill the wall with No-Fines Concrete. All voids inside and between the units must also be filled. The vertical height of any pour of No-Fines Concrete is limited to 600mm. Each pour must be allowed to harden prior to pouring the next lift. Alternatively the wall may be propped.

***Step 5: Additional Courses***

Sweep the top of the previous course of units clean of any loose no fines concrete. Place the next course of units so that the kidney holes fit over the pins of the two units below. Pull the unit towards the face of the wall until it locks with the pins on both sides. Repeat Steps 3 and 4.

***Step 6: Installing Capping Units***

Lay capping units, backfill and compact to required grade. It is recommended that the capping units be secured using masonry construction adhesive or epoxy cement.

# GRAVITY WALL

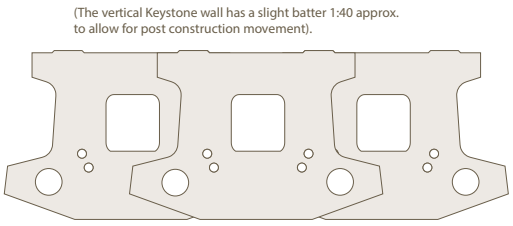
## Overview

For low, non-critical walls, (i.e. walls covered in the table on the next page) the Keystone Retaining Wall System is effective as a gravity wall structure, utilising their weight and interaction of the units to resist earth pressures.

## Construction Guidelines

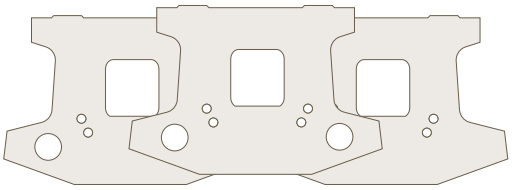
Setback options include:

- Two sets of pin holes are provided in Keystone units.
- For vertical construction, install pins in the front holes.
- For 1 in 8 setback construction, install pins in the back holes.
- Vertical installation must be used when designing walls with curves or corners.




Install pins in front holes for near vertical walls

OR



Install pins in rear holes for 1:8 setback walls

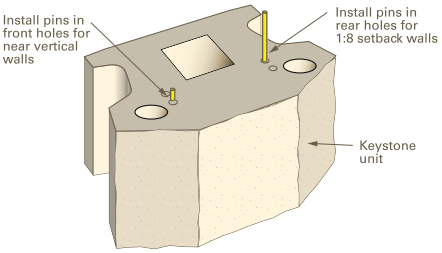
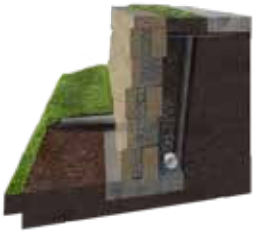
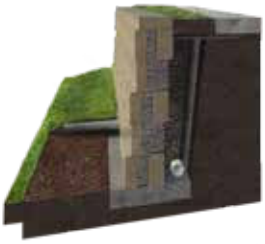



Figure 3 - Installation of Pins

# GRAVITY WALL

**Table 3 - Maximum Wall Height and Gravity Fill Walls**

| *Surcharge Load* | *Backfill Type* | *Wall Height* | |
|---|---|---|---|
| | | *Vertical* | *1 in 8 Setback* |
| no surcharge and level backfill  | *Poor* | *800* | *900* |
| | *Average* | *900* | *1000* |
| | *Good* | *1000* | *1200* |
| Max 14° or 1:4 | *Poor* | *600* | *900* |
| | *Average* | *700* | *900* |
| | *Good* | *800* | *1100* |
| 5kPa and level backfill  | *Poor* | *400* | *500* |
| | *Average* | *500* | *600* |
| | *Good* | *600* | *800* |

**Important:** Please consult with the regulating council for local design requirements prior to the design and construction of a retaining wall. Councils in general require that retaining walls be designed and certified by a suitably qualified engineer where the wall is over 0.5m in height and/or where there is surcharge loading such as a roadway, house, or other structure near the wall.

