HELIFIX

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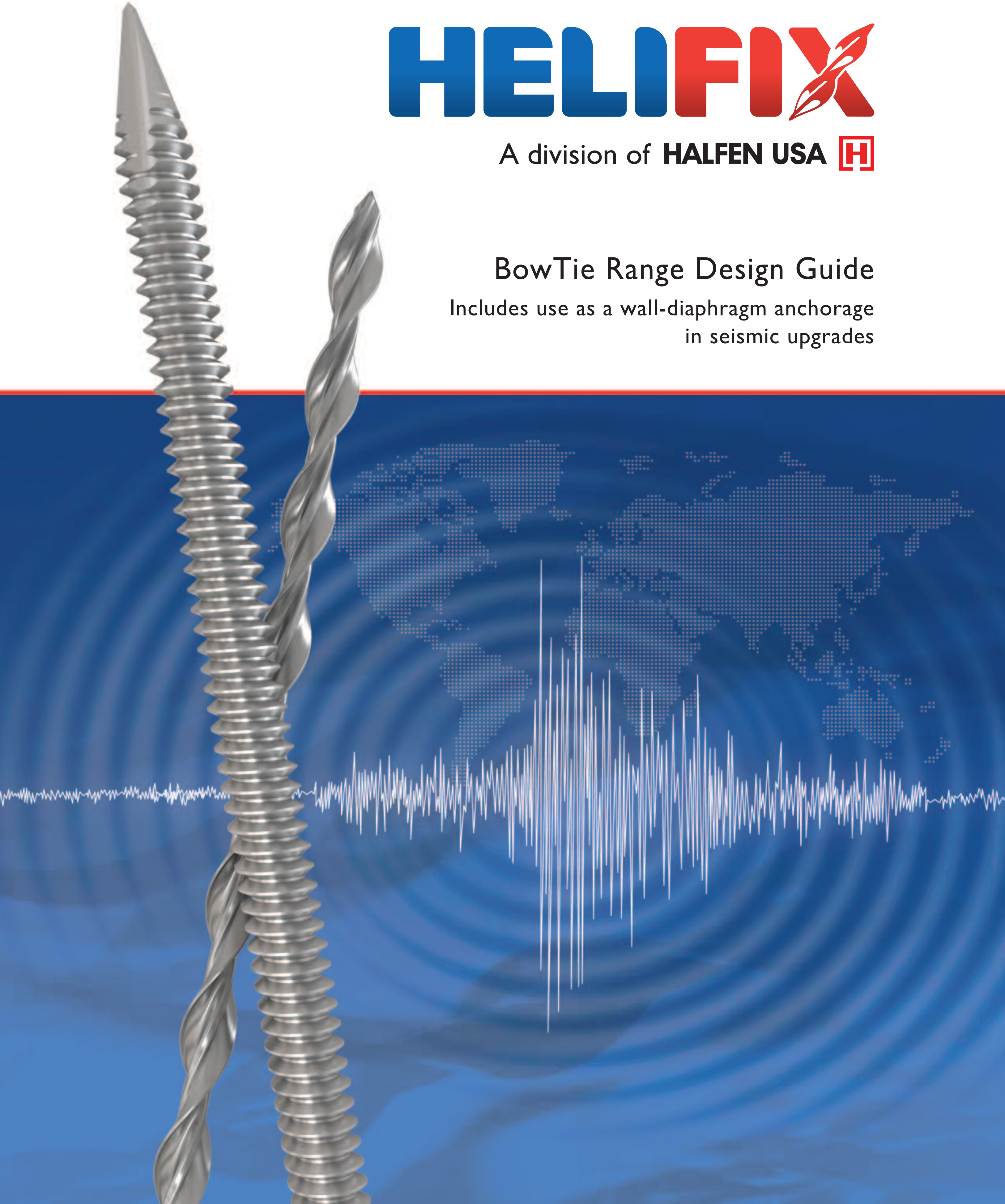
BowTie Range Design Guide

Includes use as a wall-diaphragm anchorage in seismic upgrades



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Contents

The BowTie range

The Helifix BowTie connects masonry walls to internal wood floor or ceiling joists. There are two types of BowTie, the standard BowTie and the BowTie HD.

The standard BowTie is a helically shaped tie manufactured from stainless steel, grade 316, as standard. This tie is used when tying masonry to joist ends. Ties are available in two standard diameters, 8mm (5/16") and 10mm (3/8"), and in a variety of different lengths. Installation requires the use of an electric hammer drill and setting tool to drive one end of the tie into the end of the wood joist to produce a mechanical connection. Access to the joist is achieved by first drilling a small clearance hole through the masonry. HeliBond grout is used to bond the tail of the tie to the masonry. A concealed installation is achieved by patching the entry hole with appropriate matching materials.

