BLK V1.0

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Sustainable Cost Effective Construction & Coating Systems

Block

Engineering Design

8 YEARS

Ecoclean Technologies

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Supercoat™

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11.0 Bracing Design

11.1 General

Horizontal forces, such as wind and earthquake loading, applied to a building are to be resisted by bracing walls. Bracing walls are located generally at right angles to the walls subjected to these forces. All bracing components in the building shall be interconnected to adequately transfer the imposed loads. These connections are achieved in the following ways:

- The ceiling/floor/roof is designed to act as a diaphragm.
- The roof is appropriately held down (refer to NZS 4229)
- Wall intersections are appropriately connected (refer to Detail **BLK 3.0** and **BLK 3.1**).
- Load transfer to footings via reinforcement and dowels.

11.2 Distribution of Bracing Walls

Bracing walls shall be designed to resist the imposed loads determined in accordance with NZS 4229:2013, to ensure that lateral wind and earthquake forces from ceiling and floor diaphragms, and wall elements are adequately transferred into the foundations via internal and external bracing walls.

Bracing walls can be located at a maximum spacing of 8 metres. Note, the movement joint spacing (6 metres max.) may govern the bracing wall size and location.

11.3 Reinforcement Requirements of Bracing Walls

- Vertical reinforcement consists of reinforcement bars centrally located in 50mm diameter holes drilled on-site through the centre of the block wall width. After inserting the reinforcement, the holes are then filled for the full height of the wall with a 4:1 grout mix (i.e., 4 parts sand to 1 part cement), with a characteristic compression strength of 17 MPa at 28 days. The following rules apply to positioning reinforcement bars along a length of wall:
    - Spaced at a maximum horizontal distance of 1000mm.
    - Located 150mm from the ends or corners of a run of wall, such as movement joints.
    - Vertical edge of windows and door openings, and external and internal corners.
- Horizontal reinforcement consists of a bond beam located at the top of the wall.

Typically, the bond beam is reinforced with two reinforcement bars (12mm diameter) and filled with an aggregate grout. The grout shall have characteristic compression strength of 15 to 20 MPa at 28 days. Reinforcement is to be designed and specified by the structural design engineer

11.4 Basic Load Data used to Derive Tables

Weights of Components Used in the Earthquake Bracing Demand Evaluation.

11.4.1 Bracing Unit (BU) Demand Calculations.

Figure 4 Loads used in Design Calculations

Heavy Roof	Includes concrete tiles, timber roof trusses & ceiling	0.84 kPa
Light Roof	Includes Steel sheet/tile roof cladding, timber trusses and ceiling	0.46 kPa
Timber Floor	Includes Supercrete 75mm Soundfloor, timber joists and ceiling	0.75 kPa
Supercrete™ SFP Floor	Includes 20mm levelling screed	2.00 kPa

All Live Loads as per AS/NZS 1170

Total horizontal forces have been calculated from AS/NZS 1170 assuming:

$\mu = 1.75$
period of vibration < 0.4 seconds
site subsoil category (D) flexible or deep soil sites

$S_P = 0.78$

$K_\mu = 1.43$
$R = 1.0$

$N (T, D) = 1.0$

Z = Zone 1 (0.2), Zone 2 (0.3), Zone 3 (0.46), Zone 4 (0.6)

$\Psi_E = 0.3$

Bracing Demand Evaluation

The weights of the Supercrete™ Blocks used in the earthquake bracing demand evaluation are presented in Table 12.

Table 12. Supercrete™ Block Weights

Type	Nominal Wall Thickness (mm)	Mass of Wall (kg/m²)	Unit Weight of Wall (kN/m²)	Factored Unit Weight of Wall (kN/m²) See note below
Single Skin Supercrete™ Block Working Density 525 kg/m³	150	79	1.0	1.1
	200	105	1.3	1.5
	250	131	1.6	1.9
	300	158	2	2.3

Table 13. Earthquake Bracing Unit (BU) Demand for Supercrete™ Block

Bracing Unit Demand for Supercrete™ block walls subjected to an **Earthquake** shall be calculated in accordance with NZS 4229, using Table 13 - *Earthquake Bracing Demand for Supercrete™ Block Walls* in place of *NZS 4229 - Table 4.3*

Single Storey or Top Storey of Building (with light roof)	Supercrete™ Block Wall Thickness (mm)	Concrete Slab on Ground — Minimum Bracing Units/m² in Earthquake Zone: Zone 1	Zone 2	Zone 3	Zone 4	If top storey is timber refer to NZS 3604 for Bracing Unit Demand
Single Skin Supercrete™ Wall (525 kg/m³)	150	18	27	42	54	
	200	21	32	49	63	
	250	20	29	44	58	
	300	28	42	64	83	
For Heavy Roof	Add	4	4	4	6	

Bottom of Two Storey (with light roof)	Supercrete™ Block Thickness (mm)	Intermediate Supercrete™ SFP Floor (2)				Intermediate Timber Floor (3)			
		Minimum Bracing Units per m² in Earthquake Zone							
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Single Skin Supercrete™ Wall both storeys	150	41	62	94	123	33	49	75	98
	200	44	65	100	130	38	57	87	114
	250	49	74	113	147	47	70	107	139
	300	72	108	165	215	58	86	132	172
For Heavy Roof	Add	4	4	4	6	4	4	4	6
300 thick Foundation Wall (2m maximum height)		Supercrete™ SFP Floor at both levels (2)				Timber Floor at both levels (3)			
200 thick Single Skin Supercrete™ Wall both storeys	All thicknesses	88	132	202	263	66	98	150	196

1) Table 13 has been developed using the same principles as NZS 4229. It is based on a 7m square box building with a 45° pitch roof. The roof space has an allowance for a habitable attic using 40% of the plan area with a Live Load of 1.5kPa & a timber floor. Wall height between floor levels, & ceiling level for top or single storey = 2.4m
2) All Intermediate Supercrete SFP floors are assumed as 200mm thick and include a 20mm topping screed
3) "Timber Floor" denotes a Supercrete 75mm Soundfloor on timber joists.
4) The above table has been derived for Site Sub-soil Classes D or E. Where it has been proven from geotechnical investigation that the site sub-soil is better than Class D then the following factors can be applied to all values in Table 13 for the other classes:

Site Sub-soil Classes A & B 0.63
Site Sub-soil Class C 0.79

11.5 Bracing Capacity - Background

11.5.1 Bracing Design

A masonry bracing wall with wide-spaced reinforcement can fail in four ways, as follows:

1. Shear failure of the material between reinforcing bars, as for an unreinforced wall. This is resisted by the shear strength of the masonry material.
2. Overturning of the wall as a whole about its toe. This is resisted by its self-weight, any vertical load from above, and the tie-down action of the vertical reinforcing bars.
3. Sliding on the base. This is resisted by friction at the base or damp-proof course layer, and dowel action of the vertical reinforcing bars where they cross the plane at the base of the wall.
4. Shear failure of the reinforced section, where shear cracks cross the reinforcing bars. This can be considered to be resisted by an enhanced shear capacity of the material, which takes into account the presence of the reinforcing steel.

In order to perform its function properly, a reinforced masonry bracing wall must have vertical steel reinforcing rods at each end of the wall and distributed along its length, and horizontal steel reinforcing at the top of the wall forming a bond beam. There is usually no requirement for horizontal steel at the bottom of the wall because the wall is firmly tied by the vertical steel to a slab or footing that is capable of performing the function of a bottom bond beam. The vertical and horizontal steel must be tied together to ensure proper location and action.

11.5.2 Development of Bracing Capacity Tables

The bracing capacity tables in this manual give bracing capacities in bracing units for a range of wall sizes and conditions.

All reinforcement has been assumed to be D12 rods with a yield strength of 300 MPa. The maximum spacing of vertical rods is 1000mm. Dowel action strength of the vertical rods has been taken as 6.75 kN per D12 reinforcement bar.

A bond beam must be included in all walls covered by the tables. No cases are governed by reinforced shear failure, but the bond beam should be included in all walls for shrinkage control. In every case the bond beam nominally consists of two D12 reinforcing bars located in the top course of the wall and tied to vertical reinforcement (refer Section 7).

Reinforcement is to be designed and specified by a structural engineer.

The following approach has been used to generate the tables for this manual:

- Shear failure of the material (criterion 1, see above) has been checked using the approach of AS3700 (Clause 7.5.1(b)) but never governs for the range covered in the tables.
- Shear failure of the reinforced material (criterion 4, see above) has been checked using the approach of AS3700 (Clause 8.6) but never governs for the range covered in the tables.
- Overturning of the wall (criterion 2, see above) was checked and the load capacity calculated. This condition tends to govern for cases where the wall is relatively tall and short (with height/length greater than about 1).
- Sliding on the base (criterion 3, see above) was checked and the load capacity calculated. This condition tends to govern for cases where the wall is relatively long (with height/length less than about 1).

Designers can treat cases outside the range covered by the tables. In particular, this would be required to account for the effects of vertical load. However, if this is done, all four failure criteria set out above must be checked. Failure modes 1 and 4 can be checked by using the method given in AS3700 or another suitable approach. The approaches used to analyse failure modes 2 and 3 are set out below.

11.5.3 Design Procedure for Overturning

For the tables in this manual, calculation of the overturning capacity has been carried out by an analysis of the wall as a reinforced section cantilevered from the based. A capacity reduction factor of 0.75 has been used. Calculation of equilibrium for the section is based on a linear strain distribution and a maximum tensile strain in the extreme reinforcing bar of 0.0015. Figure 5 shows how the equilibrium of the section is determined. The rectangular stress block is taken to have a width of 0.85 times the depth to the neutral axis and a maximum stress of 0.85 times the characteristic compressive strength of the AAC masonry, f'm.

Once the position of the neutral axis is determined, the overturning capacity is calculated by considering the moment generated by the compression stress block (ignoring any reinforcement in compression) and the reinforcement in the tension zone.

A more detailed analysis for individual cases would take account of any imposed load from above and the effect of any bonding of the wall to intersecting walls.

11.5.4 Design Procedure for Sliding

Analysis of the sliding capacity is based on a similar analysis of the reinforced section as illustrated in Figure 5 with a linear strain distribution through the section and a maximum tensile strain in the extreme reinforcing bar of 0.0015. As for overturning, the rectangular stress block is taken to have a depth of 0.85 times the depth to the neutral axis, and a compressive stress level of 0.85 f 'm.

Once the position of the neutral axis is determined, the sliding resistance is calculated as the sum of a friction component on the compression stress block and the dowel action of the bars. For the tables in this manual, the friction coefficient has been taken as 0.3 in accordance with AS3700 (Table 3.3). A capacity reduction factor of 0.75 has been used.

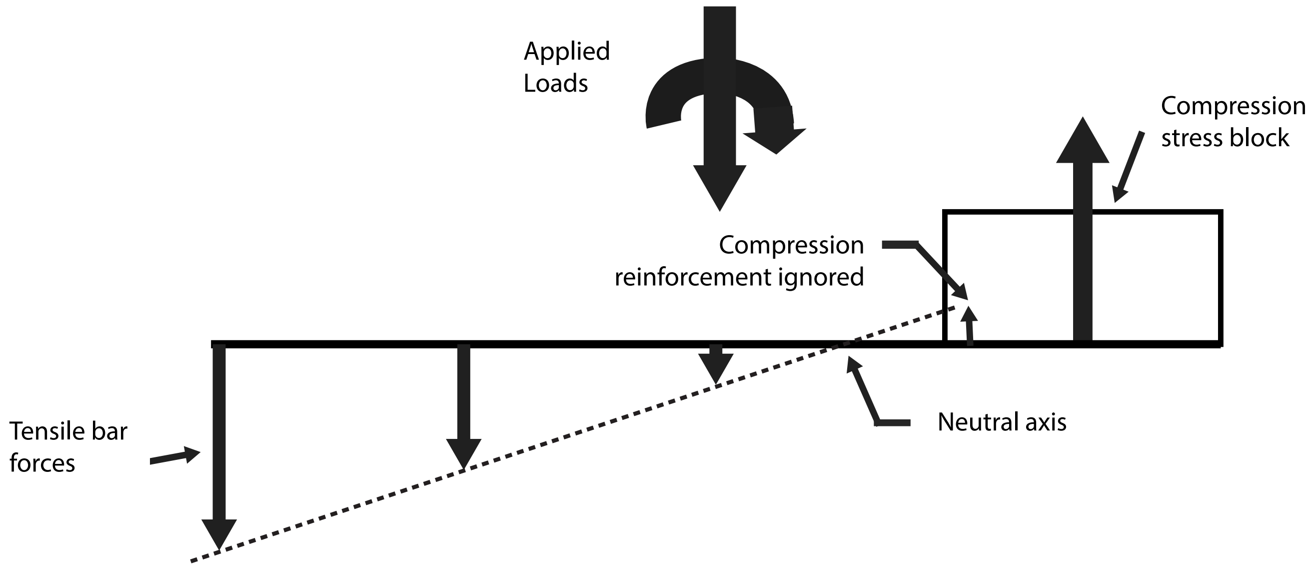


Figure 5 Equilibrium Calculation for Forces at Base of Bracing Wall

11.6 Bracing Capacity Tables

Adopt Tables 14 to 17 – Design Bracing (Shear) Capacities of Supercrete Walls (NZ Bracing Units) in place of **NZS 4229, Table 5.1.**