## Retained Soil Descriptions

***Poor Soils*** Include fine sands, gravelly clays, sandy clays, silty sands. Angle of internal friction ≥ 25°

***Average Soils*** Include well graded sands, gravelly sands. Angle of internal friction ≥ 30°

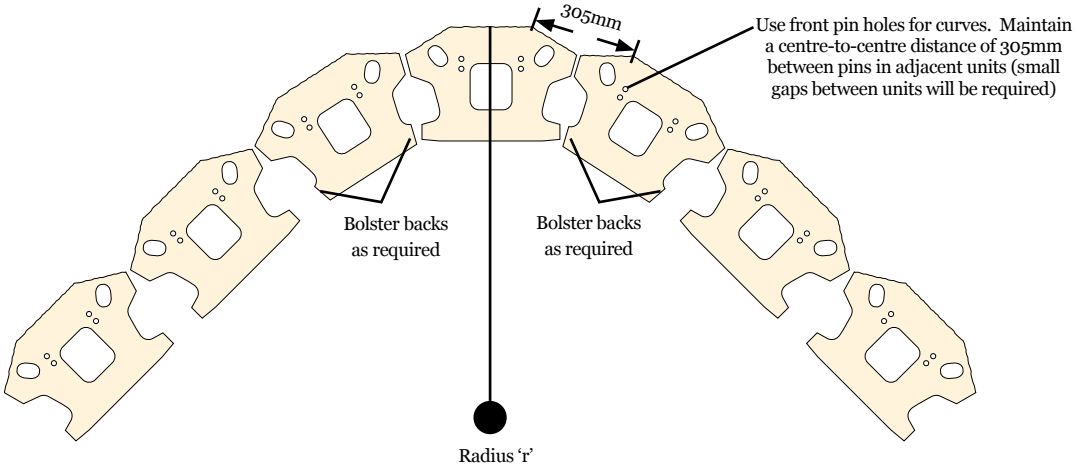
***Good Soils*** Include gravels, sandy gravels, crushed sandstone.Angle of internal friction ≥ 35°

Table 3:

Refer to max. wall heights disclaimer on the back page of this brochure. The gravity wall heights are maximum heights calculated in accordance with CMAA RW03 Appendix D guidelines and a qualified engineer should confirm the suitability of the product for each intended application.

# CURVES

## Convex Curve




3 unit 90° Corner: r = 900mm

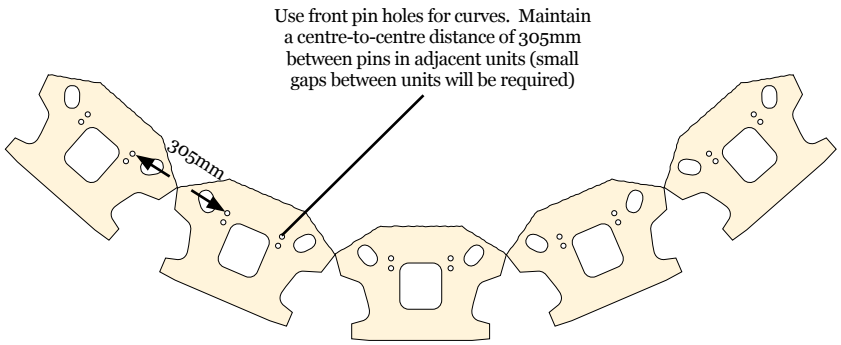
4 unit 90° Corner: r = 1250mm

5 unit 90° Corner: r = 1540mm

6 unit 90° Corner: r = 1830mm

7 unit 90° Corner: r = 2120mm

## Concave Curve



# KEYSTONE RETAINING WALLS

## Typical Specifications

### 1. Scope of Work

#### 1.1 Extent

This specification covers the works for construction of segmental, reinforced-soil retaining structures. The works include footing excavation, foundation preparation, drainage, backfill and compaction and related items necessary to complete the work indicated on drawings and as further specified.

All retaining wall construction is to be carried out in accordance with the levels, distances and details as shown on the drawings and in accordance with this specification.

The Keystone reinforced retaining wall system shall also be constructed in accordance with the manufacturers installation guidelines by a suitably qualified and experienced contractor.

#### 1.2 Responsibilities

The Contractor shall be responsible for carrying out the installation of all retaining walls in accordance with this specification and the associated contract documents.