The BowTie HD is a larger tie and comprises a more conventional threaded profile. The tie is manufactured from stainless steel, grade 304 as standard. The thread is produced by cold rolling a 9mm (3/8") round bar to leave a threaded rod of nominal 12mm (1/2") diameter. It has a self-cutting tip at one end and a short section of a reduced diameter at the other to allow a fitting tool to be connected for installation. The intended use is tying masonry to joist sides. Installation involves drilling a clearance hole through the masonry before driving the BowTie HD through the first and subsequent joists, using a setting tool fitted to a drill set on rotary only, to create a mechanical connection within the wood. HeliBond grout is used to bond the outer end of the tie to the masonry. A concealed installation is achieved by patching the entry hole with appropriate matching materials.

HeliBond, a high performance, injectable, non-shrink, cementitious grout, is used to bond BowTies to masonry. Refer to the HeliBond technical datasheet for full details, available online.

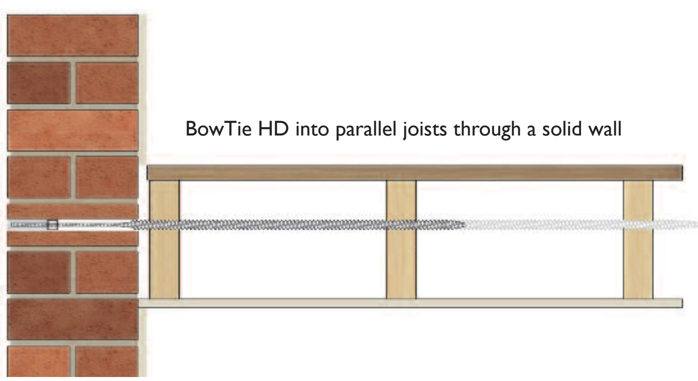
Applications

BowTies are used to stabilize or reinforce building walls by securing the masonry to the wood joists of the internal floor and roof diaphragms. They are installed externally and provide a rapid, reliable and economical solution that is fully concealed as no unsightly external plates are required.

- Quick, easy, non-disruptive external installation
- Self-tapping design – no splitting of timbers
- Effective in all common wall materials
- Suitable for hardwood use
- Easily tested for security of connection
- Fully concealed – no unsightly external plates
- For stabilizing bowed external building walls
- For seismic upgrades

BowTie HD

- BowTie HDs are recommended when installing into joist sides

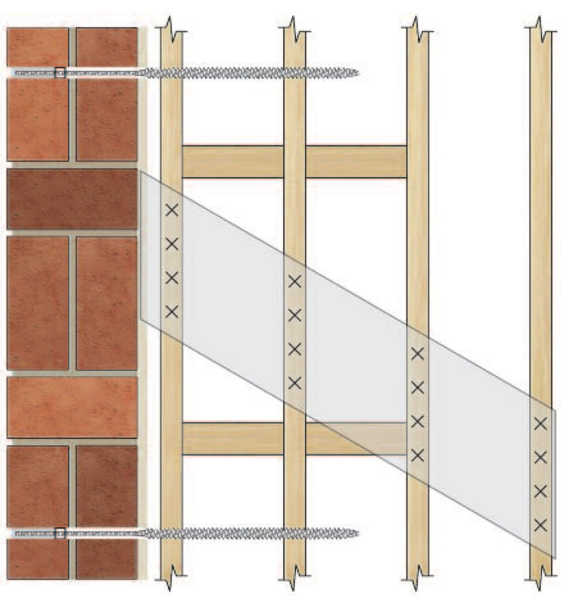


BowTie HD into parallel joists through a solid wall

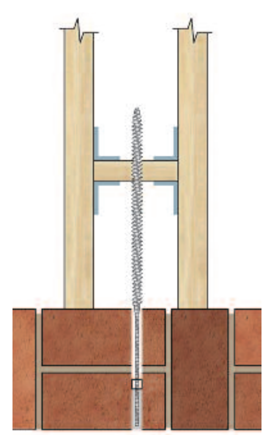
BowTie

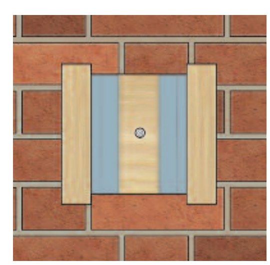
- Standard helical BowTies are recommended when installing into joist ends

BowTie into joist end through a solid wall



BowTie HDs into roof space joists through a solid wall. Additional wood blocking and plywood overlay may be required to create the necessary diaphragm action





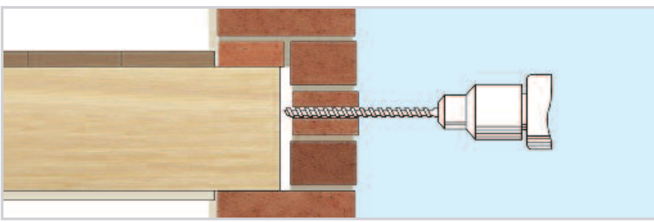
BowTie HD installed through blocker fitted between parallel joists