NOTE: Bracketed rod sizing indicates minimum number of vertical reinforcement bars required
20 Bracing Units (BU) = 1kN of shear Force

Table 14. Bracing (Shear) Capacity of 150mm Thick Supercrete Walls

Wall Height (mm)	Bracing Capacity BU (NZ Bracing Units)									
	Wall Length (mm)									
	900mm	1200mm	1800mm	2400mm	3000mm	3600mm	4200mm	4800mm	5400mm	6000mm
Rod No/Size	(2 x D12)	(2 x D12)	(3 x D12)	(4 x D12)	(5 x D12)	(5 x D12)	(6 x D12)	(7 x D12)	(8 x D12)	(8 x D12)
1200	220	305	455	605	750	760	900	1050	1205	1205
1400	180	265	455	605	750	760	910	1050	1205	1215
1600	160	225	455	605	760	760	910	1060	1215	1215
1800	140	210	415	605	760	760	910	1060	1215	1215
2000	120	180	370	605	760	765	920	1060	1215	1225
2200	115	170	340	575	760	765	920	1070	1225	1225
2400	105	150	310	530	765	765	920	1070	1225	1235
2600	95	140	290	490	750	765	920	1070	1225	1235
2800	95	130	265	455	700	780	930	1080	1235	1240
3000	85	120	255	425	655	780	930	1080	1235	1240

Table 15. Bracing (Shear) Capacity of 200mm Thick Supercrete Walls

Wall Height (mm)	Bracing Capacity BU (NZ Bracing Units)									
	Wall Length (mm)									
	900mm	1200mm	1800mm	2400mm	3000mm	3600mm	4200mm	4800mm	5400mm	6000mm
Rod No/Size	(2 x D12)	(2 x D12)	(3 x D12)	(4 x D12)	(5 x D12)	(5 x D12)	(6 x D12)	(7 x D12)	(8 x D12)	(8 x D12)
1200	220	310	455	605	760	760	910	1060	1215	1225
1400	190	265	465	605	760	765	920	1070	1225	1225
1600	160	235	465	615	765	765	920	1070	1225	1235
1800	140	210	425	615	765	765	930	1080	1235	1235
2000	130	190	385	615	765	780	930	1080	1235	1240
2200	120	170	350	595	765	780	930	1090	1240	1240
2400	115	160	320	550	780	785	940	1090	1240	1250
2600	105	150	305	510	780	785	940	1090	1250	1260
2800	95	130	295	475	730	785	950	1100	1250	1260
3000	85	130	265	445	680	795	950	1100	1260	1270

Table 16. Bracing (Shear) Capacity of 250mm Thick Supercrete Walls

Wall Height (mm)	Bracing Capacity BU (NZ Bracing Units)									
	Wall Length (mm)									
	900mm	1200mm	1800mm	2400mm	3000mm	3600mm	4200mm	4800mm	5400mm	6000mm
Rod No/Size	(2 x D12)	(2 x D12)	(3 x D12)	(4 x D12)	(5 x D12)	(5 x D12)	(6 x D12)	(7 x D12)	(8 x D12)	(8 x D12)
1200	225	310	465	615	765	765	920	1070	1225	1235
1400	190	275	465	615	765	780	930	1080	1235	1240
1600	170	235	465	615	765	780	930	1080	1240	1240
1800	150	220	435	615	780	780	940	1090	1240	1250
2000	130	190	400	625	780	785	940	1100	1250	1260
2200	120	180	360	615	785	785	950	1100	1260	1260
2400	115	160	330	570	785	795	950	1110	1260	1270
2600	105	150	310	530	785	795	960	1110	1270	1280
2800	95	140	285	490	750	805	960	1120	1270	1280
3000	95	130	275	465	710	805	970	1120	1280	1290

Table 17. Bracing (Shear) Capacity of 300mm Thick Supercrete Walls

Wall Height (mm)	Bracing Capacity BU (NZ Bracing Units)									
	Wall Length (mm)									
	900mm	1200mm	1800mm	2400mm	3000mm	3600mm	4200mm	4800mm	5400mm	6000mm
Rod No/Size	(2 x D12)	(2 x D12)	(3 x D12)	(4 x D12)	(5 x D12)	(5 x D12)	(6 x D12)	(7 x D12)	(8 x D12)	(8 x D12)
1200	225	310	465	615	765	780	930	1080	1235	1240
1400	200	275	475	625	780	780	940	1090	1240	1250
1600	170	245	475	625	780	785	940	1100	1250	1260
1800	150	220	445	625	785	785	950	1100	1260	1260
2000	140	200	405	625	785	795	950	1110	1260	1270
2200	120	180	370	615	795	795	960	1120	1270	1280
2400	115	170	340	575	795	805	970	1120	1280	1290
2600	105	150	310	540	795	805	970	1130	1290	1300
2800	95	140	290	500	780	815	980	1140	1290	1310
3000	95	130	275	475	730	815	980	1140	1300	1320

11.7 Vertical Load Capacity of Walls

The ultimate vertical load capacity of reinforced Supercrete™ loadbearing block walls can be determined conservatively from Charts 1 to 12 Appendix B

These are based on un-reinforced walls constructed with Supercoat™ Superbond Adhesive, following the requirements outlined in Section 7.3 of the Australian Standard AS 3700-2001: ***Masonry Structures***.

11.8 Lateral Load Capacity of Spanning Walls

Although not required by NZS 4229, the load capacity of Supercrete™ Block walls should be checked for out-of-plane lateral wind and earthquake loads.

The ultimate out-of-plane bending capacity of reinforced Supercrete™ loadbearing block walls can be determined conservatively from Charts 13 to 20, in Appendix B for un-reinforced block walls.

These are based on un-reinforced walls constructed with Supercoat™ Superbond Adhesive, following the requirements outlined in Section 7.4 of the Australian Standard AS 3700-2001: Masonry Structures. Supercrete NZ Ltd suggests designing the wall thickness, such that the wall spans vertically with no influence of vertical edge restraint (from intersecting walls or returns).

This will allow movement joints to be positioned later without detrimentally affecting the design lateral load capacity of the wall.

11.9 Diaphragm Design

Structural diaphragms at roof, ceiling or floor level, which provide lateral support to Supercrete™ Block walls against horizontal wind and earthquake loads, should be designed in accordance with NZS 4229. In using NZS 4229, Table 9.1 – Nail fixing for ceiling and roof diaphragms, Supercrete walls should be considered to be "P" (partially filled).

11.10 Bond Beams

Where earthquake or wind loads are transmitted through diaphragm action of floors and roofs, which would be the case in the majority of situations, a continuous bond beam shall be provided at the top of all external and internal walls of all single level buildings. Bond beams shall be a minimum of 250mm deep and of the same width as the block wall, including AAC facings.

Bond beams can be easily constructed using 50mm wide AAC closure blocks fixed to the top of the block wall with thin bed adhesive. Nominally two D12 reinforcement bars are then place centrally in the core and grout filled.

NOTE: The bracing values in Tables 14 to 17 above are for walls with a 250 deep bond beam reinforced with 2 x D12 rods.

Reinforcement shall be designed and specified by a structural engineer. Refer to Section 10 Construction Details.

- It is not advisable to use high tensile steel for the vertical reinforcing or the bond beam reinforcement as the use of high tensile steel with low compressive strength concrete could lead to an explosive failure of the concrete. It is not balanced design philosophy to use high strength steel in low strength concrete
- A suitably qualified structural engineer shall perform the bracing design. An appropriate bond beam, having the required strength and stiffness to transmit the horizontal forces shall form part of all bracing walls.

11.11 Residential Footing System Designs for Supercrete™ Blockwork

External and internal Supercrete™ Blockwork walls shall be constructed on appropriately proportioned reinforced strip footings or stiffened raft slabs on ground.

Where buildings meet the requirements of NZS 4229:2013 *Concrete Masonry Buildings Not Requiring Specific Engineering Design*, and are founded on either rock, sand or any other bearing strata that does not exhibit seasonal movement, then strip footings can be proportioned to comply with Section 6 of NZS4229.

Where buildings are not founded on bearing strata noted above, or where it is decided to use integrally cast stiffened raft or slab-on-ground footing system, then the selection of the foundation type shall be based on the recommendations outlined in AS2870.1: 2011 *"Residential Slabs and Footings"*. This standard covers the selection of footing designs for the usual range of site conditions, soil types and slopes. Where unusual site or load conditions are encountered, advice should be obtained from a practicing Structural Engineer

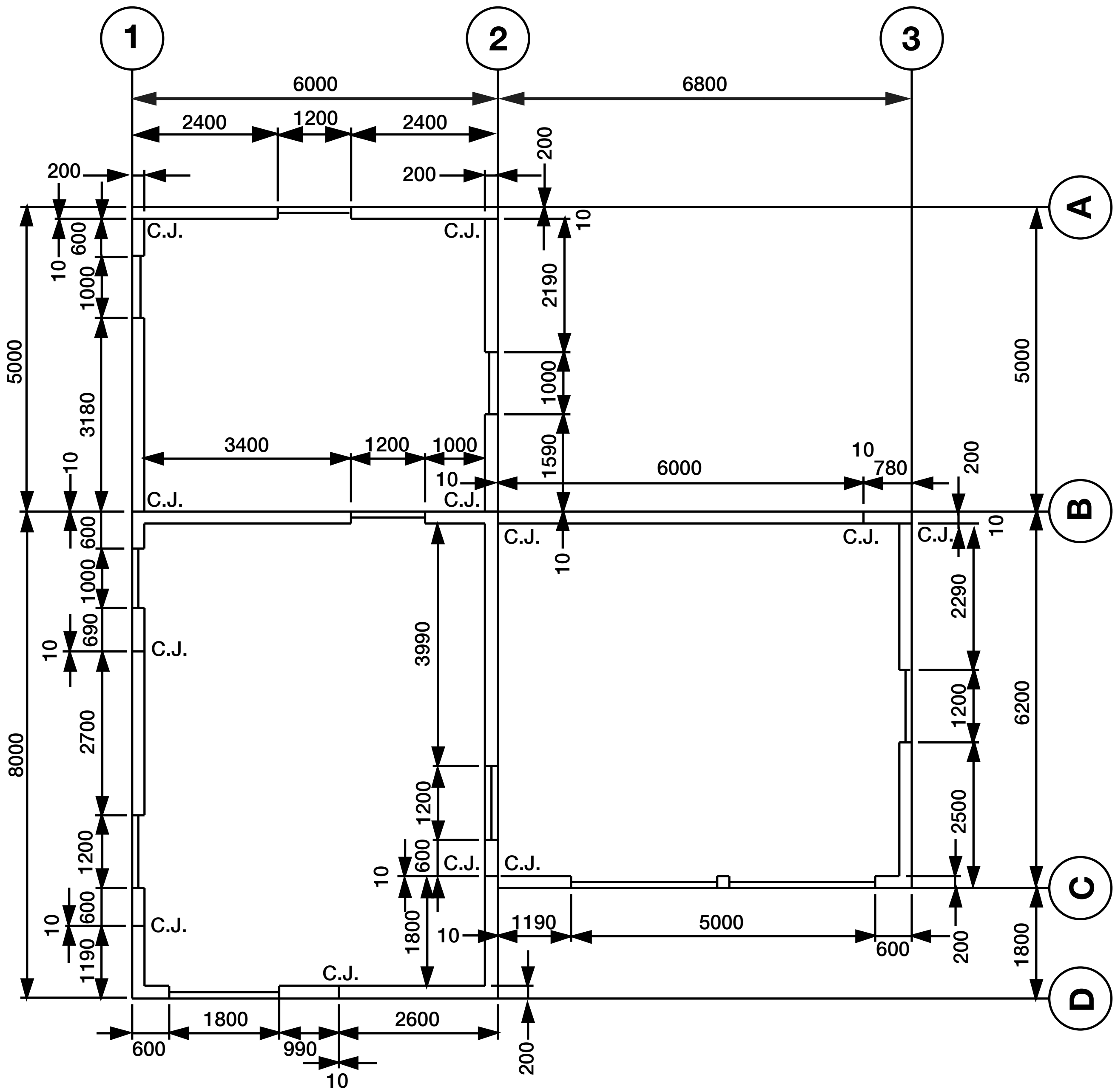
Appendix A – Design Example Single Story Construction

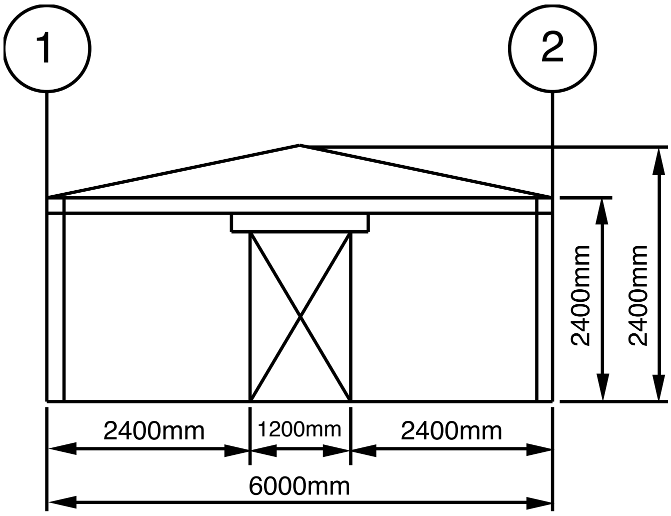
A single storey house located in Earthquake Zone 1 is constructed with 2400mm high x 200mm thick external Supercrete™ Block walls and a light roof. The ridge height is 3000mm.