### 2. Standard Specification

Wherever reference is made to Standards Association of Australia (SAA) the requirements of the editions and amendments, shall apply to the relevant materials or operations and be deemed to be incorporated in this specification.

In the case of a conflict between the referenced standard specification and code and this specification, the more stringent provisions shall apply.

The following is a summary of standard specifications applicable to this subsection of the work:

AS1012 Methods of Testing Concrete

AS4456 Concrete Masonry Units

AS3600 Concrete Structures

AS4456.4 Masonry Units — Compressive Strength

AS4678 Earth Retaining Structures

AS1289 Methods of Testing Soils

Materials or operations not covered by the above standard codes shall conform to the appropriate Australian Standard.

### 3. General Requirements

#### 3.1 General

Terms used in this specification shall have the meanings assigned to them as follows:

'Approved' shall mean approved in writing by the Engineer. 'Or equal approved' shall mean equivalent in performance, quality and price to that specified and approved by the Engineer.

Where limits to the properties of soils are defined elsewhere herein these properties shall be determined by the methods laid down in AS1289.

The term 'construction area' in this Part shall be defined as an area to be excavated or an area to be cleared and filled.

#### 3.2 Regulations

The Contractor shall comply with all relevant Acts, Regulations and By-Laws in respect of all work specified herein, including temporary timbering, strutting, guard rails and all safety measures to be adopted.

#### 3.3 Certification

The Contractor's Geotechnical Engineer shall certify that the bearing capacity of the foundation is as per the foundation requirements specified on the drawings. The Geotechnical Engineer shall also inspect and certify that the Reinforced Soil Block material is as specified on drawings with regard to friction angle, and bulk density.

### 4. Materials

#### 4.1 Masonry Units

The retaining wall units shall be manufactured in accordance with AS4456 Concrete Masonry Units. Block types and sizes for Keystone retaining walls shall be as shown on the drawings or specified herein.

#### 4.1.1 Tolerance

Permissible tolerance in the manufacture of retaining wall units shall comply with AS4456.3 - 1997. In the case of Keystone units, the tolerance of ± 2mm shall not apply to profiled or textured faces. Non conforming concave distortions shall be rejected.

#### 4.1.2 Strength

Retaining wall units shall be manufactured with a minimum compressive strength of 10MPa. A minimum of ten (10) samples must be tested to obtain a mean compressive strength, tested to failure as per AS4456.4 — 2003 under normal compressive and laboratory conditions.

#### 4.1.3 Colour

The colour and texture of masonry units shall be as specified and shall remain consistent with the 'sample range' approved by the project Superintendent.

#### 4.1.4 Handling/Storage/Delivery

Keystone units shall be delivered on pallets to minimise damage during transportation. The Contractor shall store and handle units so as to prevent units from damage, which may affect the aesthetic quality or structural integrity of the finished wall.

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### 4.2 Connecting Pins

High strength pultruded fibreglass pins shall be used to interlock and align all Keystone units in a running bond pattern. Pins shall also provide an integral connection between the Keystone units and the geogrid.

### 4.3 Geogrids

The reinforcing elements for the reinforced soil structure shall be as shown on the drawings.

If required, each consignment of geogrids delivered to site shall be accompanied by a Quality Control Tensile Test Certificate from the manufacturer.

### 4.4 Approved Reinforced Soil Block Backfill

Material for backfilling between geogrids for the Keystone retaining wall shall be 'Approved Backfill' defined as sand, crushed sandstone or broken rock obtained from excavations or approved borrow areas. Such material shall be

• Free of rock fragments greater than 75mm in size.

• Free of clay lumps retained on a 75mm sieve.

• Free of organic matter.

• Within the following grading requirements;

Sieve Size % Passing by Weight

75mm - 100%

26.5mm - 50 - 100%

4.75mm - 25 - 75%

0.425mm - 10 - 50%

0.075mm - 0 - 20%

• Non-plastic in that the fraction passing 0.425mm has a Plasticity Index of not greater than 15.

• Capable of being brought to a moisture content suitable for compaction as specified elsewhere herein, under the weather conditions prevailing on site.