BowTie

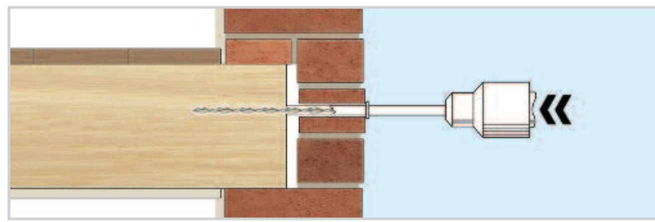
Standard BowTies are used when securing the masonry to the joist ends. Installed externally, the self-tapping helical BowTie is inserted through a clearance hole and power-driven into the joist end before being bonded into the masonry to restrain the bowing wall.

Installation Procedures

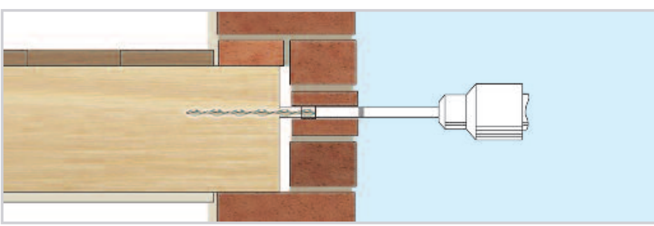
1. Mark the positions of the joists on the external wall.
2. Drill clearance holes, normally 12mm (1/2"), **through the masonry only**, in line with the centre of the joists.
3. Clean out the hole to clear any dust or debris.
4. Fit the power support tool into an SDS rotary hammer drill and insert the BowTie.
5. Drive the BowTie (roto stop) into the joist to the required depth (75mm (3") minimum).
6. Fit the sleeve over the tie and push it to the back of the hole in the masonry (use the support tool).
7. Inject Helifix HeliBond grout into the hole to fill it completely.
8. Make good all holes at the surface with brick dust or matching mortar or leave ready for any decoration.



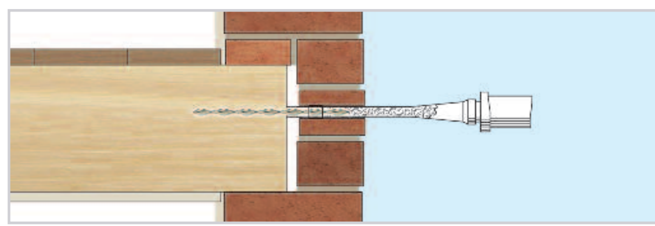
1. Mark the position of the joist centre on the external wall and then drill a clearance hole, normally 12mm (1/2"), through the wall (and first joist if parallel to the wall). Clean out the hole



2. Fit the BowTie Support Tool to an SDS rotary hammer drill, insert the BowTie and drive it into joist end to the required depth – at least 75mm (3") (or through the second joist if parallel)



3. Fit the plastic sleeve over the BowTie and use the support tool to push it to the back of the hole in the masonry (in the outer wythe in a cavity wall)



4. Inject HeliBond grout to fill the hole and bond the BowTie to the masonry and then make good

Technical Specifications

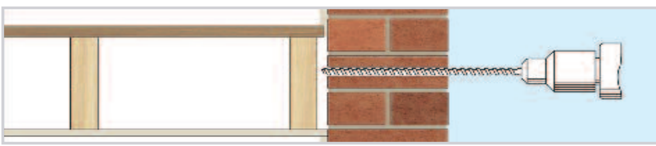
Material:	Austenitic stainless steel Grade 316 as standard (Grade 304 also available)
Diameter:	8mm (5/16") and 10mm (3/8")
Cross sectional area:	BowTie 8mm (5/16") = 10mm² (1/64 in²) BowTie 10mm (3/8") = 15mm² (1/64 in²)
Length:	Thickness of the wall + any cavity + sufficient to drive 75mm (3") minimum into the joist end
Standard lengths:	Cut lengths up to 500mm (20")
Diameter of masonry clearance hole:	12mm (1/2")
Tie density:	As per specification
Bonding agent (near wythe only):	HeliBond cementitious grout
RECOMMENDED TOOLING	
For drilling clearance holes and insertion of BowTies:	SDS rotary hammer drill 650/700w with roto stop
For injection of HeliBond grout:	Applicator gun and injection sleeve
For load testing:	Helifix Load Test Unit

BowTie HD

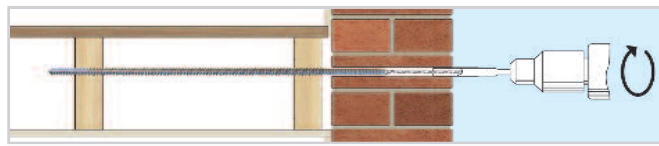
The heavy duty BowTie HD is a 12mm (1/2") diameter threaded bar with a self-cutting end used to secure the wall masonry to two or three parallel joists. Installed externally for minimum inconvenience, the BowTie HD is inserted through a clearance hole and then driven into the first and subsequent joists before being bonded into the masonry.

