Centre for Building Performance Research

Retrofitting House Foundations to Resist Earthquakes
A Literature Review

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Introduction:

If a major earthquake were to occur in New Zealand many thousands of houses would be severely damaged. Post earthquake, these houses would no longer provide a safe environment for their occupants and would in turn become a liability in terms of costly repair. “Many of the houses [in New Zealand] that were considered ‘weak’ were built prior to the introduction of formal construction Standards.”[a] Thus this fragility is a paramount issue in New Zealand dwellings. To minimise damage and post earthquake paralysis, retrofitting of building subfloor and foundations is of paramount consideration. This is the focus of this report; divided into six sections of common foundation types occurring in New Zealand the report outlines retrofit details to increase earthquake performance and decrease the damage and need for repair post earthquake. These six types of foundation include internally piled foundations, full piled foundations, partial foundation walls, full foundation walls, full foundation walls/internal piles and slabs on ground. These six types relate very closely to New Zealand conditions to ensure that this report is meticulously aligned to the dwellings it aims to benefit.

[a] Thomas, G C and Irvine, J D. *The Adequacy of House Foundations for Resisting Earthquakes: the Cost-Benefit of Upgrading; EQC Non-Biennial Project 6UNI/530.* Victoria University of Wellington, Wellington, 2007, p 9.

Definition of Retrofit:

Retrofitting involves the improvement of the details and connections of a dwelling foundation and subfloor whilst keeping as much of the dwelling itself in tact and untouched. Limitations in this type of construction include the tight and confined spaces often found in a dwelling subfloor, dealing with damp, moisture and rot which may occur, and mitigating the negative effects of previous construction methods which no longer meet today's standards. The benefits of remedial work however are sound and positive; reducing the possibility of evacuation, death or injury, improving the likelihood of continued building use post earthquake, improving health and safety and reducing repair cost, especially important at a time when inflation occurs and labour and materials are in strong demand.

Report Structure:

The following section on foundation types and appropriate retrofit details is divided into the six sections outlined in the introduction above. These types of foundations are defined and details and research outlined which relate specifically to that particular foundation type. Following this section is the annotated bibliography, where the articles, conference proceedings, theses, websites and books consulted are noted and their relevance and information content discussed. An appendix has been included at the conclusion of this report containing additional information which may be perused.

Foundation Types and Appropriate Retrofit Details:

Internally Piled Foundation:

This consists of a piled foundation system where piles on the exterior perimeter support the roof and superstructure and interior piles support loads from the floor(s) and internal walls. Often a jack stud is employed between the pile and the wall plate.[b]
Note: As jack studs also occur in Full Foundation Wall foundation types, details on retrofitting such foundations are included in the Full Foundation Wall section of this report.

The following five details have been suggested for use in a retrofit of an internally piled foundation by James Irvine, in his thesis *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* The first two details illustrate remedial pile solutions, both of which are seen in NZS3604:1999. The major limiting factor for the braced pile solution is the placement and the height of the foundation; it requires a minimum of 450mm between the bearers and CGL so will not apply to all dwellings of this foundation type.

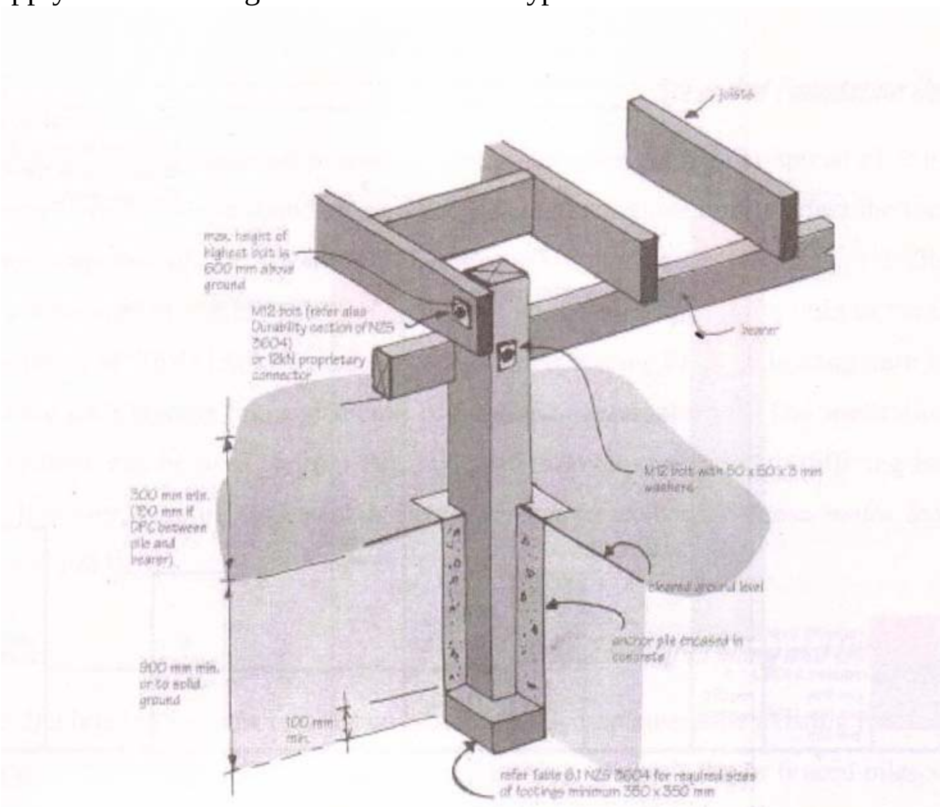


Figure 1
Anchor Pile Solution
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 164.

[b] Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 45.