The 'Approved Backfill' shall be stockpiled on site, and inspected and approved by the Geotechnical Engineer that the material satisfies the specification above the design friction angle and dry density values as specified on drawings. Testing for dry density and friction angle shall be in accordance with section 6 herein.

### 4.5 Drainage

All retaining walls are to contain drainage systems that prevent the build up of hydrostatic pressure behind walls. This is to include a 12-20mm free draining clean hard aggregate, used to fill all voids within the retaining wall units and to extend 300mm behind the units.

Drainage is to be installed as per the drawings and as per the manufacturers recommendations.

### 4.6 Concrete Works

All concrete for use in footings for retaining walls shall have a compressive strength after 28 days of 25MPa unless specified otherwise.

The supply, placement, finishing and curing of reinforcement and insitu concrete shall comply in every respect with AS3600.

### 4.7 Hold and Witness Points

The following shall be deemed a Hold Point:

• Submission of test results and samples of all retaining wall components.

The following shall be deemed a Witness Point:

• On-site slump and strength testing of concrete.

## 5. Construction of Keystone Retaining Walls

### 5.1 Foundations

Excavation is to be to the lines and grades shown on the drawings. The reinforced soil block foundation size shall be constructed as per drawings unless alterations are made by the Geotechnical Engineer, who may require tests on the sub-grade material, to be carried out by a registered N.A.T.A. Testing Laboratory.

The reinforced soil block foundation subgrade shall be proof rolled with a heavy steel drum roller (minimum applied intensity of 4t/m width of drum with at least 8 passes) without vibration. Any material which is soft, visibly deformed, unstable or deemed unsuitable by the Contractor's geotechnical consultant shall be excavated and replaced with approved fill and compacted to achieve dry densities of between 98% and 103% of Standard Maximum Dry Density at moisture content of ±2% of Standard Optimum Moisture Content.

The foundation shall be inspected and approved by the Geotechnical Engineer, who shall verify that the foundation bearing capacity exceeds the required bearing capacity as specified on drawings. The approval of the reinforced soil block foundation shall be deemed a HOLD POINT.

Detailed excavation for the mass concrete footing shall proceed following acceptance of the foundation. The footing subgrade shall be inspected by the Contractor's Geotechnical Engineer and any areas deemed soft, unstable or unsuitable by the Geotechnical Engineer shall be excavated and replaced as described above.

The footing shall be constructed as shown on the drawings. It could be shown as compacted roadbase or concrete. For concrete, the footing shall be poured to the correct level using formwork edge boards, or other methods which ensure the cor-

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rect level of the footing. The concrete footing shall be screeded flat. The level of the footing or first course of blocks shall be verified by survey methods, and approved by the Contractors QA representative. This shall be deemed a WITNESS POINT.

### 5.2 Unit Installation

Foundations and all courses are laid level. Batters are achieved by inserting the fibreglass connecting pins into the appropriate holes. The Keystone retaining walls shall be constructed with batters as shown on the drawings.

First course of units shall be placed side by side on the base levelling pad. Units shall be levelled side to side and front to back and checked for alignment. The accurate placement of the first course is most important, to ensure acceptable horizontal and vertical tolerances. Two fibreglass connecting pins shall be inserted into the appropriate holes to interlock and align units.

The front set of pin holes shall be used for near vertical setback. The rear pair of holes shall be used for 25mm (1:8) setback. All voids in units and between units shall be filled with drainage fill as specified in section 4.5. Drainage fill shall extend to 300mm behind units.

Units shall be placed in a running bond pattern. Top of units shall be swept clean of excess material. Kidney holes of units above shall be positioned over pins in units below. Units shall be pulled toward the face of the wall to interlock the pins with units on either side. Levels and alignment of each course shall be checked. Each course shall be filled, backfilled and compacted prior to placement of the next course. The Keystone wall shall be surveyed for vertical level tolerance every 3 courses. This shall be deemed a HOLD POINT.

### 5.3 Drainage Installation

The drainage measures shall be installed as shown on drawings. 100mm diameter agricultural pipe shall be used for subsoil drainage behind the first course of Keystone units. The subsoil drain shall be placed with a minimum 1% fall as shown on drawings.