Installation Procedures

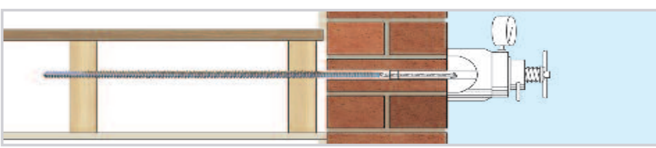
1. Mark the positions of the joists on the external wall.
2. Drill clearance holes, normally 16mm (5/8"), **through the masonry only**, in line with the centre of the joists.
3. Clean out the hole to clear any dust or debris.
4. Fit the power support tool into an SDS rotary hammer drill and insert the BowTie HD.
5. Install the BowTie HD (with hammer off) into and through the first and second joists (and third joist, if specified). When the BowTie HD is between joists, proceed slowly and take care to avoid 'whip'.
6. Fit the sleeve over the tie and push it to the back of the hole in the masonry with the BowTie Injection Tube.
7. Inject Helifix HeliBond grout into the hole to fill it completely.
8. Make good all holes at the surface with brick dust or matching mortar or leave ready for any decoration.



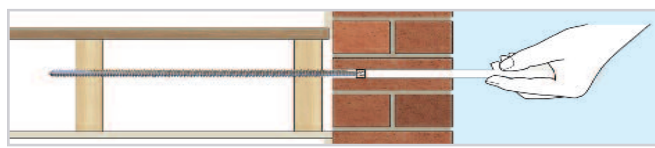
1. Mark the position of the joist centre on the external wall and then drill a clearance hole, normally 16mm (5/8"), through the wall. Clean out the hole



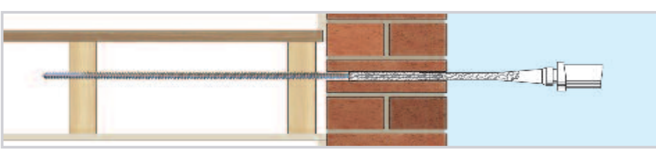
2. Fit the BowTie HD Support Tool to an SDS rotary hammer drill, insert the BowTie HD and drive it (off hammer) into, and through, the first and second joists



3. Test security of anchors in the joists



4. Fit the plastic sleeve over the BowTie HD and use the support tool to push it to the back of the hole in the wall (outer wythe in a cavity wall)



5. Inject HeliBond grout to fill the hole and bond the BowTie HD to the masonry and then make good

Technical Specifications

Material:	Austenitic stainless steel Grade 304 (1.4301)
Diameter:	12mm (1/2")
Cross sectional area:	63mm^2 (3/32in^2)
Length:	Thickness of the wall + any cavity + sufficient to drive into the second parallel joist (or third where specified)
Standard lengths:	1m and 1.5m (40" and 60") – in packs of 5
Diameter of masonry clearance hole:	16mm (5/8")
Tie density:	As per specification. Refer to specification and testing information on page 7
Bonding agent (near wythe only):	HeliBond cementitious grout
RECOMMENDED TOOLING	
For drilling clearance holes and insertion of BowTie HDs:	SDS rotary hammer drill 650/700w with hammer-stop
For installation of BowTie HDs:	BowTie HD driver
For injection of HeliBond grout:	Applicator gun

Specification & Testing

BowTie specifications must take into account the engineering objectives and the physical characteristics and condition of the masonry and wood into which ties are to be installed. Anchorage capacities are dependent on these physical factors and can be expected to vary from building to building. On-site tension testing may be undertaken to confirm achievable loads. Guidance may be sought from results of independent testing listed below (Ismail 2014).

BowTie has been tested in New Zealand using local materials to establish the seismic performance of the system as a wall-diaphragm anchorage. The test programme included laboratory and on-site testing into original hardwood (Rimu), new build wood (H3 treated pine), and historic clay brick masonry.

Characteristic maximum values are presented in Tables 1 and 2. Achievable anchorage capacities will depend on the physical condition of the wood and masonry present at site. Thus appropriate care should be exercised when using these values and appropriate strength reduction factors applied when designing wall-diaphragm anchorages.

Table 1. Maximum achievable BowTie anchorage capacities in wood (Ismail 2014)

BowTie type	Minimum penetration when installed into joist end	Minimum penetration when installed into joist side	Condition of joist	Recommended maximum achievable anchorage capacity (kN)***
10mm (3/8") standard	60mm (2 1/2")	–	Good*	2.0
10mm (3/8") standard	80mm (3 1/8")	–	Good*	3.0
10mm (3/8") standard	100mm (4")	–	Good*	4.0
10mm (3/8") standard	120mm (4 3/4")	–	Good*	4.5
12mm (1/2") HD	–	100mm (4")	Good*	9.0
12mm (1/2") HD	–	100mm (4")	Excellent**	17.0
12mm (1/2") HD	–	150mm (5 7/8")	Excellent**	17.0

* Hard wood such as Rimu that has no signs of excessive moisture or rot, with borer less than 5% of the total surface area.
** Machine graded new H3 joists. *** Achievable loads should be tested on site.