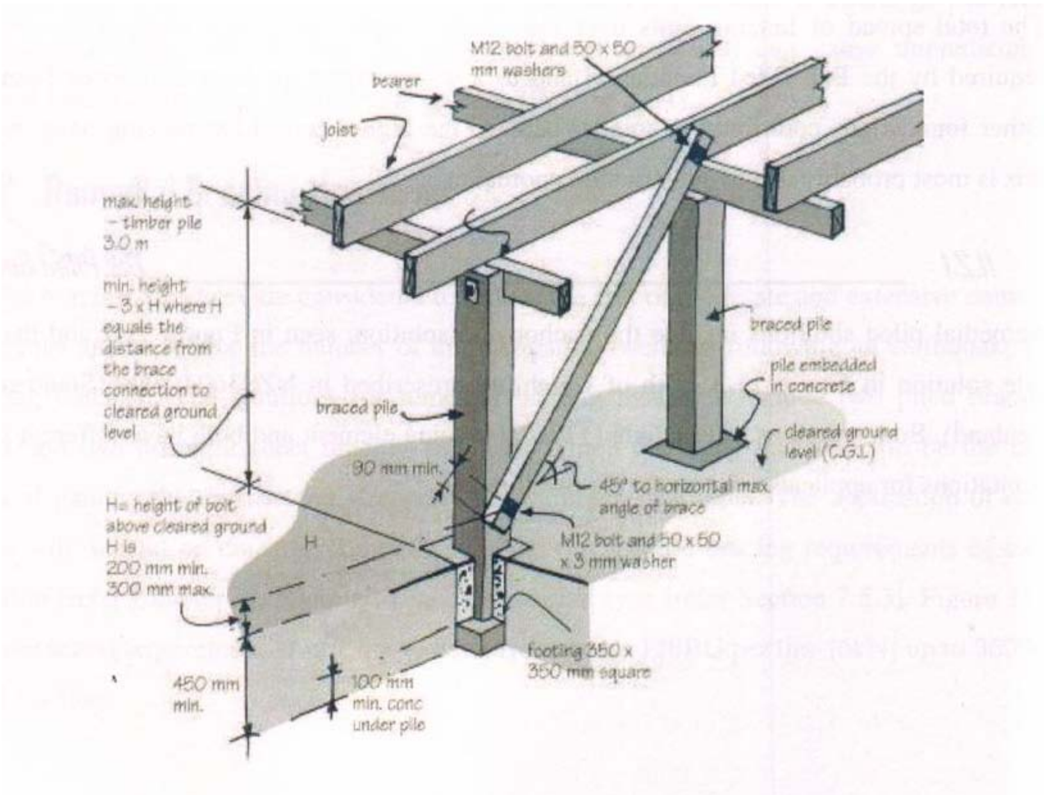


Figure 2
Braced Pile Solution, Braced from Pile to Joist
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 164.

Bracing of this type of foundation with a plywood panel is ideal as the strength, ease of application and finish of this panel is superior to that of a cement sheeting panel. The figure below illustrates a sheet bracing remedial solution and requires constructing framing between piles and fixing the perimeter directly to this framing. This is thus much cheaper if the piles are timber.

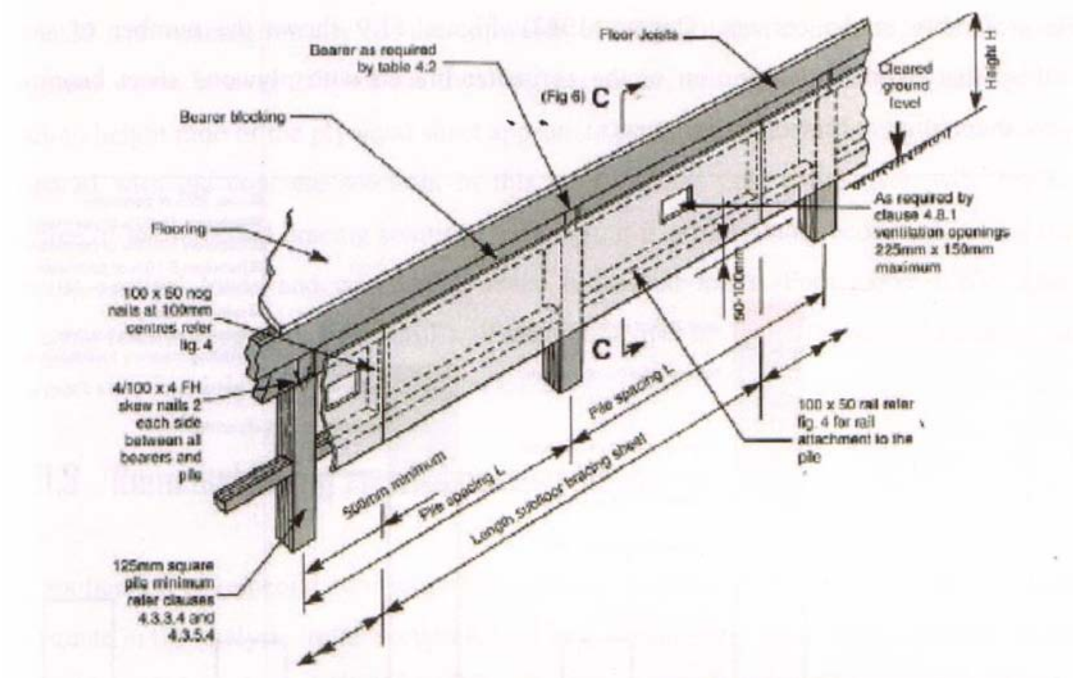


Figure 3
Sheet Bracing Remedial Solution
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 167.

Alternatively, concrete piles may have a concrete infill wall cast between them. The bracing element must be integrally cast with the existing footings of the dwelling foundation. It is recommended that dwellings with a heavy roof type or a larger area (over 100square metres) should have longer infill walls to meet bracing requirements. This concrete infill wall remedial solution is illustrated below.