'T' piece connection fittings shall be used at all outflow points to connect the subsoil drainage to a 100mm diameter pipe stub which extends 300mm past the face of the Keystone wall.

The pipe stub material shall be UPVC or HDPE and shall be approved by the project Superintendent.

The outflow points shall be at a maximum of 60m centres. The locations of the outflow points shall be determined by the Superintendent. The outflow pipe stub shall be supported on the concrete footing, and shall pass between two Keystone units with 60mm of the facing removed by sawcutting. The gap above the pipe in the first course shall be neatly patched with cement mortar.

The drainage measures shall be inspected by the QA representative after the installation of the first and second course is complete. Inspection and approval of the drainage installation shall be deemed a HOLD POINT.

### 5.4 Placement of Geogrid

The Geogrid shall be placed between Keystone units as specified on the drawings. Geogrids shall be cut to the required length. Geogrids may be longer than required, but shall not be shorter than the specified length shown on the drawings. The Geogrids shall be placed with the roll direction perpendicular to the face of the Keystone wall. Correct orientation of the geogrids shall be verified by the Contractor.

After compaction, the layer of select backfill below each geogrid, shall be raked to a depth of 25mm to ensure good interlock between the geogrid and the select backfill. The Geogrid shall be laid horizontally on compacted backfill and connected to the Keystone units by hooking geogrid over the fibreglass pins. The geogrid shall be pulled taut against pins to eliminate slack from connections and loose folds. The back edge shall be staked or secured prior to backfilling to maintain tension in the geogrid. Each block shall be checked for level accuracy, as out of position transverse bars will lead to sloping blocks. If the course above a layer of geogrid is found to be not level, then the blocks shall be removed, and the geogrid repositioned to ensure it is level.

For a straight length of wall, the geogrids shall be laid side by side without joints or overlaps. Where the wall is convex, the geogrids shall not be cut, but shall be overlapped with a minimum of 75mm of compacted fill between them. For a concave wall the position of the layers of grid shall be alternated between consecutive geogrid layers to cover the triangular gaps between strips of geogrid. Refer to Fig 5.4.

The QA Representative shall inspect and keep records of the position of grid and the type of grid placed for each layer of geogrid. The number of courses between each successive layer of geogrid shall be noted. The QA Representative shall also check this. This shall be deemed a WITNESS POINT.

### 5.5 Placement of Reinforced Soil Backfill

Prior to placement of 'Approved Backfill' in the reinforced soil block, the Geotechnical Engineer shall approve the material and confirm that the friction angle and dry density of the material is in accordance with the drawings for that particular section of the project. This shall be deemed a HOLD POINT.

All backfill imported or otherwise shall be as specified on the drawings. Backfill shall be spread in a maximum of 200mm layers, in such a manner that minimises the voids directly underneath the geogrid. Fill should be deposited using suitable plant which causes fill to cascade onto geogrids. Placement of fill on top of the geogrids shall start from the wall face and work back from

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the wall face in order to minimise slack or loss of pretension from the grid. Care should be taken to not mix the reinforced soil block backfill material with the drainage material. If backfill material mixes with the drainage material, then the drainage material is to be removed and replaced with clean material.

Compaction shall be to 98% of Standard Maximum Dry Density. Compaction shall start at the wall face and work back from the wall face. Compaction testing shall be in accordance with section 6 specified herein. Compaction testing shall be deemed a WITNESS POINT.

Tracked construction equipment shall not be operated directly on the geogrid. A minimum thickness of 150mm of backfill material shall be placed prior to the operation of tracked construction equipment. Rubber tyred equipment may passover the geogrids at very slow speeds. Sudden braking or sharp turning shall be avoided to prevent displacement of geogrids.

Construction plant and all other vehicles having a mass exceeding 1000kg shall be kept at least 1m from the back of the Keystone units. Compaction of the 1m zone behind the

Keystone units shall be restricted to:

• Vibrating rollers with a mass < 1000kg

• Vibrating plate compacters with a mass < 1000kg

• Vibro tampers having a mass < 75kg

Surface drainage during and after construction of the wall shall be provided to minimise water infiltration in the reinforced soil zone.