Table 2. Maximum achievable BowTie anchorage capacities resin-fixed into masonry (Ismail 2014)

BowTie type	Minimum effective embedment	Minimum thickness of the wall	Min URM* sliding shear strength (kPa)	Maximum achievable anchorage capacity (kN)**
8mm (5/16")or 10mm (3/8") standard	70mm (2 3/4") to 210mm (8 1/4")	–	–	3 to 5
12mm (1/2") HD	210mm (8 1/4")	220mm (8 5/8")	150	11
12mm (1/2") HD	310mm (12 1/4")	330mm (13")	150	13.5

* Unreinforced masonry must be free from any apparent cracking/damage, and anchors installed in bricks not mortar beds.
** Achievable loads should be tested on site.

Design Guidance[†]

Notation

b_w	Wall thickness (m)
$C(0)$	Site hazard coefficient for $T_p = 0$ sec (fraction of g)
C_{Hi}	Floor acceleration coefficient for level i (constant)
$C_i(T_p)$	Part spectral shape factor at level i (constant)
$C_p(T_p)$	Horizontal acceleration coefficient (fraction of g)
g	Acceleration due to gravity (m/sec²)
h_e	Wall height (N)
h_i	Height of the hinge location (m)
h_n	Total height of the structure (m)
N(0,D)	Near-fault factor (constant)
N_t	Axial load due to upper storeys (N)
R	Return period factor (constant)
R_p	Part risk factor (constant)
T_p	Natural period of the wall (sec)
V_o*	Design out-of-plane lateral force (N)
W_w	Self weight of the wall (N)
Z	Seismic hazard factor (constant)
γ	Modal participation factor (constant)

Step 1

Calculate seismic demand (V_o*)

The first step in the design of a parapet restraint is to establish the design lateral seismic forces. A linear static analysis procedure, the Equivalent Static Lateral Force Method, is normally performed for assessing strength demands on an out-of-plane URM parapet wall when subjected to a design level earthquake. Although URM response is highly inelastic and nonlinear, the outlined detailed linear static method provides a reasonable estimate of the seismic demands. The procedure reproduced herein was adapted by Ismail (2014) from NZS1170.5 loading standards (2004) and NZSEE guidelines (2006) for the assessment of out of-plane URM walls. Figure 1 shows the flow chart for the calculation of seismic demands on the anchorage.

Design out-of-plane lateral force for URM walls can be calculated in accordance using NZS 1170.5 (2004) defined spectra for parts and portions (refer Equation 1), where $C_p(T_p)$ is the horizontal acceleration coefficient; γ is the modal participation factor for the rocking system; R_p is the part risk factor and is taken as 1; and W_w is the weight of the wall tributary area.