This is a simplified design to illustrate the design of the bracing walls; the following design aspects have been excluded: foundation design, connection design and assessment of site compliance.

The "Wall Layout" configuration shown is used to illustrate the bracing capacity calculation.

IMPORTANT: It is the designer's responsibility to check the adequacy of the walls and allow for the effects of applied loads, movement of the structure, movement joints, chasing, arrangement of openings, strength, fire resistance and robustness.





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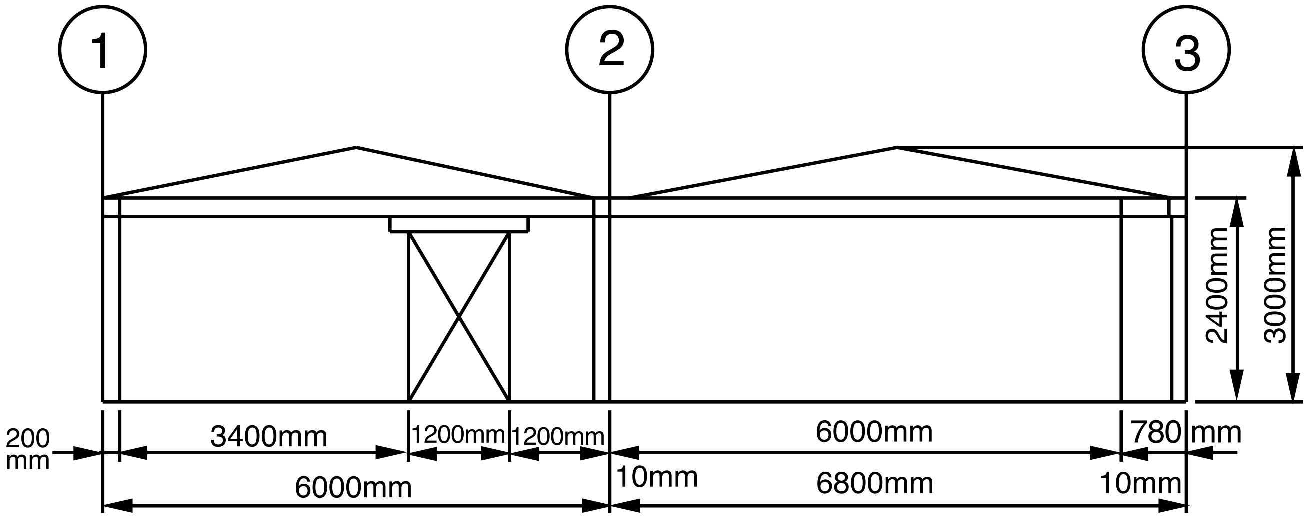

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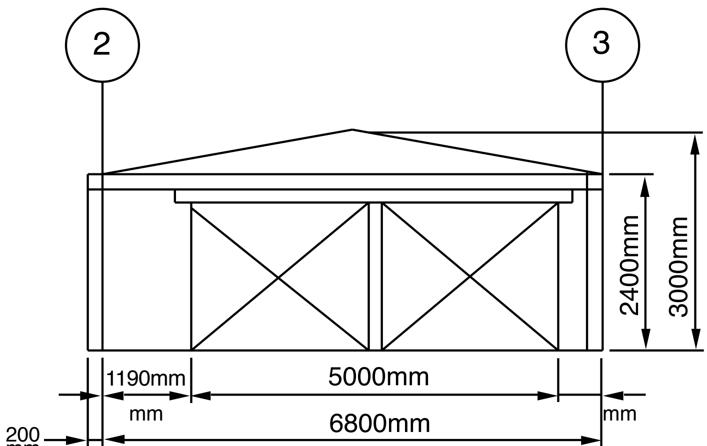

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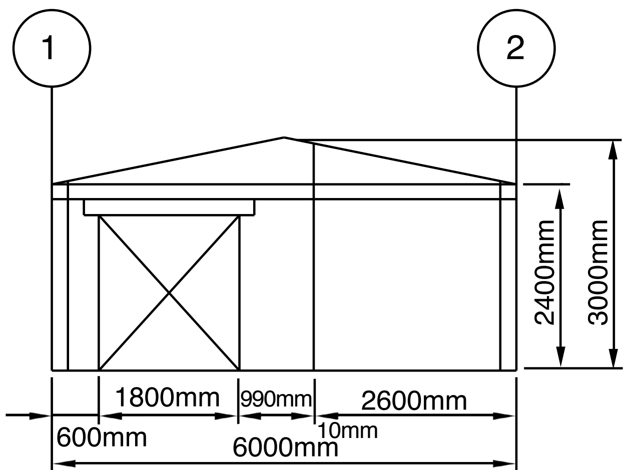

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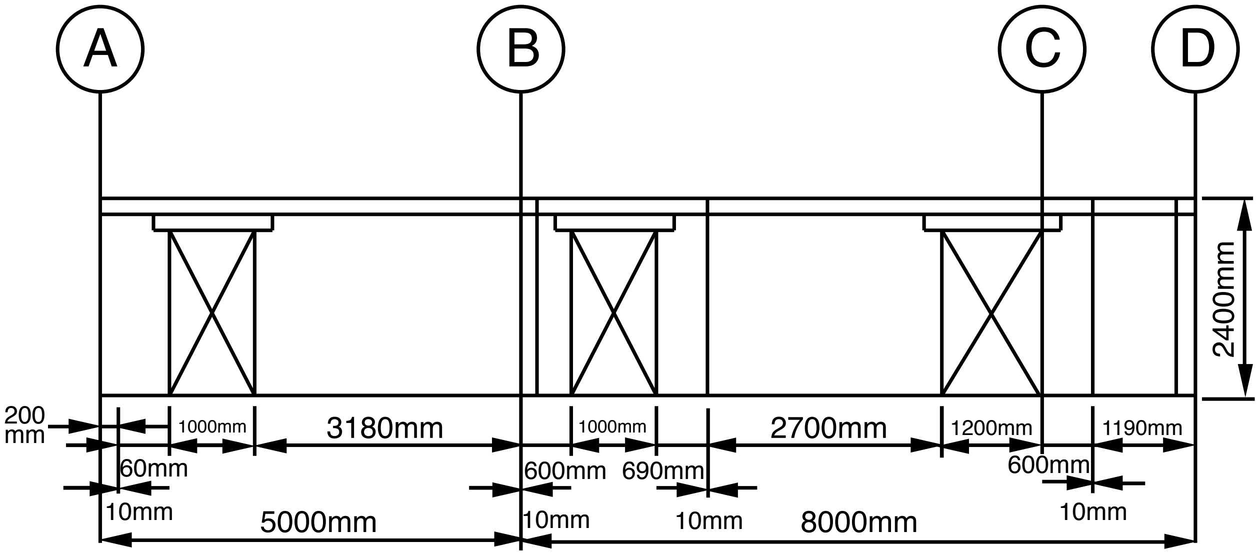

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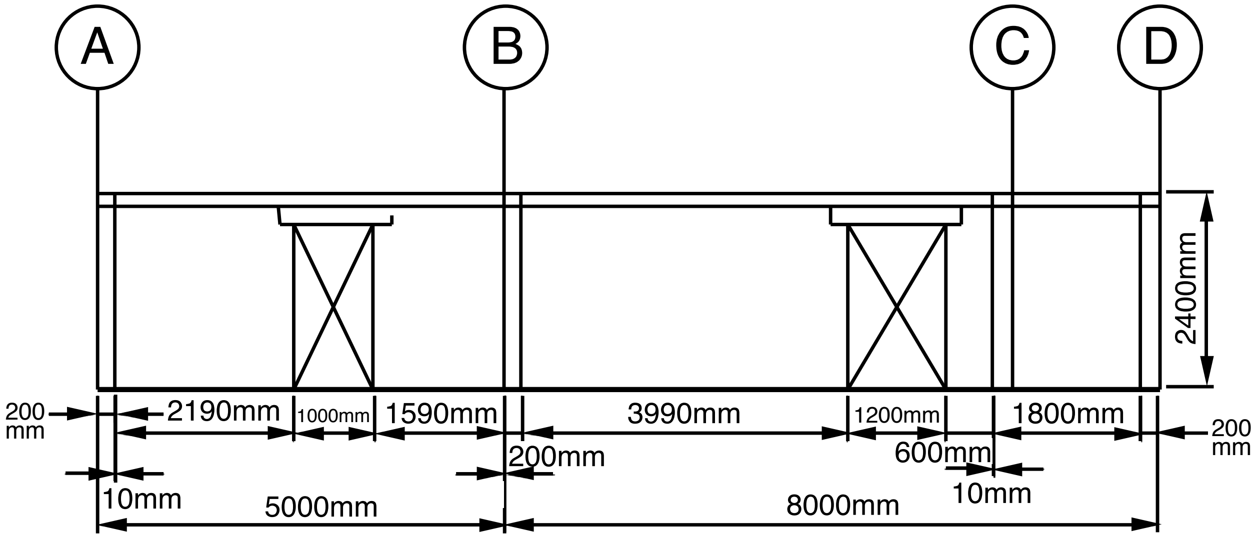

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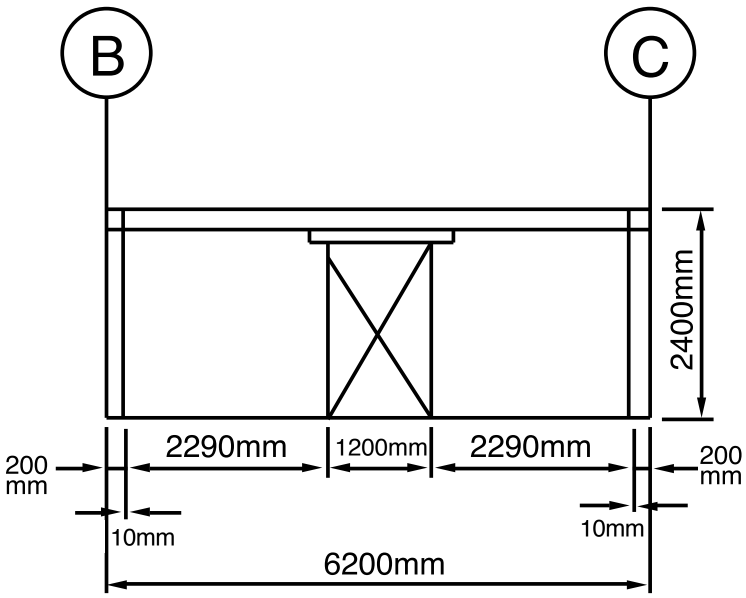

GRID 3

Step 1 – Wall Bracing Demand Evaluation

NZS4229 Fig 4.1

Step 1A - Determine Earthquake Zone

NZS4229 Fig 4.1

→ Earthquake Zone 1

EQ Zone 1

Step 1B - Determine Bracing Unit Demand for Earthquake Loading

Section 11
Table 13

→ Demand = 21 BU/m^2 (200mm thk Supercrete External Wall)

EQ Demand 21BU/m^2

Step 1C - Determine Total Bracing Demand for Earthquake Loading

Plan Area = 120.2m^2

→ EQ Demand = 21 x 120.2 = 2525 BU

EQ Demand 2525BU's

Step 1D - Determine Bracing Demand Loading for Wind Loading

Single Storey Structure, Single storey height = 2.4m

Height to apex = 10m

NZS4229 Fig 4.2 → Demand across Ridge = 111 BU/m

NZS4229 Fig 4.2 → Demand along Ridge = 111 BU/m

Wind Demand
111BU/m across
111BU/m along

Step 1E - Determine Total Bracing Demand for Wind Loading

Wall Length across Ridge = 13m

Total Wind Demand across Ridge =111 x 13 = 1442 BU

1442BU across

Wall Length along Ridge = 6 + 6.8 = 12.8m

Total Wind Demand along Ridge =111 x 13 = 1421 BU

1421BU along

Step 1F - Determine Total Bracing Demand

Earthquake Demand = 2525 BU

Worst Case Wind Demand = 1442 BU

→ Earthquake governs loads

Design Demand
2525BU

Step 2 – Determine Bracing Capacity

Two approaches for assessing the bracing strength of the walls in the example are illustrated. These are *Individual Diaphragms Approach* and *Bracing Line Approach*