**5.6 Hold and Witness Points**

The following shall be deemed a HOLD POINT:

• Approval of foundation material by the Geotechnical Engineer.

• Inspection and approval of 'Approved Backfill' for use in reinforced soil block by the Geotechnical Engineer.

• Survey of the Keystone Wall every 3 courses.

• Inspection and approval of the drainage installation by the QA Representative.

The following shall be deemed a WITNESS POINT:

• Survey verification that the first course is installed at the correct level, and inspection and approval of footing by the QA Representative.

• Inspection of level and type of geogrid at each layer by the QA Representative.

• Compaction Testing by the Geotechnical Engineer.

**6. Material Testing**

**6.1 Testing of 'Approved Backfill'**

Each source of 'Approved Backfill' shall be pretreated by 5 cycles of repeated compaction, and then tested for dry density and friction angle. Material for use as 'approved backfill' shall be inspected and approved for use by the Geotechnical Engineer. A stockpile at least equivalent to 5 days reinforced soil wall construction shall be maintained on site at all times.

This will allow time for friction angle testing of the approved backfill should visual inspection of the material when it is received on site indicate that testing is required. Notwithstanding the above the following minimum testing shall be carried out:

• Dry Density shall be tested at a frequency of 1 test per 400m$^3$ of approved backfill.

• Friction angle shall be tested at a frequency of 1 test per 2000m$^3$ of approved backfill.

If the dry density results are not within ±5% of the specified design value, then the Engineer shall be notified, and the material not approved for use until the design has been verified.

**6.2 Testing for Compaction**

Compaction will be checked by standard maximum dry density test and field density test for materials other than sand or by the density index and field density tests for sands as specified on drawings and herein.

Tests will be carried out in groups of at least three, and compaction of the layer concerned will be considered to be satisfactory if no single result falls outside the specified density range. Should the results not reach this standard the Sub-Contractor shall again roll the area, if necessary after scarifying, adding water, blading to reduce the moisture content and/or removing and replacing excessively moist fill as may be required.

Should the Geotechnical Engineer consider that the depth of insufficiently compacted material is greater than can be effectively compacted from the surface, material shall be removed to a depth at which compaction is satisfactory and replaced and compacted in 200mm maximum layers.

The standard maximum dry density referred to herein for materials other than sand shall be maximum standard dry density as determined in accordance with AS1289 - Test numbers 5.1.1.

The modified maximum dry density referred to herein for materials other than sand shall be the maximum modified dry density as determined in accordance with AS1289 - Test 5.2.1.

The field density referred to herein for all materials shall be the dry density of the material in place as determined in accordance with AS1289 - Test 5.3.1.

The percentage of the standard maximum dry density (Dry Density Ratio) elsewhere herein for materials other than sand shall be calculated from the formula given in AS1289.5.4.1.

The maximum and minimum densities of cohesionless materials shall be determined in accordance with AS1289 - Test E5.1. The Density Index specified elsewhere herein for sands shall be calculated from the formula given in AS1289.E6.1.

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### 6.3 Frequency of Testing

The following testing frequencies relate to acceptance on a 'not-one-to-fail' basis. The testing should be carried out in essentially randomly chosen locations and at the frequencies as given below. However, it may be appropriate to undertake testing in specific locations, based on visual appearance or past experience.

Where a test or group of tests is carried out on an area which has been subjected to essentially the same preparation and compaction procedures, the whole of this area is considered to be represented by this test or group of tests. The uniform area is generally known as a work lot. On this basis, if one or more tests indicate compliance with the specification has not been achieved, the whole of the area which has been submitted for testing is deemed not to comply, unless it can be demonstrated that the area in which the non-complying test result(s) can reasonably be separated from the whole. It should not be assumed a test result applies only to the area immediately surrounding it.

Required frequency of testing, is not less than 1 test per layer of 200 mm thickness per material type per 400m$^3$ which is 1 test per layer per 100 linear metres of wall construction. If different sources of 'approved backfill' are used within the 100 linear metre work lot, then 1 test per type of material is required. If the work is staged in sections of less than 100 linear metres, then 1 test per section is required.

The testing frequency may be re-assessed to the approval of the Engineer, if a high degree of uniformity becomes evident during construction.

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