EQUATION 1

$$V_o^* = C_p(T_p)\gamma R_p W_w$$

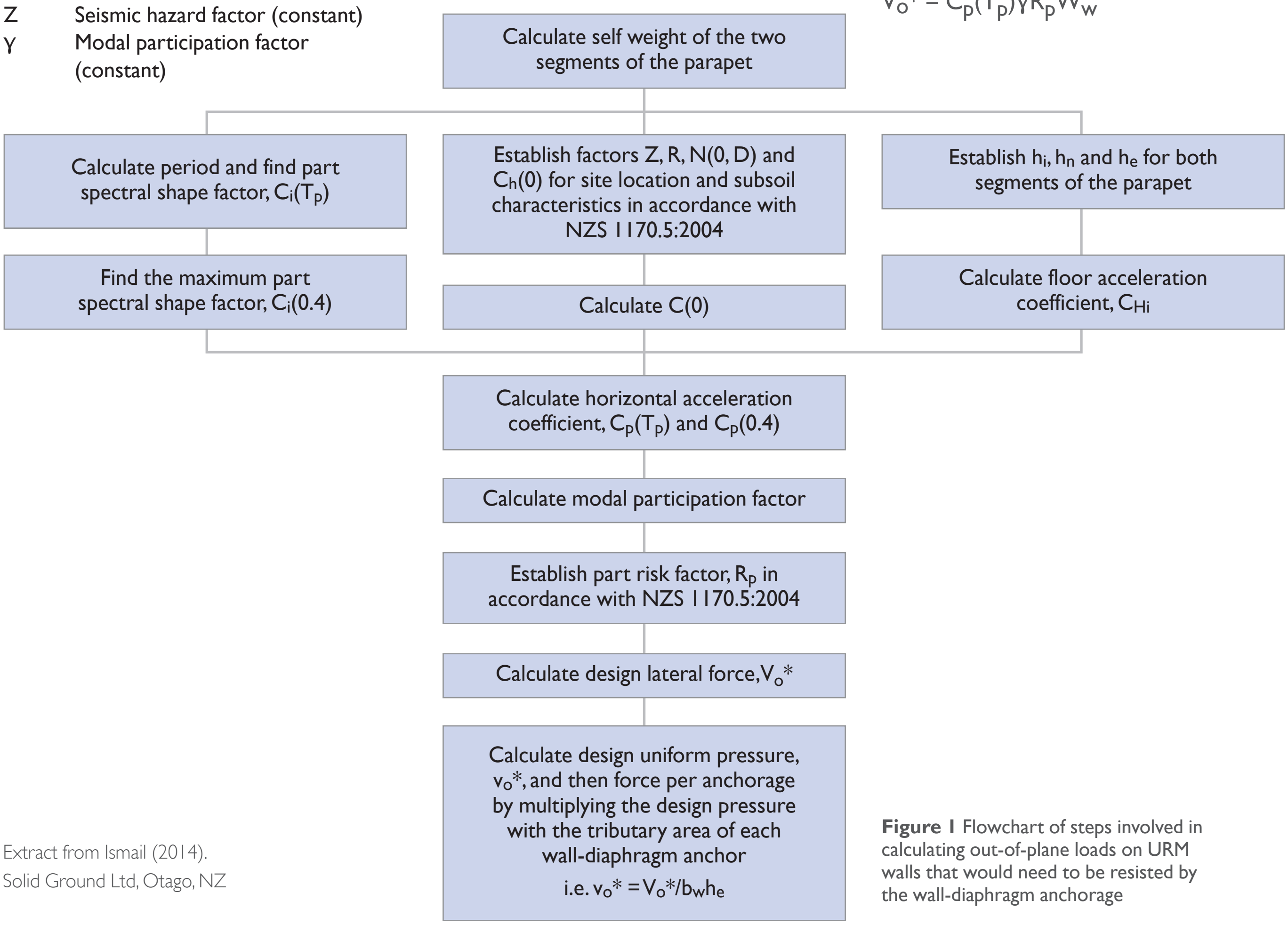


Figure 1 Flowchart of steps involved in calculating out-of-plane loads on URM walls that would need to be resisted by the wall-diaphragm anchorage

† Extract from Ismail (2014). Solid Ground Ltd, Otago, NZ

For loads on out-of-plane URM walls supported by flexible diaphragms, a design horizontal acceleration coefficient for the level of structure that supports the wall, $C_P(T_P)$, is calculated using Equation 2. Where C(0) is the site hazard coefficient for Tp = 0 sec and is calculated in accordance with values suggested by NZS 1170.5 (2004) as given by Equation 3; C_{Hi} is the floor acceleration coefficient for level i; and $C_i(T_P)$ is the part spectral shape factor at level i.

EQUATION 2

$$C_p(T_p) = C(0)C_{Hi}C_i(T_p)$$

EQUATION 3

$$C(0) = C_h(0)ZRN(0,D)$$

Where $C_h(0)$ is the spectral shape factor for $T_P = 0$ sec, values for different soil type profiles; Z is the seismic hazard factor and must be determined in accordance with Section 3.1.4 of NZS 1170.5 (2004); R is the return period factor and must be determined in accordance with Section 3.1.5 of NZS 1170.5 (2004) but limited such that ZR does not exceed 0.7; N(0,D) is the near-fault factor and must be determined in accordance with Section 3.1.6 of NZS 1170.5 (2004).

The floor acceleration coefficient, C_{Hi}, is calculated using either of Equations 4 to 6 as appropriate for the floor height, h_i, and if two height limitations are satisfied then the smaller of the two is used. In Equations 4 to 6, h_i is the floor height supporting the out-of-plane loaded URM walls and h_n is the total height of the structure. The part spectral shape factor, $C_i(T_P)$, is calculated using Equation 7, where T_P is the natural period of the URM wall.

EQUATION 4

$$C_{Hi} = \left[1 + \frac{h_i}{6}\right] \qquad \text{for all } h_i < 12 \text{ m}$$

EQUATION 5

$$C_{Hi} = \left[1 + 10\frac{h_i}{h_n}\right] \qquad \text{for } h_i < 0.2\, h_n$$

EQUATION 6

$$C_{Hi} = 3 \qquad \text{for } h_i \geq 0.2\, h_n$$

EQUATION 7

$$C_i\,(T_p) = 2(1.75 - T_p) \text{ and } 0.5 < C_i(T_p) < 2.0$$

The natural period for a URM wall is established by solving the equation of motion for free vibration. Typically, URM walls can either have one way bending deformation mode when supported between two adjacent diaphragms or perform as cantilever when supported at the base only. Based on the location of hinges and the boundary conditions, equations of motion for free vibration/ rocking were solved and Equations 8 and 9 were established for continuous and cantilever boundary conditions respectively.