Approach 1 - INDIVIDUAL DIAPHRAGMS APPROACH

Step 2A - Determine Bracing Lines, location of movement joints (C.J. or A.J.) and Bracing Panels

Refer to figures showing Bracing Lines, Movement Joints & Bracing Panels

Step 2B - Determine required Minimum Capacity of Individual Bracing Lines

In general, each wall has to support a minimum of 60% of the Total Bracing Demand, although this can be reduced to 30% where the opposite wall can be shown to resist 100%

Diaphragm	**Plan Area (m^2)**	**Total Bracing Demand** (BU's)	**60% of Demand** (BU's)
D1	6 x 5.0 = 30.0	630	378
D2	6 x 8.0 = 48.0	1008	605
D3	6.8 x 6.2 = 42.2	887	532

Step 2C - Determine Bracing Capacity of each Bracing Line

Grid A

Section 11
Table 15

Bracing Line	**Panel Height (m)**	**Panel Length (m)**	**Bracing Capacity** (BU's)
A	2.4	2.4	550
	2.4	2.4	550
			1100

Capacity of Grid A is 940 BU's exceeding the demand of 378 BU's

→ Bracing Line Grid A is OK

Bracing Line Grid A, OK

Grid B

Diaphragm D3

Bracing Capacity of wall on Grid C < 30% of demand, therefore 100% of demand carried by wall on Grid B

100% of Bracing Demand = 887 BU's

Diaphragms D1 & D2

Section 11
Table 15

Bracing Line	**Panel Height (m)**	**Panel Length (m)**	**Bracing Capacity** (BU's)
B	2.4	3.39	783
	2.4	1.2	160
	2.4	6.0	1250
			2193

Grid B internal bracing wall is common to diaphragms D1 & D2, then bracing demand is taken as 40% of the sum of total bracing of diaphragms D1 & D2

Grid B demand = 0.4 x (630 + 1008) + 887 = 1543 BU's

Grid B external bracing wall for diaphragm D3 is taken as 100% of the bracing demand for diaphragm D3

Grid B bracing capacity is 2193 BU's, exceeding required demand of 1543 BU's

→ Bracing Line Grid B is OK

Bracing Line Grid B, OK

Grid C

Section 11
Table 15

Bracing Line	**Panel Height (m)**	**Panel Length (m)**	**Bracing Capacity** (BU's)
C	2.4	1.19	160
			160

Capacity of Grid C is 160 BU's which is less than 267 BU's (30% of the 887 BU demand)

→ Bracing is carried by Bracing Line Grid B

Bracing Line Grid C, OK

Grid D

Section 11
Table 15

Bracing Line	**Panel Height (m)**	**Panel Length (m)**	**Bracing Capacity** (BU's)
D	2.4	2.99	780
	2.4	3.0	780
			1560

Capacity of Grid D is 1560 BU's exceeding the demand of 605 Bu's

Bracing Line Grid D is OK

Bracing Line Grid D, OK

Section 11
Table 15

Grid 1

Bracing Line	Panel Height (m)	Panel Length (m)	Bracing Capacity (BU's)
1	2.4	3.80	782
	2.4	2.79	703
	2.4	1.19	160
			1645

Grid 1 external bracing wall is common to diaphragms D1 & D2, hence the bracing demand is taken as 60% of the sum of the total bracing demand of diaphragms D1 & D2

Grid 1 demand = 0.6 x (630 + 1008) = 983 Bu's
Capacity of Grid 1 is 1645 Bu's exceeding the demand of 983 BU's
Bracing Line Grid 1 is OK

Bracing Line Grid 1, OK

Section 11
Table 15

Grid 2

Bracing Line	Panel Height (m)	Panel Length (m)	Bracing Capacity (BU's)
2	2.4	2.19	473
	2.4	1.59	266
	2.4	4.19	940
	2.4	2.00	396
			2075

Grid 2 external bracing wall supports diaphragm D1 and the internal bracing wall common to diaphragms D1 & D2 so the bracing demand is taken as 60% of diaphragm D1 and 40% of the sum of the bracing demands of diaphragms D2 & D3

Grid 2 demand = 0.6 x 630 + 0.4 x (1008 + 887) = 1136 BU's

Capacity of Grid 2 is 2075 BU's exceeding the demand of 1136 BU's
Bracing Line Gris 2 is OK

Bracing Line Grid 2, OK

Section 11
Table 15

Grid 3

Bracing Line	Panel Height (m)	Panel Length (m)	Bracing Capacity (BU's)
3	2.4	2.4	550
	2.4	2.4	550
			1100

Capacity of Grid 3 is 1100 BU's exceeding the demand of 532 BU's
Bracing Line Grid 3 is OK

Bracing Line Grid 3, OK

Step 2D – Check Bracing Capacity of Overall Building

Bracing Direction	Panel Height (m)	Panel Length (m)	Bracing Capacity (BU's)
Across Ridge	2.4	2.40	550
	2.4	2.40	550
	2.4	3.39	783
	2.4	1.20	160
	2.4	6.00	1250
	2.4	2.99	780
	2.4	3.00	780
			4853
Along Ridge	2.4	2.79	703
	2.4	1.19	160
	2.4	2.19	473
	2.4	1.59	266
	2.4	3.98	891
	2.4	2.40	550
	2.4	2.00	396
	2.4	2.40	550
	2.4	2.40	550
			4539

Step 2E – Conclusion

Overall Capacity across ridge is 4853 BU's exceeding the demand of 2525 BU's

Bracing Capacity across ridge is OK

Overall capacity along ridge is 4539 BU's exceeding the demand of 2525 BU's

Bracing Capacity along ridge is OK

It was established that sufficient individual and overall Bracing Capacity has been provided by the house design

Bracing Capacity OK

Approach 2 – BRACING LINE APPROACH

Step 2A - Determine Bracing Lines, location of movement joints Bracing Panels

Refer to figures showing Bracing Lines, Movement Joints & Bracing Panels

Step 2B – Determine Bracing Demand for Individual Bracing Lines

Section 11
Table 13

→ The Critical Loading Case was for earthquake, where the Bracing Demand was 21 BU/m²
Bracing Demand is 21 BU/m²

Demand 21 BU/m²

The Bracing Demand for the Bracing Line is determined by multiplying the Bracing Demand by the plan area supported by the Bracing Line

The plan area is taken as the wall length multiplied by the tributary widths of the diaphragms supported by the wall

The Bracing Demands of individual bracing lines are shown in the table below

Bracing Line	Tributary Width (m)	Wall Length (m)	Deman of Bracing Line (BU's)
A	5.0 / 2 = 2.5	6.0	21 x 2.5 x 6 = 315
B	(5.0 + 6.2) / 2 = 5.6	12.8	21 x 5.5 x 12.8 = 1479
C/D*	8 / 2 = 4	12.8	21 x 4 x 12.8 = 1076
1	6 / 2 = 3	13.0	21 x 3 x 13 = 819
2	(6 + 6.8) / 2 = 6.4	13.0	21 x 6.4 x 13 = 1748
3	6 / 2 = 3	6.2	21 x 3 x 6.2 = 391

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* Treat as a single wall as the offset is less than 2.0m.
The tributary width is determined from the larger diaphragm

Step 2C – Determine Bracing Capacity of each Bracing Line

The total bracing capacity provided by the individual panels along a bracing line can be determined as outlined in the *Individual Diaphragm Approach* and listed in the table below

Section 1
Table 15

Bracing Line	Bracing Line Capacities (BU's)
A	550 + 550 = 1100
B	783 + 160 + 1250 = 2193
C/D*	160 + 780 + 780 = 1720
1	782 + 160 + 703 = 1645
2	473 + 266 + 940 + 396 = 2075
3	550 + 550 = 1100

* Treat as a single wall as the offset is less than 2.0m.
The tributary total bracing capacity is taken as the sum of the bracing capacities for the individual panels of both Grids C & D

Step 2D – Check Adequacy of Bracing Line

Bracing Line	Bracing Demand (BU's)	Bracing Capacity (BU's)	Remarks
A	315	1100	✓OK
B	1479	2193	✓OK
C/D*	1076	1720	✓OK
1	819	1645	✓OK
2	1748	2075	✓OK
3	391	1100	✓OK

Step 2E – Conclusion

It has been shown that sufficient individual and overall bracing capacity has been provided in the design of the house

→ House has sufficient bracing capacity

Bracing Capacity OK

Step 3 – Determine Wall Reinforcement

The minimum reinforcement requirements of the bracing walls are outlined in Section 7 of this document

Construction details illustrating the configuration of reinforcement at footings, bond beams, lintels and movement joints are presented in Section 10

Step 4 – Design Ceiling Diaphragm

The need for a ceiling diaphragm and the construction details of the diaphragm can be determined from Section 9, NZS 4229

Step 5 – Bond Beam Design

The design of bond beams shall be determined from Section 7 of this document and Section 10 of NZS 4229

Construction details can be found in Section 10

Step 6 – Lintel Design

Lintels shall be designed in accordance with Section 7 of this document and Section 11 of NZS 4229

Construction details can be found in Section 10

Step 6a – Determine Weight of Roof

	Roof has a Light Roof Dead Load of 0.46kPa and a maximum span of 6.0m	
NZS 4229 Fig 6.1 NZS 1170.0 Table3.2	Dead Load (D.L.) weight = 6 /2 x 0.46 = 1.38 kN/m Live Load (L.L.) weight = 6 / 2 x 0.25 = 0.75 kN/m	1.38kN/m (DL) 0.75kN/m (LL)
NZS 1170 Section 4.2.2	1.2 D.L. + 1.5 L.L. = 1.2 x 1.38 + 1.5 x 0.75 = 2.78 kN/m	2.78kN/m Action

Appendix B – Additional Design Charts

B1 - Vertical Load Capacity

The capacity of a wall under vertical compression loading depends upon various factors including, the cross-sectional properties, compressive strength of the material, slenderness of the member and the eccentricity of loading at the ends. End eccentricity is determined primarily by a) the type of loading (roof, floor etc.) and b) any bending moments imposed at the ends in conjunction with the vertical loading. Because AS3700 considers that there is no mutual support between the leaves of a cavity wall under compression loading, these charts apply equally to single leaf walls and the separate leaves of cavitywalls.

No distinction is made between simple supports and those that are continuous or have other possible rotational restraint connections. While AS3700 Clause 7.3, provides for two separate approaches (design by simple rules and design by refined calculation), the following charts are for use with the former as this is sufficient for most cases.

There are two distinct loading cases to be considered:

1. Loading from a concrete slab supported by the wall. This case is treated according to the AS3700 provisions for concrete slab loading.
2. Loading from Supercrete floor panels supported by the wall. This case is treated according to the AS3700 provisions for loading other than by a concrete slab.
   Note: This loading condition would also apply to roof loads supported by the wall.

AS3700 uses slenderness coefficients av and ah, as shown in Table below, to cater for various support conditions.

Table B1.1 Slenderness Coefficients (from AS 3700 Clause 7.3.3.3)

Support at the Top & Bottom	a_v
Lateral support at Top & Bottom	1.0
Lateral Support at bottom only	2.5
Support at the Sides	a_h
Lateral Support at both Vertical Edges	1.0
Lateral Support at one Vertical Edge	2.5

The following Design Charts have been prepared using the coefficients shown in Table above and the expressions for slenderness ratio in AS3700 Clause 7.3.3.3, for various loading and support conditions. A capacity reduction factor of 0.45 (AS3700 Table 4.1) and the material properties shown in Section 2 in the Block Properties Design Guide have been used in producing these sets of charts. Each chart is labelled for the wall height and relevant loading case, and shows a simple diagram to indicate the various support conditions.

Separate lines are shown on the charts for block thicknesses available from 100mm to 300mm in increments of 50mm.

The length and height of the wall are clear dimensions between supports and/or free edges in all cases. The edge of an opening (window or door) must be considered as a free edge to the wall for its full height, unless a stiffening mullion is specifically designed to support the edge. Therefore, the length of wall is considered as being that between the lateral support and the edge of the opening. In considering lengths of wall, a control joint or substantial vertical chase should also be treated as a free edge. Control joints are to be located by the structural engineer in consultation with the architect or designer.

Section 6.3 in the Block Construction & Design Guide presents guidelines on appropriate control joint locations.

To use the charts, the factored compression load should be determined in accordance with the relevant New Zealand standard and compared with the load capacity given by the appropriate chart for the wall height, loading/support configuration and block thickness. Either the wall length can be used to check the wall will support the load or the load capacity can be used to determine a maximum wall length. The charts provide for the design of walls with heights up to 3m.