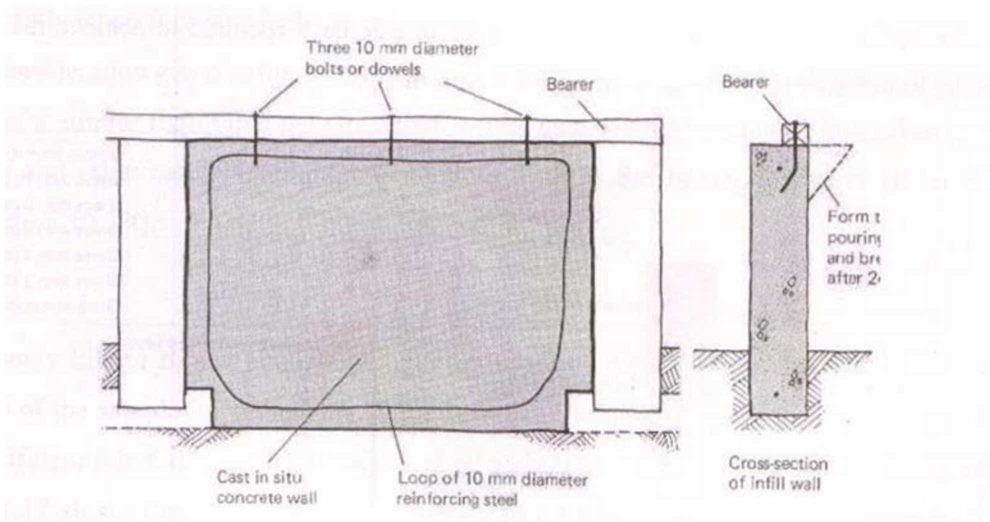


Figure 4
Concrete Infill Wall Remedial Solution
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 167.

Connections within foundations are very important; a foundation of this type may require remedial fixings. Below two fixings are detailed; depending on joist size the Z nails may be a more appropriate choice if the skew nails are not able to be driven.

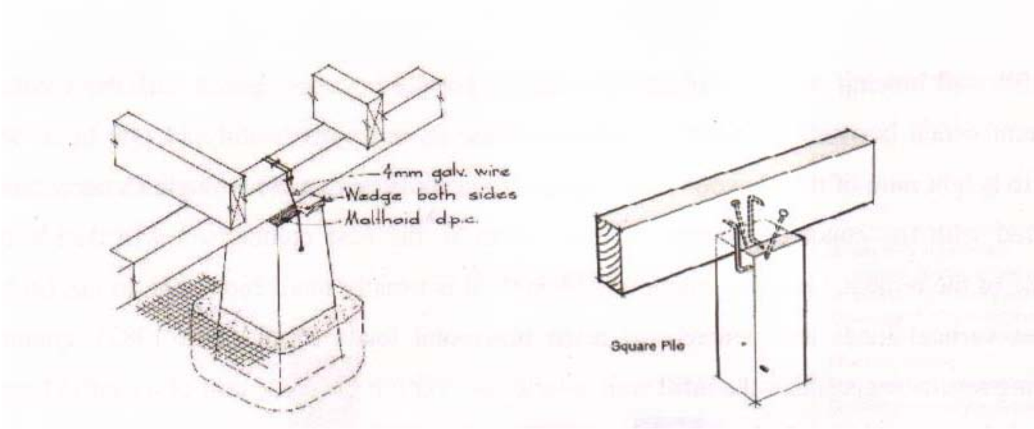


Figure 5
Left: Fixing of Bearer to Concrete Ordinary Pile Solution; Right: Fixing of Bearer to Timber Ordinary Pile Solution
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 171.

There has also been research conducted aiming to repair timber beams, which may prove relevant in this foundation type if joists or bearers are damaged. Fibreglass pultroded rods are inserted from the bottom to the top of the beam in areas of damage. Adhesive is used to bond the reinforcing rods to the timber and also to fill adjacent cracking in the beam.
The proposed repair strategy uses a high performance, low cost material which can be readily bonded to wood (see Figure 6).

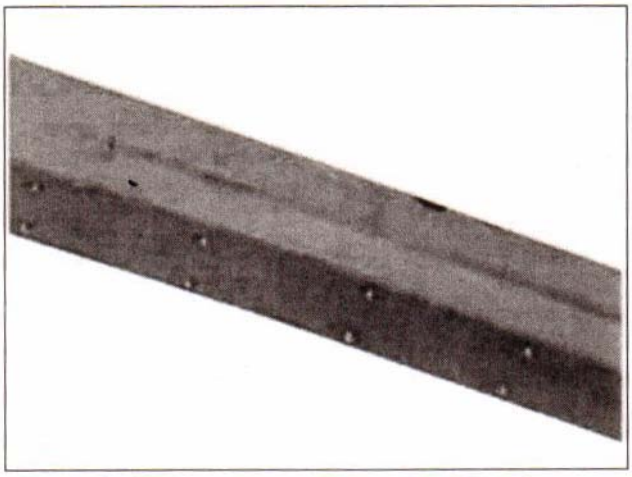


Figure 6
Proposed Shear Spike Repair Concept
Source: Radford, DW and Van Goetham, D and Gutkowski, RM and Peterson, ML. *Composite Repair of Timber Structures*. In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2002, vol 16, p 419.

The results of this experiment indicate that the fibreglass insertions recapture “both stiffness and strength of the undamaged material. Enhanced repair performance is directly related to the number and position of the shear reinforcing rods.”[c] The addition of the epoxy adhesive further increases the success and performance of the repair, and improves stiffness and strength in areas of damage. The combination of fibreglass insertions and epoxy is substantially more effective than either method applied alone.
Although this is a method designed for very deep beams, it has potential for application in seismic retrofitting of dwelling subfloors where beams or joists have been damaged but cannot be removed

[c] Radford, DW and Van Goetham, D and Gutkowski, RM and Peterson, ML. *Composite Repair of Timber Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2002, vol 16, p 425.

and replaced. On a smaller scale this method represents a retrofit repair able to reinstate the original strength and stiffness of the member.

Graeme Beattie, a researcher at the Building Research Association of New Zealand has conducted many investigations into seismic design and retrofit at a domestic scale. The following six details have been designed by Beattie; these are to be published in a study report. He explains first that the connection between the piles and the bearers in modern houses should be either a piece of 4mm diameter wire fixed to the pile and bearer with staples or with Z nails. It is paramount to ensure that these fixing have not corroded and are not damaged. These fixings are detailed below.