EQUATION 8

$$T_p = \sqrt{\frac{0.67h_e}{\left(1 + 2\frac{N_t}{W_w}\right)}}$$

EQUATION 9

$$T_p = \sqrt{2.67\left[1 + \left(\frac{b_w}{h_e}\right)^2\right]}$$

Where W_W is the self-weight of the wall, N_t is the axial load due to upper storeys, b_W is the wall thickness and h_e is the wall height. However, for anchorage design a maximum horizontal acceleration coefficient Cp(0.4) of Tp = 0.4 sec may be used in the calculation of design out-of-plane lateral forces. Likewise for out-of-plane loaded walls having an aspect ratio of more than 10 and a small overburden weight, a maximum modal participation factor of 1.5 can be used. However, for squat walls with large overburden weights, a modal participation factor for the rocking system is calculated using Equation 10 and 11 for continuous and cantilever boundary conditions respectively.

EQUATION 10

$$Y = \frac{W_w h_e^2 g}{8[0.083W_w(h_e^2 + 16b_w^2) + 2.25N_t b_w^2]}$$

EQUATION 11

$$Y = \frac{1.5}{\left[1 + \frac{b_w}{h_e}\right]}$$

Where W_W is the self-weight of the wall, N_t is the axial load due to upper storeys, b_W is wall thickness, g is accelerations due to gravity and has a value of 9.81 m/sec^2, and h_e is the wall height.

For a laterally braced URM parapet wall, the portion of parapet above bracing support acts as cantilever wall and the parapet portion between the bracing support and roof anchorage acts as face loaded two-way URM wall. Accordingly, the wall-bracing anchorages are designed for a lateral force based on the tributary area for the bracing support and the calculated uniform seismic lateral force. Figure 2 shows the deflected shape of an out-of-plane loaded wall.

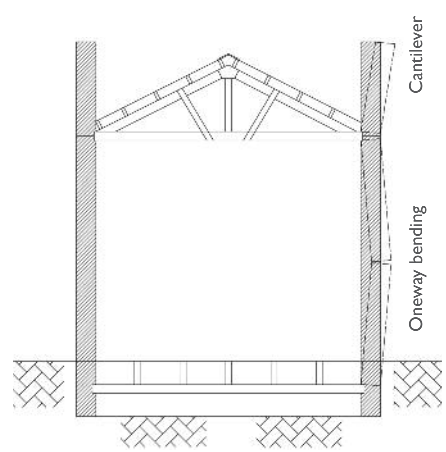


Figure 2 Deflected shapes of a properly secured URM wall when subjected to out-of-plane seismic forces

It must be noted that if wall-diaphragm anchorage is insufficient at each floor level then the wall would behave as a cantilever over the full height, resulting in an extremely small out-of-plane strength.

Step 2

Calculate capacity of one wall-diaphragm anchor (B_n)

Based on the testing results, it can be inferred that the tension capacity of a Helifix BowTie HD, when installed as a wall-diaphragm anchorage, is governed by either steel yielding, or a tensile breakout of masonry/wood, whichever is smaller. Steel yielding has been well studied and documented in building standards (MSJC 2005; ICC 2010) and can be estimated by using Equation 12.

EQUATION 12

$$øB_{an} = øA_b\,0.75f_u$$

and for $ø=0.9$, $\qquad øB_{an} = 0.68A_bf_u$

Where: **ø** = strength reduction factor and has a recommended value of 0.9 (MSJC 2005); A_b = is the effective cross sectional area of the BowTie HD and f_u = ultimate tensile strength of BowTie HD (typical value for ASTM 304 stainless steel f_u = 520 MPa).

This results in a maximum dependable tension capacity for one 12mm (1/2") BowTie HD of 11.34 kN. Whereas the tensile breakout capacity of masonry is given by Equation 13 in MSJC standards (MSJC 2005).

EQUATION 13

$$øB_{an} = 0.332\,øA_{pt}\,(f_m)^{1/2}$$

Where: A_{pt} = projected area on masonry surface of a right circular cone that can be calculated as πl_b^2 where l_b is the effective embedment length of the BowTie HD; and f_m = masonry compression strength. The MSJC standards (MSJC 2005) recommends a **ø** value of 0.5 for masonry breakout. After substituting the value of strength reduction factor and based on recent comprehensive New Zealand based research on URM materials (Lumantarna 2012) it is deemed that use of masonry flexural bond strength (f_{fb}) is more appropriate measure of masonry tensile breakout. Therefore, Equation 14 is recommended herein for calculating the anchorage capacity of BowTie HD when installed in New Zealand old URM:

EQUATION 14

$$øB_{an} = 0.5A_{pt}f_{fb}$$

It is noted here that f_{fb} can be determined more accurately by undertaking onsite testing. Typical value of f_{fb} for pre-1930 URM buildings ranges from 0.1 – 0.4 MPa.