Chart 1 – Supercrete™ Block Walls up to 2.4m Height with Four Edges Laterally Supported and Loaded by a Supercrete Floor

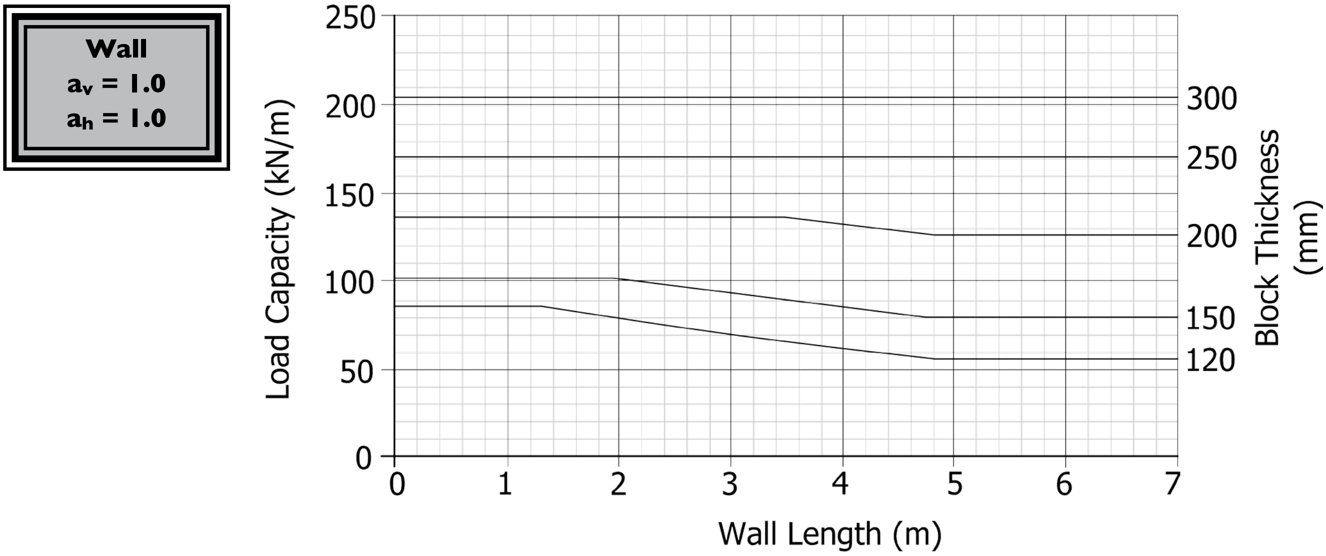


Chart 2 – Supercrete™ Block Walls up to 2.4m Height with One Side Free and Loaded by a Supercrete Floor

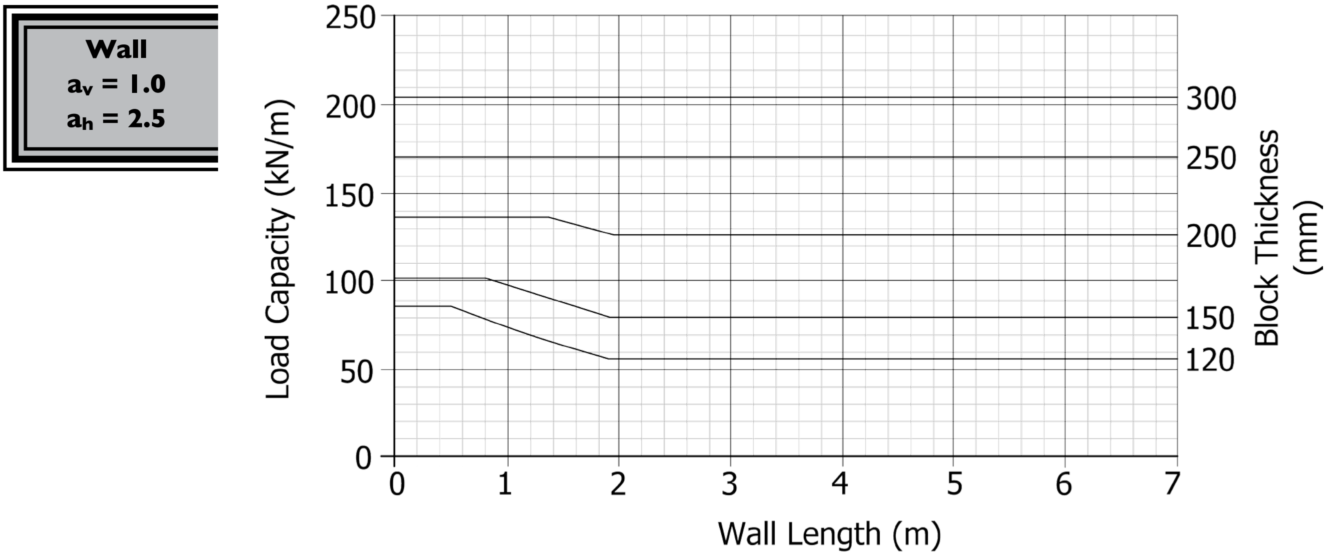


Chart 3 – Supercrete™ Block Walls up to 2.7m Height with Four Edges Laterally Supported and Loaded by a Supercrete Floor

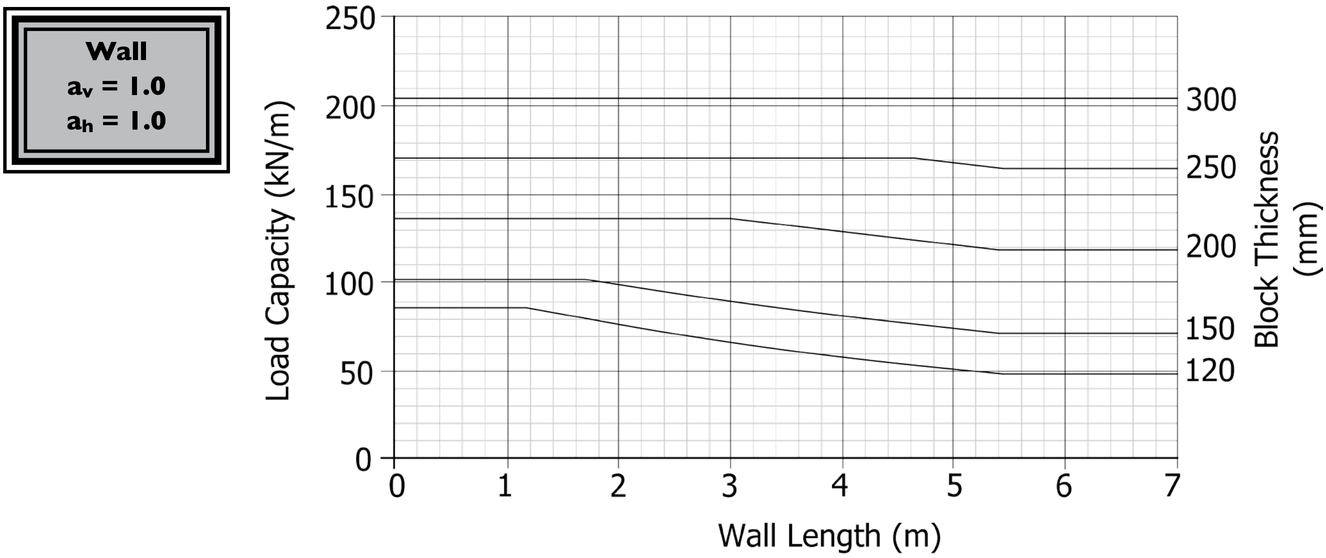


Chart 4 – Supercrete™ Block Walls up to 2.7m Height with One Side Free and Loaded by a Supercrete Floor

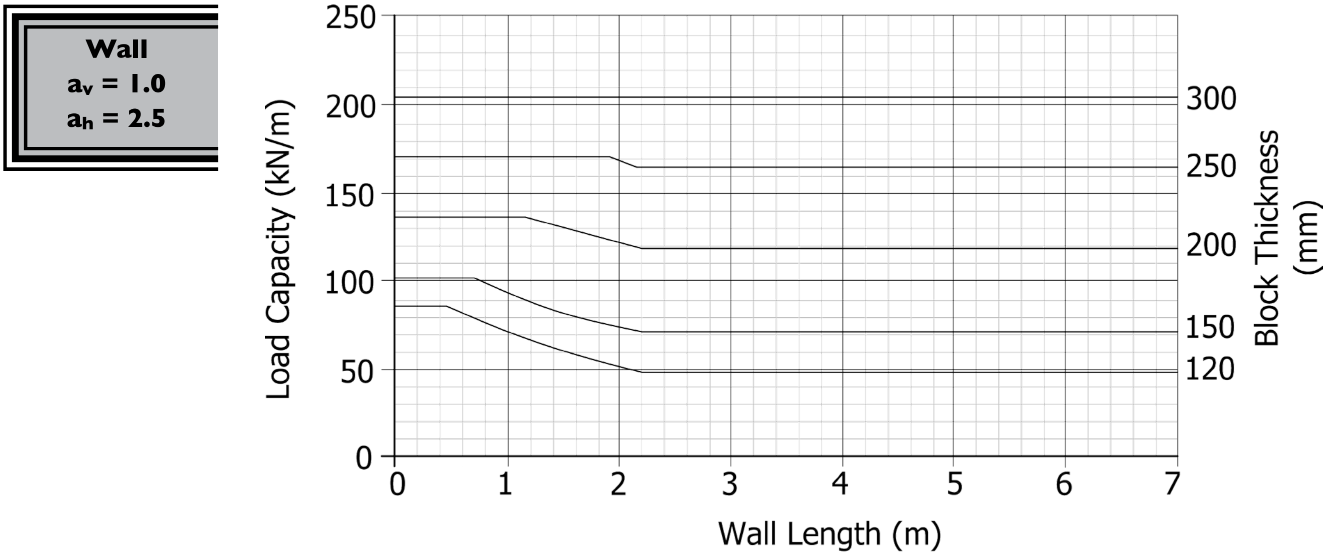


Chart 5 – Supercrete™ Block Walls up to 3.0m Height with Four Edges Laterally Supported and Loaded by a Supercrete Floor

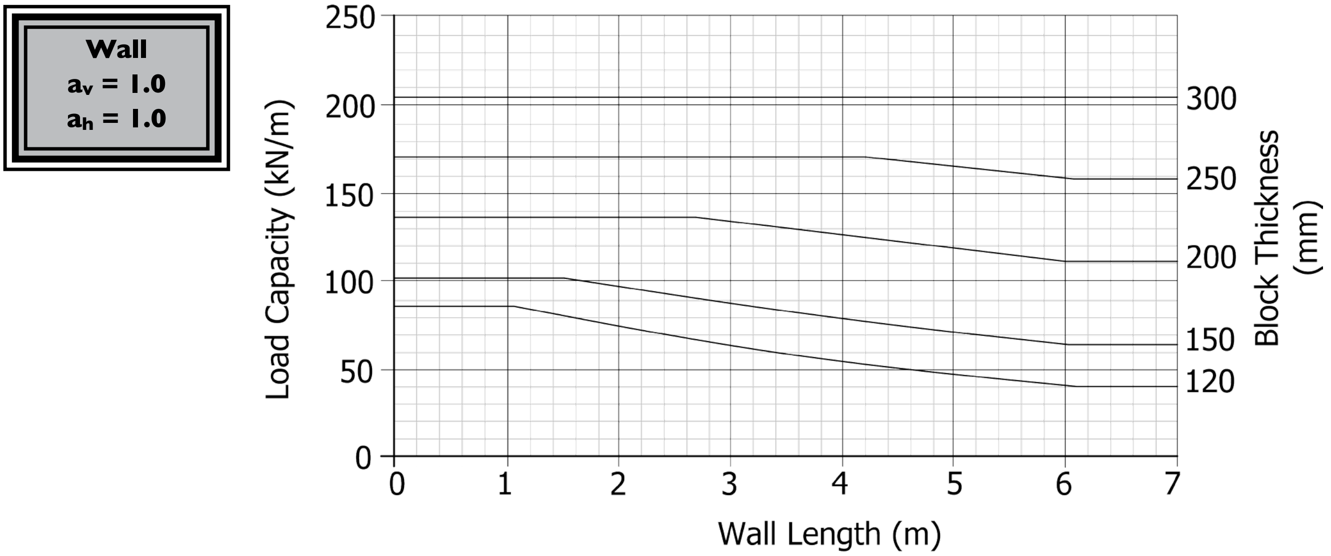


Chart 6 – Supercrete™ Block Walls up to 3.0m Height with One Side Free and Loaded by a Supercrete Floor