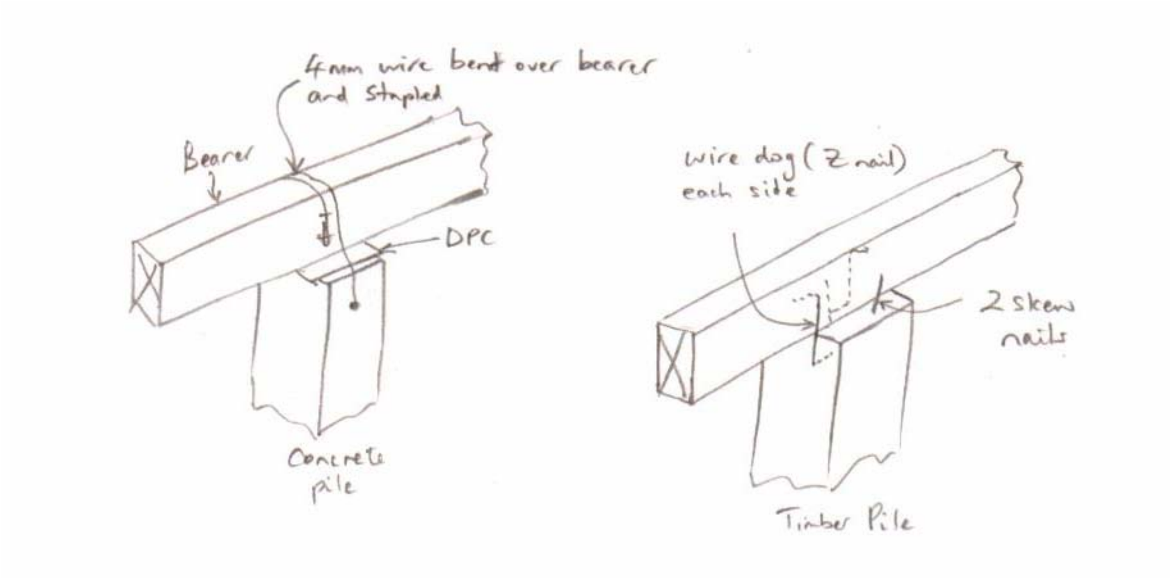


Figure 7
Typical Modern Pile to Bearer Connections
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 5.

Bracing is important in New Zealand dwelling subfloors and foundations as piles alone will not be able to resist the horizontal movement experienced in an earthquake. Should the foundation have sections of concrete foundations at the corners it may be connected remedially as detailed below.

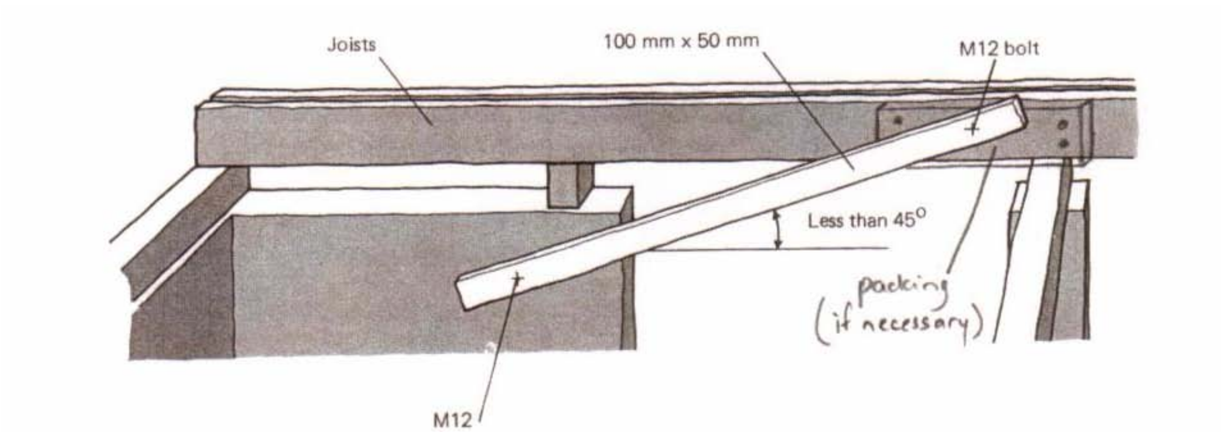


Figure 8
Corner Wall to Joist Remedial Connection Details
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 7.

Bracing with sheet materials is also a valid option for many New Zealand dwellings. Two details below illustrate a how a piled foundation may be remedially braced with sheet bracing.

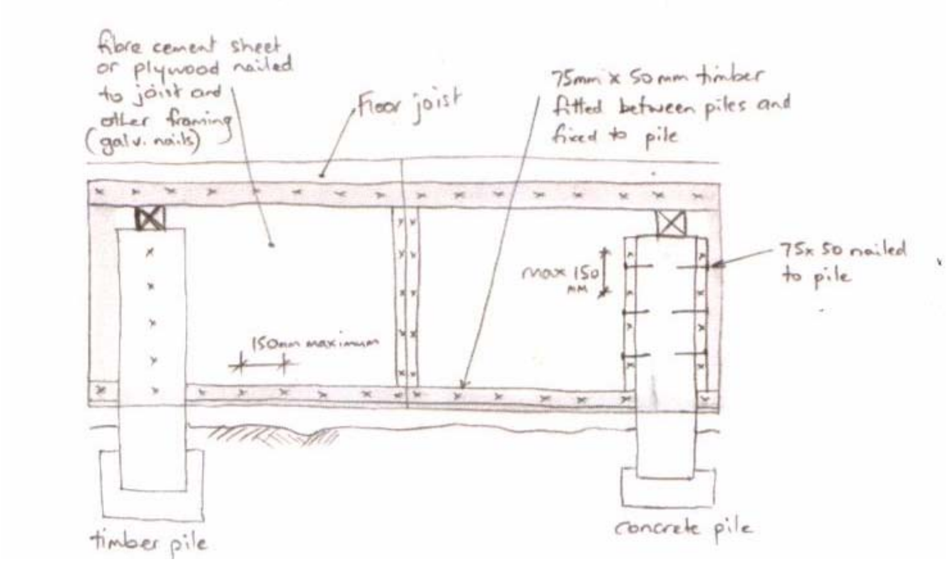


Figure 9
Bracing in a Piled House with Sheet Material: At bearer ends
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 9.