The shear strength of the Helifix BowTie HD can similarly be calculated using the Equations 15 and 16, corresponding to strength of the system associated to tie failure and masonry failure, respectively.

EQUATION 15

$$øB_{vn} = 0.5A_bf_u$$

EQUATION 16

$$øB_{vn} = 0.5A_{pv}f_{fb}$$

Where: A_b = is the effective cross sectional area of the BowTie HD; f_y = tensile yield strength of BowTie HD stainless steel (typical value for ASTM 304 stainless steel f_y = 200 MPa); A_{pv} = projected area on masonry surface of one-half of a right circular cone that can be calculated as $0.5\pi l_{be}^2$ where l_{be} is the smaller of edge distance or effective embedment length of the BowTie HD; and f_m = masonry compression strength.

The withdrawal strength of a BowTie HD can be estimated by considering mechanical action between wood and tie bar. Equation 17 is a simplified, empirical equation developed with the experimental results and may be used to estimate the anchorage capacity of Helifix BowTie HD when installed in wood joists.

However, it is noted here that the bending strength of joists, strength of associated hardware, load path continuity, and diaphragm strengths be checked using NZS3603: Wood Structures Standards to allow transfer of additional lateral force transferred from BowTie HD to diaphragm joists.

EQUATION 17

$$ø\,B_{tn} = øl_bf_{ct}$$

Where: **ø** B_{tn} = the nominal tensile anchorage capacity of BowTie HD; **ø** = strength reduction factor, 0.9 recommended for new Raidata Pine wood joists and 0.5 for old wood joists of existing URM buildings; l_b = effective embedment length of BowTie HD; and f_{ct} = bearing strength per mm embedment of BowTie HD in wood i.e. 170 N/mm. Note that the effect of age of wood joists has been accounted for in the recommended strength reduction factors.

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Design Example

Step 1

Demand on wall-diaphragm anchorage B_u

Let us say we have calculated uniform lateral pressure on a URM wall using NZS1170.5 parts and portions spectra and it is:

$v_o^* = 3.89\ kN/m^2$

If BowTie HD is installed every X m centre to centre spacing then we get a demand on each BowTie HD by calculating the tributary area.

$B_u = X \times 3.300 \times 3.89 = 12.84X\ kN$

Step 2

Capacity of wall-diaphragm anchorage

For the URM wall data, found from investigation, given in Table 1 we can then estimate capacity of a Helifix BowTie HD.

Parameter	h_e m	b_w mm	t_j mm	d_j MPa	f_{fb} MPa	s_j mm	Joist notes
Value	10	210	39.4	1.4	0.18	0.09	Good condition Rimu

Where: h_e = effective height of URM wall between two adjacent lines of wall-diaphragm anchors; b_w = nominal thickness of URM wall; t_j = width of diaphragm joists; f_{fb} = masonry flexural bond strength; d_j = depth of diaphragm joists; and s_j = spacing of diaphragm joists.

It is also found that the diaphragm has sufficient sub-diaphragm action to transfer the total anticipated lateral force to the rest of diaphragm.

i: Tensile strength of BowTie HD with $A_b = 60\ mm^2$ and $f_u = 520$ MPa

$ø\ B_{an} = 0.68 A_b f_u$
$ø\ B_{an} = 0.68 \times 60 \times 520 = 21{,}216$ N or 21.21 kN

ii: Masonry tensile breakout strength for 12 mm BowTie HD and HeliBond standard installation

$ø\ B_{an} = 0.5\ A_{pt} f_{fb}$ where $A_{pt} = \pi l_b^2$

For a typical BowTie HD installed from exterior face of the wall, $l_b = b_w$

$A_{pt} = 3.1415 \times (210)^2 = 138540.15\ mm^2$
$ø\ B_{an} = 0.5 \times 138540.15 \times 0.18$
$ø\ B_{an} = 12.47$ kN

iii: Bearing strength of BowTie HD in Wood joists

$ø\ B_{tn} = ø\ l_b f_{ct}$
$ø = 0.5$ (for installation in damage free good condition existing Rimu joists)
$f_{ct} = 170$ N/mm (recommended for BowTie HD based on experimental investigations)
$l_b = 100$ mm (when installed from side of two 50 mm (2") wide joists)
$ø\ B_{tn} = 0.5 \times 100 \times 0.17$
$ø\ B_{tn} = 8.5$ kN
Nominal anchorage capacity of BowTie HD = 8.5 kN

Step 3

Required spacing of the BowTie HD

8.5 kN = 12.84X kN

X = 0.66199 m or say round to nearest 50 mm (2") or 100 mm (4")

The recommended spacing then can be 600 mm (23 5/8") o.c.

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