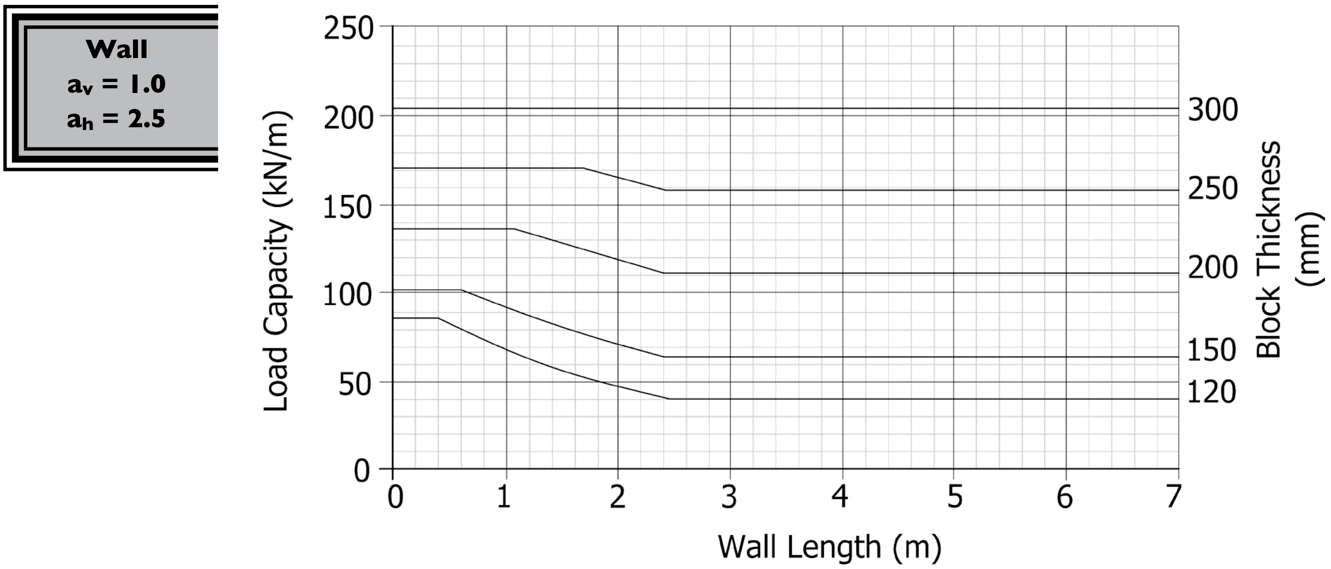


Chart 7 – Supercrete™ Block Walls up to 2.4m Height with Four Edges Laterally Supported and Loaded by a Concrete Slab

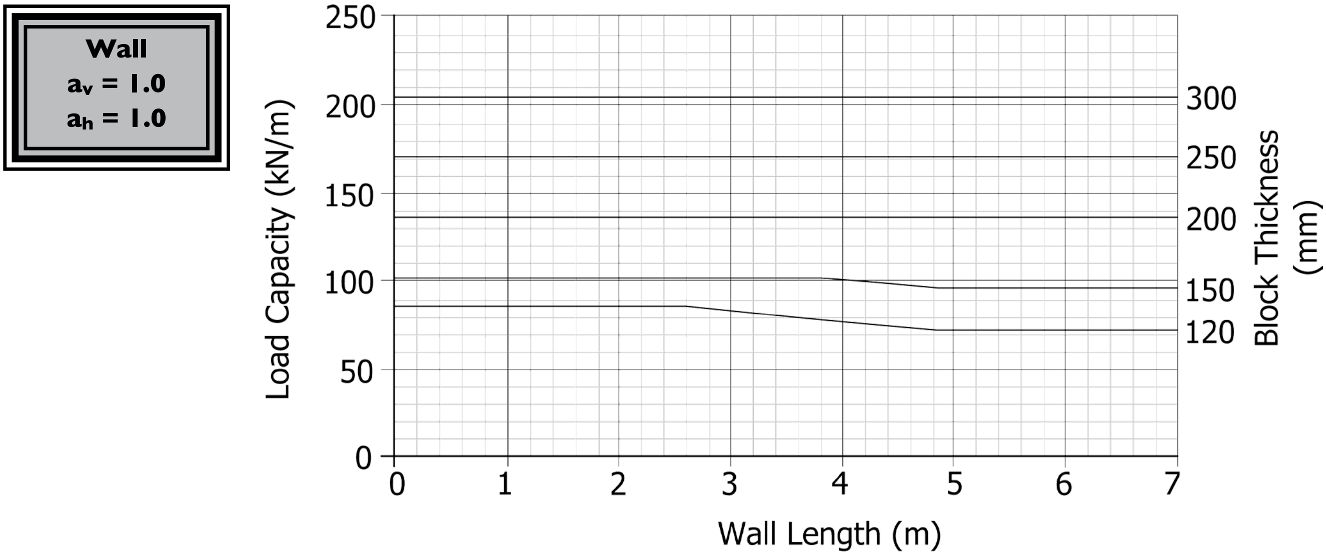


Chart 8 – Supercrete™ Block Walls up to 2.4m Height with One Side Free and Loaded by a Concrete Slab

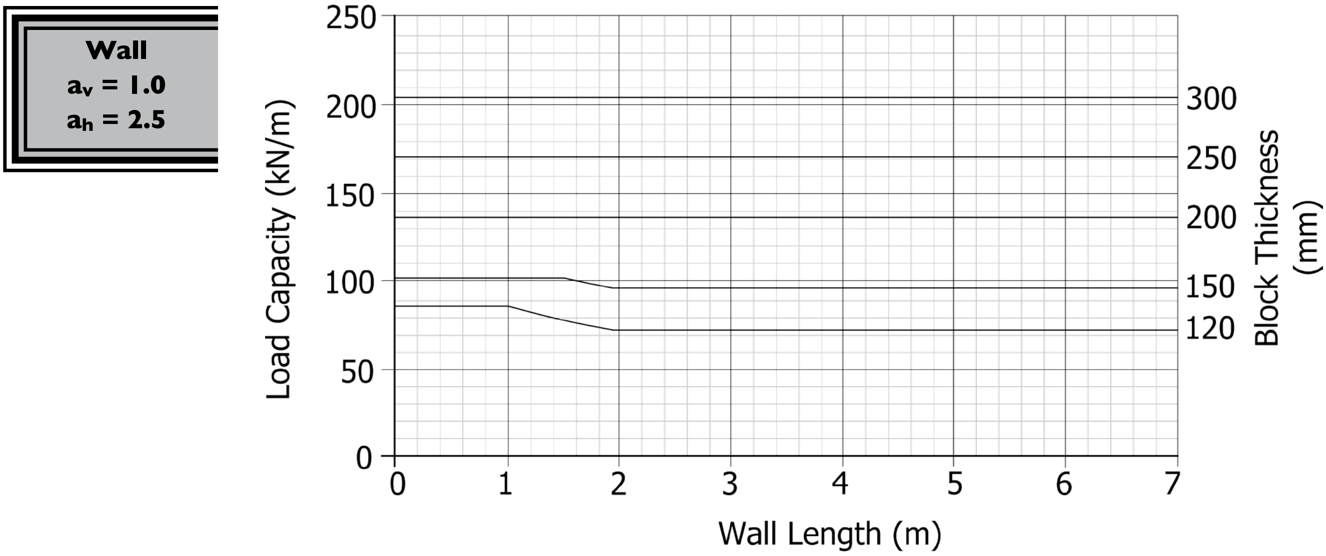


Chart 9 – Supercrete™ Block Walls up to 2.7m Height with Four Edges Laterally Supported and Loaded by a Concrete Slab

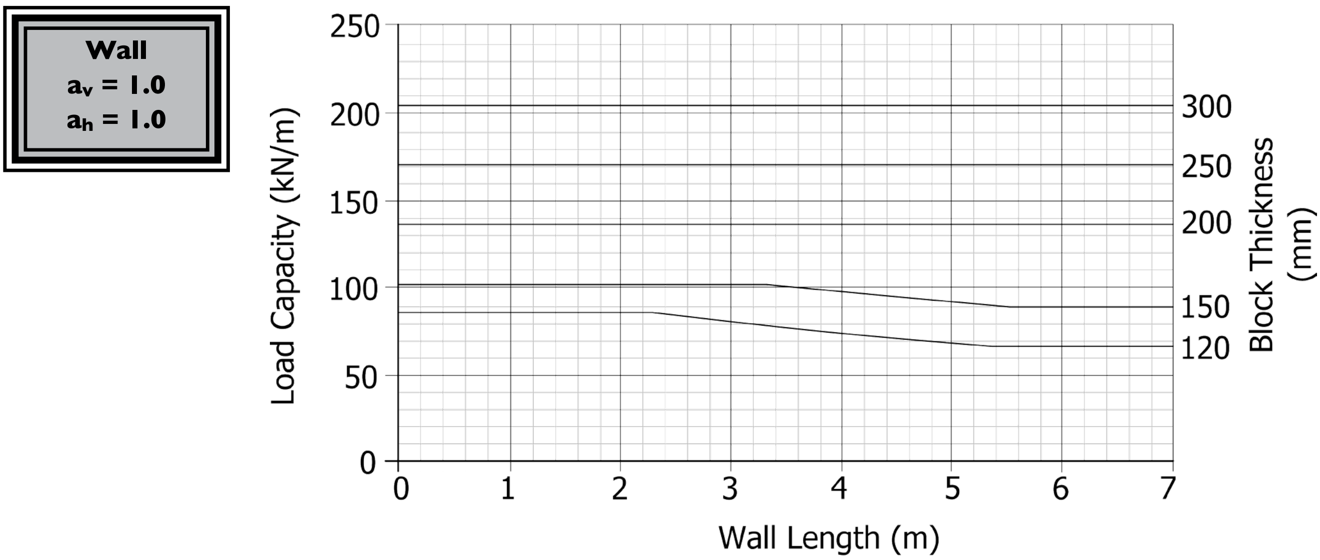


Chart 10 – Supercrete™ Block Walls up to 2.7m Height with One Side Free and Loaded by a Concrete Slab

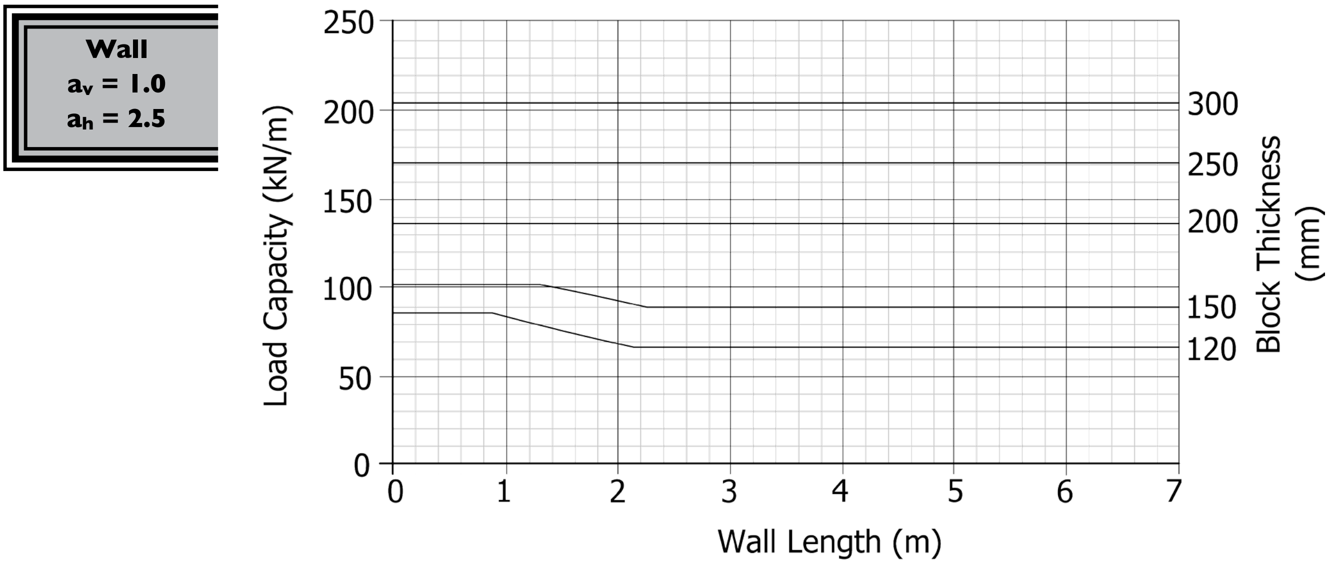


Chart 11 – Supercrete™ Block Walls up to 3.0m Height with Four Edges Laterally Supported and Loaded by a Concrete Slab