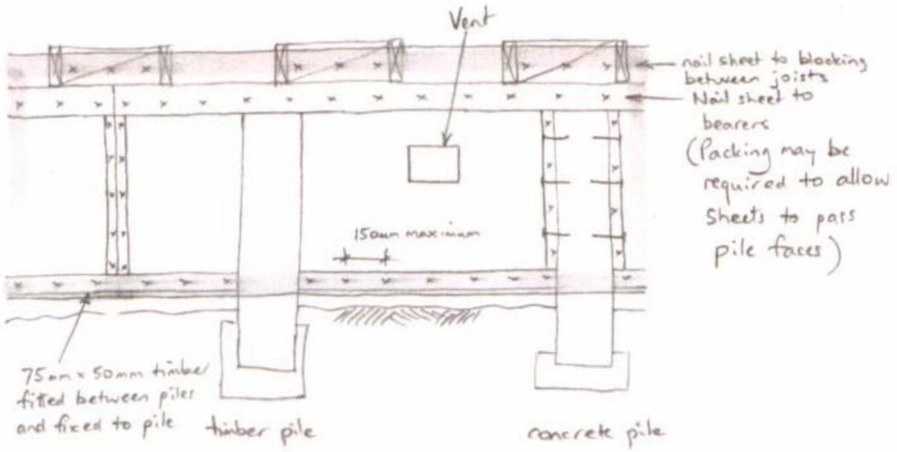


Figure 10
Bracing in a Piled House with Sheet Material: At joist ends
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 9.

Houses supported on timber piles may be braced with diagonal braces. These are placed between the piles, between a pile and a bearer, or between a pile and a joist. The latter two options are most preferable as the brace is then fixed more directly to the floor framing. At least two piles should be installed on the outside row and every second row of piles in both directions, the bolt, a hot-dip galvanised bolt, at the bottom of the pile should be a minimum of 300mm above ground level, and the slope angle of the brace should be no more than 45 degrees. The two figures below illustrate remedial timber brace details.

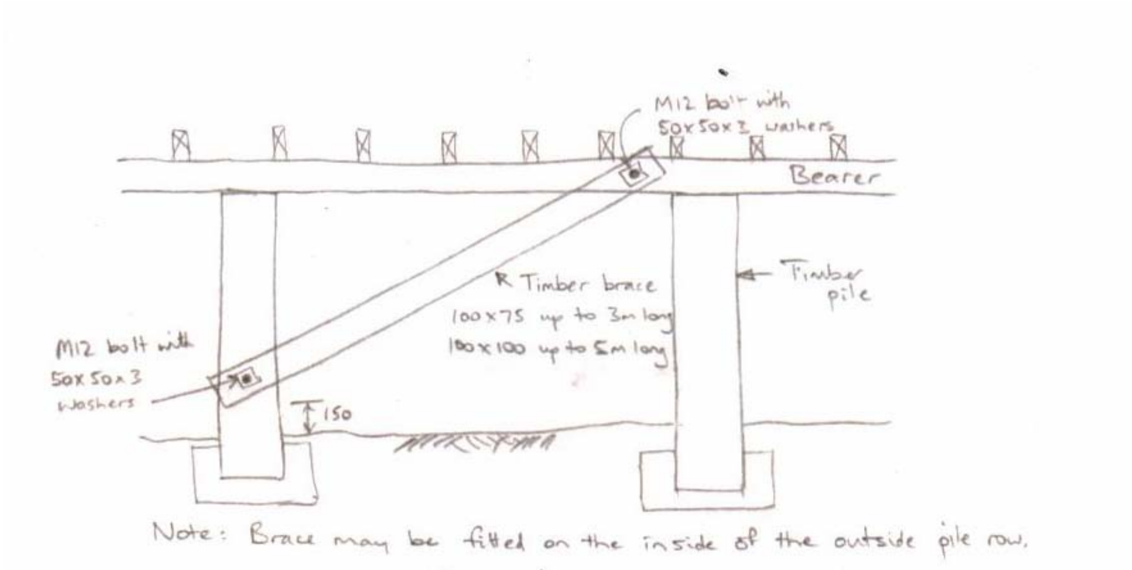


Figure 11
Added Timber Braces to Timber Piles: Fixed to a bearer
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 11.

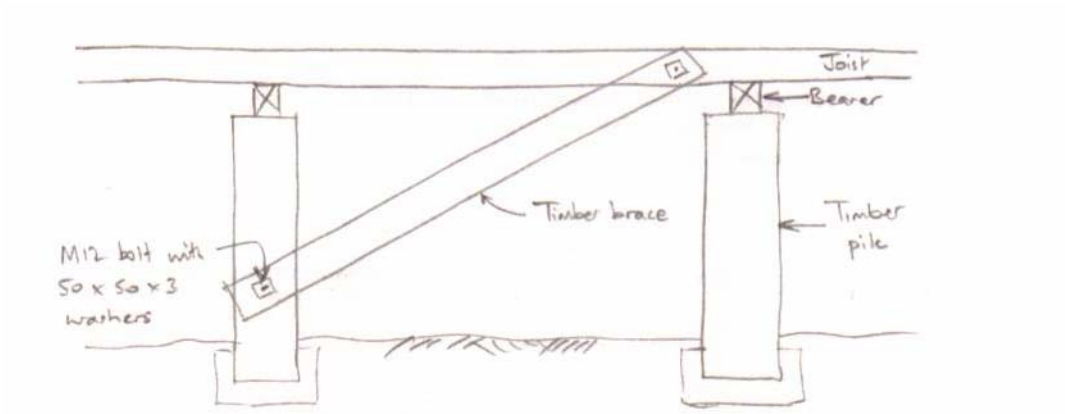


Figure 12
Added Timber Braces to Timber Piles: Fixed to a joist
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 11.