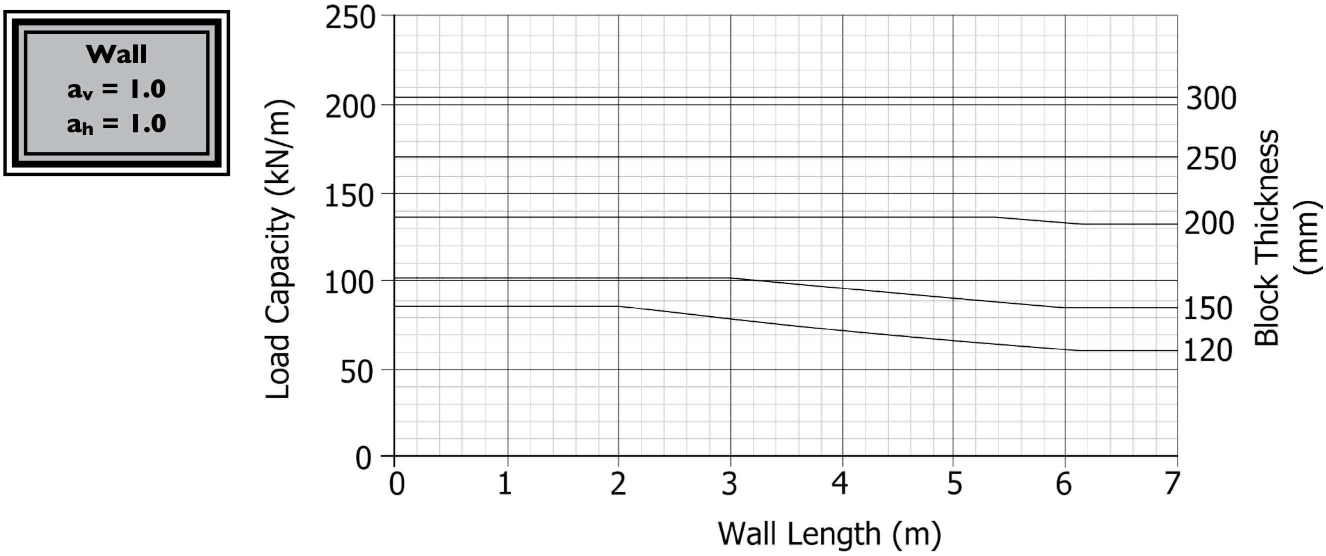
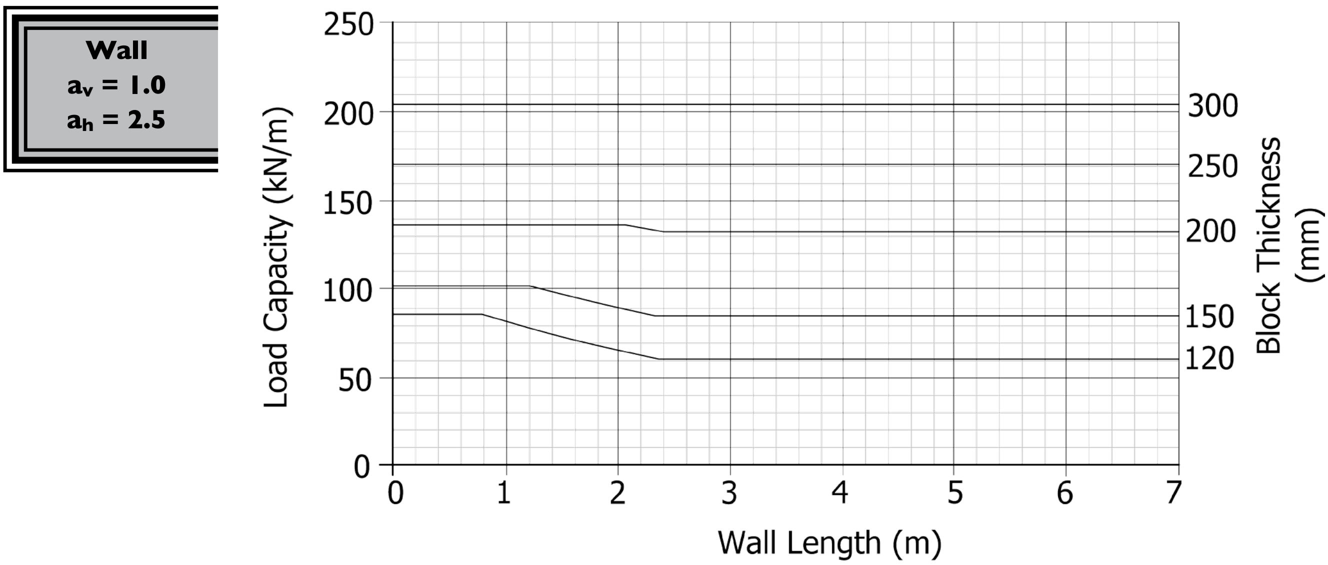


Chart 12 – Supercrete™ Block Walls up to 3.0m Height with One Side Free and Loaded by a Concrete Slab



B2 – Out of Plane Bending Capacity

The load capacity of a wall in bending depends upon various factors including the cross-sectional properties, characteristic flexural tensile strength, characteristic lateral modulus of rupture of the material, and the support conditions at the edges of the wall. Edges can either be free, simply supported, or rotationally restrained. In practice, it is difficult to achieve rotational restraint at the top or bottom edge of a wall and rotational restraint has not been considered in the following design charts even though AS3700 does provide for rotational restraint at the vertical edges. AS3700 Clause 7.4 provides for bending design, where Clause 7.4.2 covers vertical bending, Clause 7.4.3 covers horizontal bending and Clause 7.4.4 covers two-way bending.

Because AAC block behaviour differs from that of masonry block laid with conventional mortar joints AS3700 provides specifically for AAC masonry with thin-bed joints in Clause 7.4.3 and Clause 7.4.4. Chart 13 has been prepared using the vertical bending expressions in Clause 7.4.2, using a characteristic flexural tensile strength (f'mt) of 0.2 MPa and the factor kmt equal to 1.3 as specified in AS3700 for AAC masonry. It has also been prepared using the self- weight of the Supercrete Block since vertical loading increases the vertical bending strength. Chart 14 has be prepared using the horizontal bending expression in Clause 7.4.3.2(b) for Supercrete Block of various thicknesses and also using the appropriate characteristic lateral modulus of rupture for masonry units.

For walls in two-way bending, AS3700 uses coefficients b_v and b_h as shown in Table B2.1 to allow for various support conditions.

Table B2.1 Bending Coefficients (from AS 3700: Table 7.5)

Conditions at Top & Bottom	b_v
Lateral Support at Top & Bottom	1.0
Lateral Support at Bottom only	0.25
Conditions on the Vertical Sides	b_h
Lateral Support on both Sides	1.0

Chart 15 to Chart 20 have been prepared using the above coefficients and the expressions for bending in AS3700 Clause 7.4.4.3 for Supercrete Block walls with heights of 2.4, 2.7 and 3.0 metres. Each chart shows a simple diagram to indicate the various support conditions.

Separate lines are shown on the charts for the available block thicknesses from 75mm to 300mm. Since no wall is to be of length greater than 6m without a control joint charts 13 to 20 are terminated just past this length.

A capacity reduction factor of 0.6 has been used for Charts 13 to 20 as required by AS3700 Table 4.1. The length and height of the wall are clear dimensions inside supports in all cases.

To use the charts, the factored out-of-plane load should be determined in accordance with the relevant NZ standard and compared with the load capacity given by the appropriate chart for the wall height, support configuration and block thickness.

If additional moment capacity is required, there are various options available to the design engineer such as increasing the block size, substituting a different material in that section of wall or encasing a steel frame within the wall.

Chart 13 – Vertical Bending for Supercrete™ Block Walls

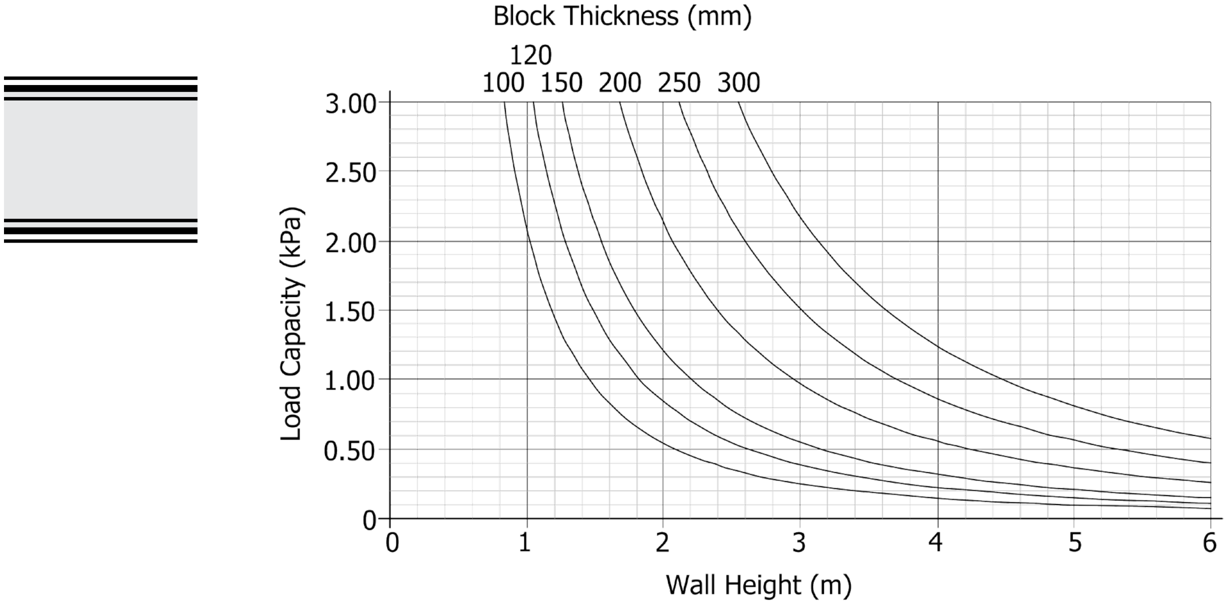


Chart 14 – Horizontal Bending for Supercrete™ Block Walls

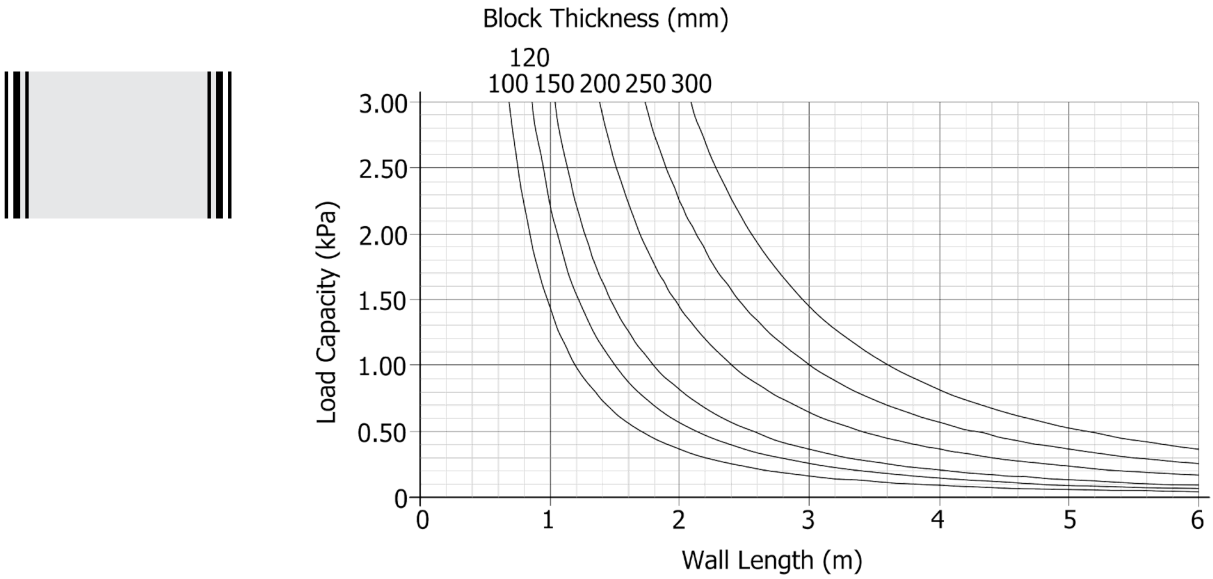


Chart 15 – Two-way Bending for Supercrete™ Block Walls 2.4m High with Four Sides Laterally Supported