In some cases, particularly in overseas domestic examples, the existing wooden floor may need to be stiffened. Stiffening of existing wooden slabs to increase their seismic performance can be achieved by nailing new planks to the original (see Figure 13) or by placing a new concrete slab (see Figure 14). Connection to the wall must also be considered (see Figure 15).

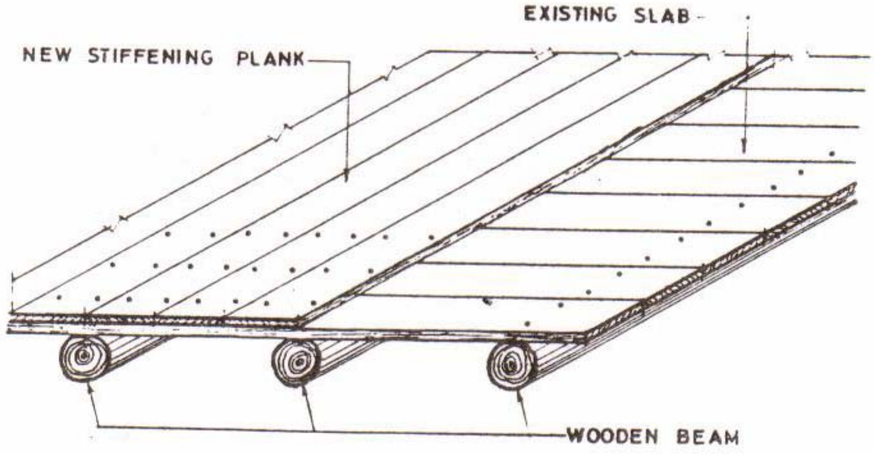


Figure 13
Stiffening of Wooden Floor by Wooden Planks
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 68.

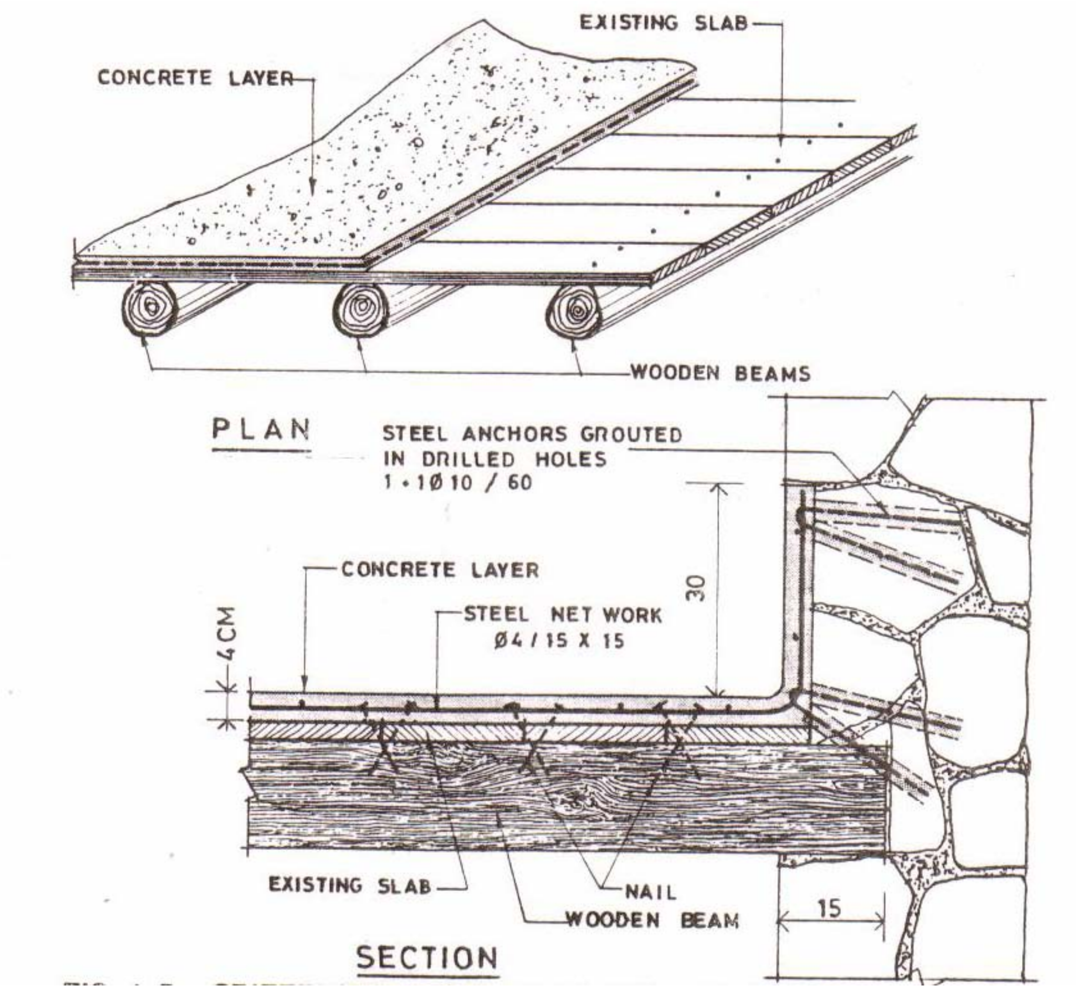


Figure 14
Stiffening of Wooden Floor by Reinforced Concrete Slab and Connection to Wall
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 68.

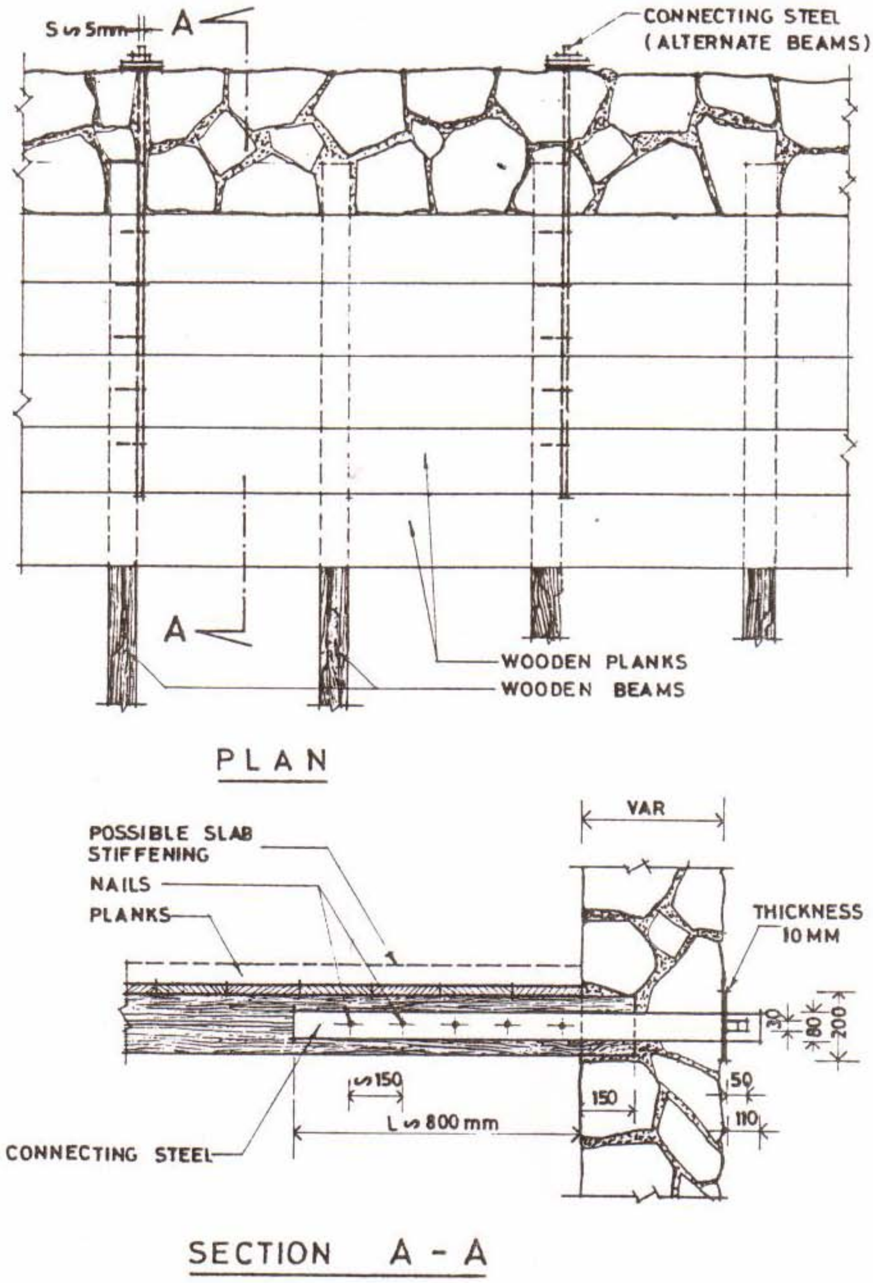


Figure 15
Connection of Floor to Wall
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 69.

There has been research conducted to retrofit concrete and masonry structures with jackets of composite fibres bonded with a polymer matrix to enhance shear strength, flexural ductility or lap splice performance. For columns "active confinement is achieved by placing a specified thickness of the composite jacket material over the region of the column to be confined, and pressure grouting the gap between the column and the jacket with either epoxy or cement grout"[d] (see Figures 16 and

[d] Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 365.

17). This is a method suitable for retrofit pre-earthquake or repair post-earthquake. This may prove relevant to this foundation type if concrete piles are present rather than timber, and their shear strength or aspects of their performance need to be enhanced.

Figure 16
Circular Column Retrofitted with Fibreglass/Epoxy Composite Jackets
Source: Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 367.

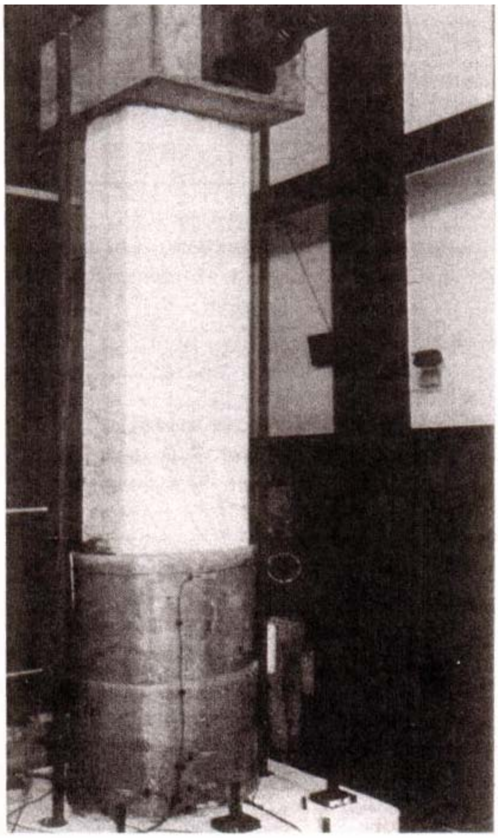


Figure 17
Rectangular Column Retrofitted with Fibreglass/Epoxy Composite Jackets
Source: Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 367.

The results of testing indicate "very satisfactory performance of the retrofitted columns."[e]

Professor Battacharyya, an engineer based in Kharagpur, India, has published his own research into the retrofitting of building structures, particularly steel and concrete frames. His method of retrofitting may relate to the internal or full piled foundation types where settle or concrete may be in need of remedial attention.
The welding of steel angles, channels or bars is quite common to increase the load carrying capacity of the existing structural steel framing (see Figure 18). Columns can also be reinforced by welding cover plates or similar onto both of the flanges. To fix deteriorated column bases the approach is to shore the column, remove deteriorated material and weld or bolt reinforcing to the column.