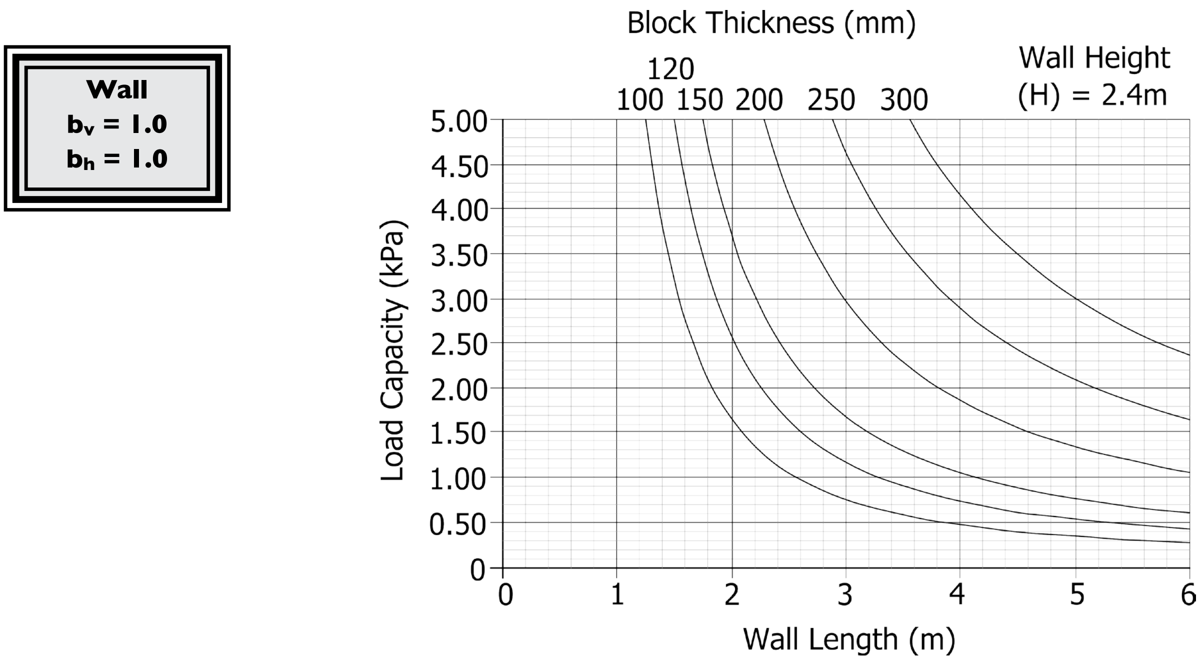


Chart 16 – Two-way Bending for Supercrete™ Block Walls 2.7m High with Four Sides Laterally Supported

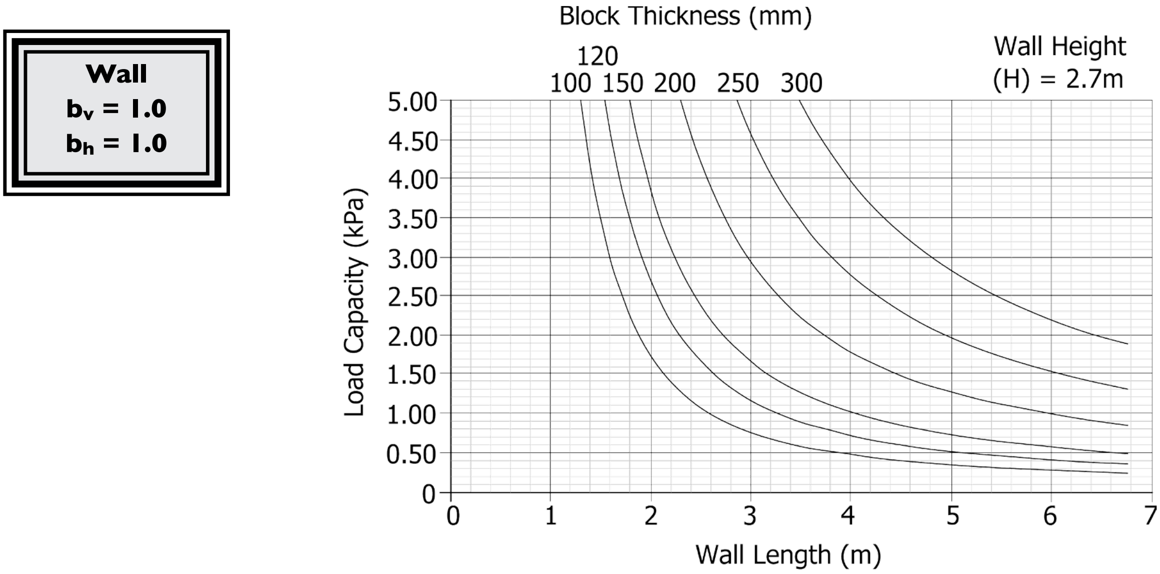


Chart 17 – Two-way Bending for Supercrete™ Block Walls 3.0m High with Four Sides Laterally Supported

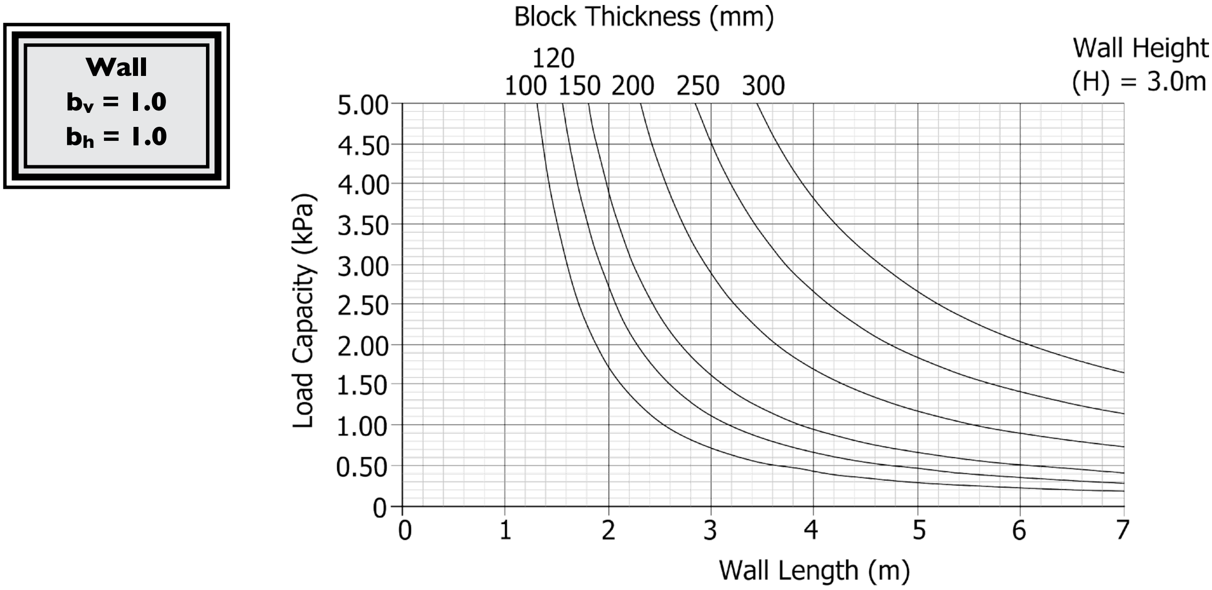


Chart 18 – Two-way Bending for Supercrete™ Block Walls 2.4m High with Top Free and Three Sides Laterally Supported

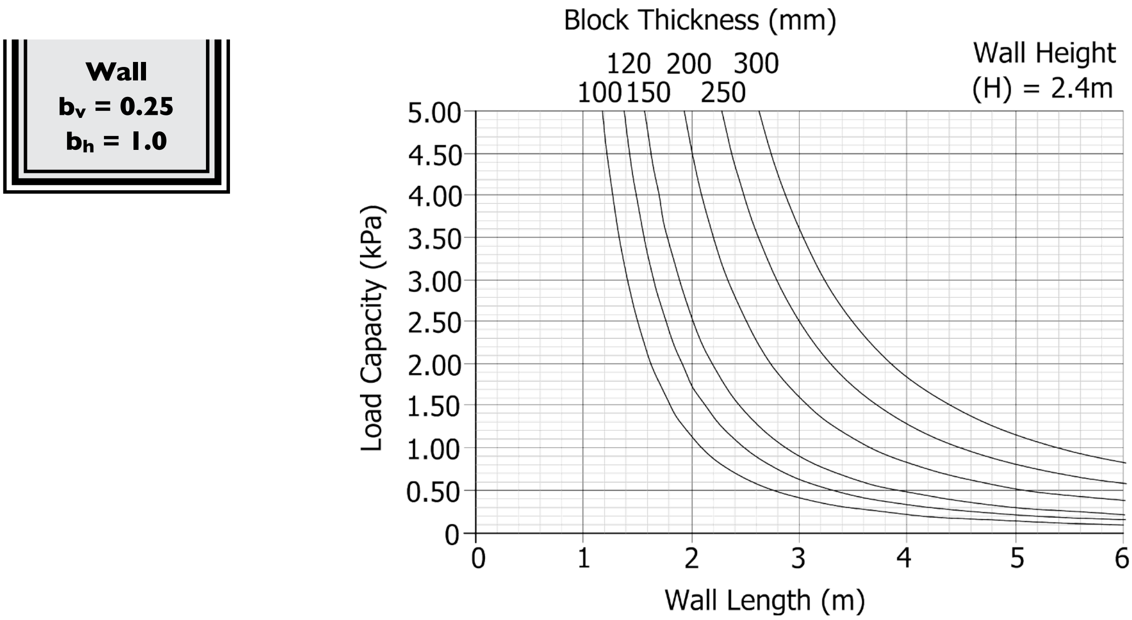
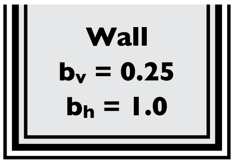


Chart 19 – Two-way Bending for Supercrete™ Block Walls 2.7m High with Top Free and Three Sides Laterally Supported



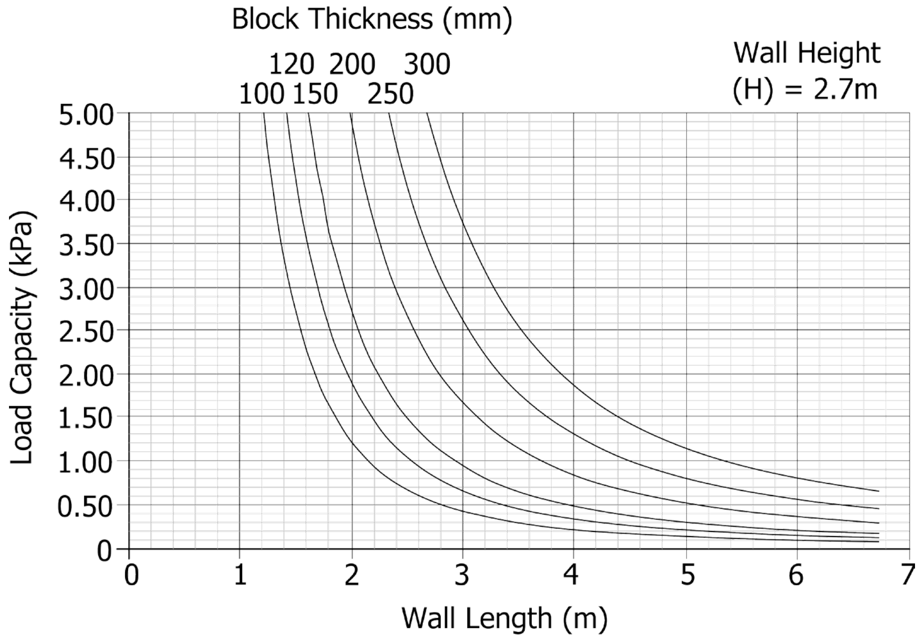
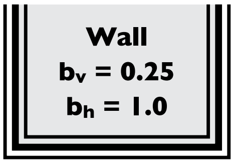
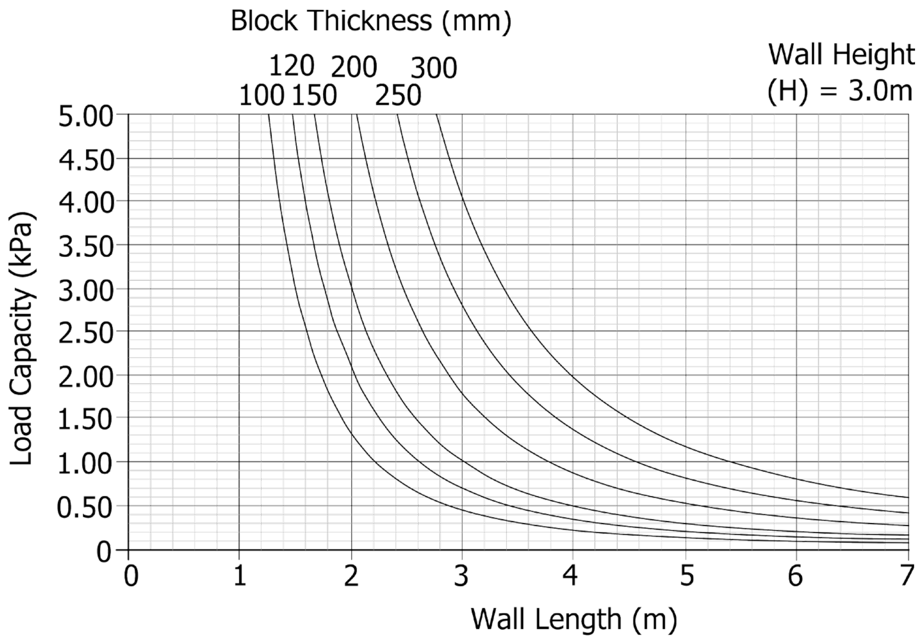


Chart 20 – Two-way Bending for Supercrete™ Block Walls 3.0m High with Top Free and Three Sides Laterally Supported





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