[e] Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 368.

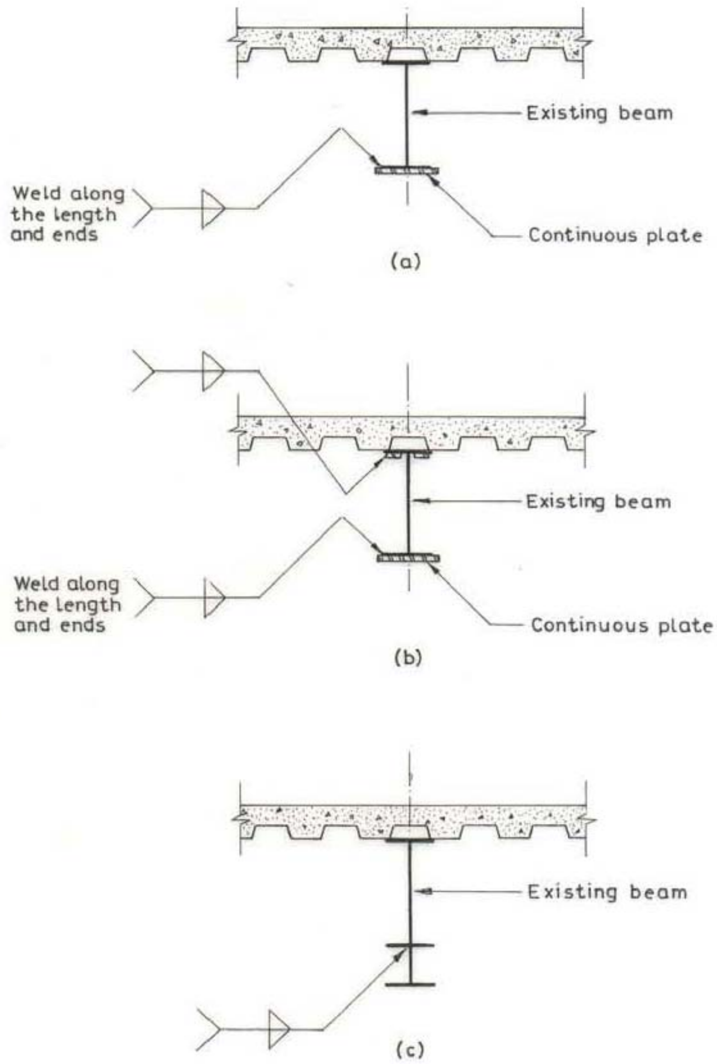


Figure 18
Reinforcing Existing Steel Beams
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

Renovating concrete structural elements is also possible through the addition of reinforcing. Adding a steel channel on each side of an existing concrete beam is a solution which allows the channels to be connected to the concrete columns. The three beams are interconnected with bolting (see Figure 19). Flexible steel channels could also be used, fastened to the existing concrete at the ends. The intention is to induce an upward force by deflecting the beams downward through jacking or wedging the space between the underside of the slab and the beams (see Figure 20).

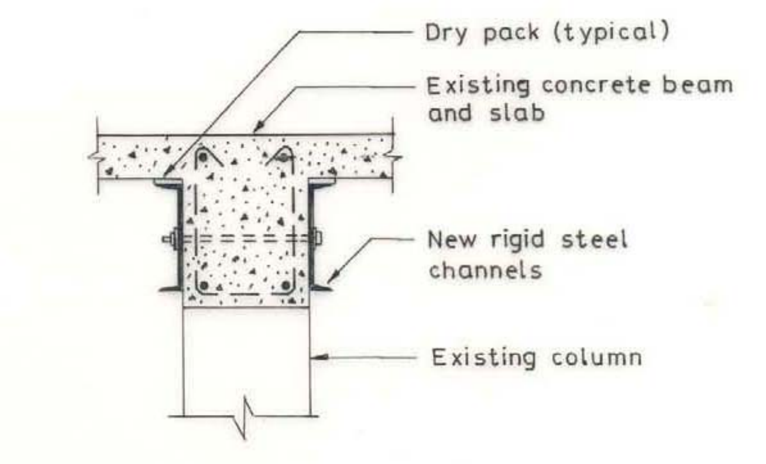


Figure 19
Adding Steel Beams on each side of an Existing Concrete Beam
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

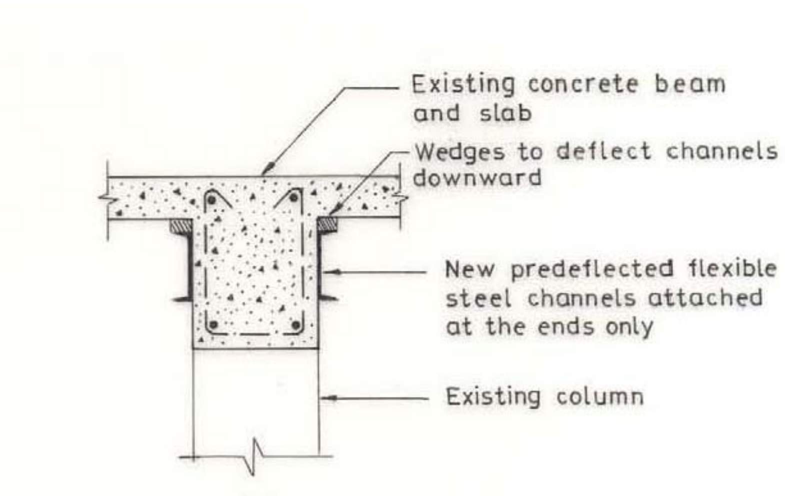


Figure 20
Adding Steel Beams on each side of an Existing Concrete Beam
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

The concrete section may be enlarged to strengthen it. New reinforced concrete is placed around the existing beam; proper interconnection is critical for the functioning of the whole. The sections can be tied together with stirrups (see Figure 21), by short dowels (see Figure 22), or by enveloping the beam with a new floor overlay (see Figure 23).

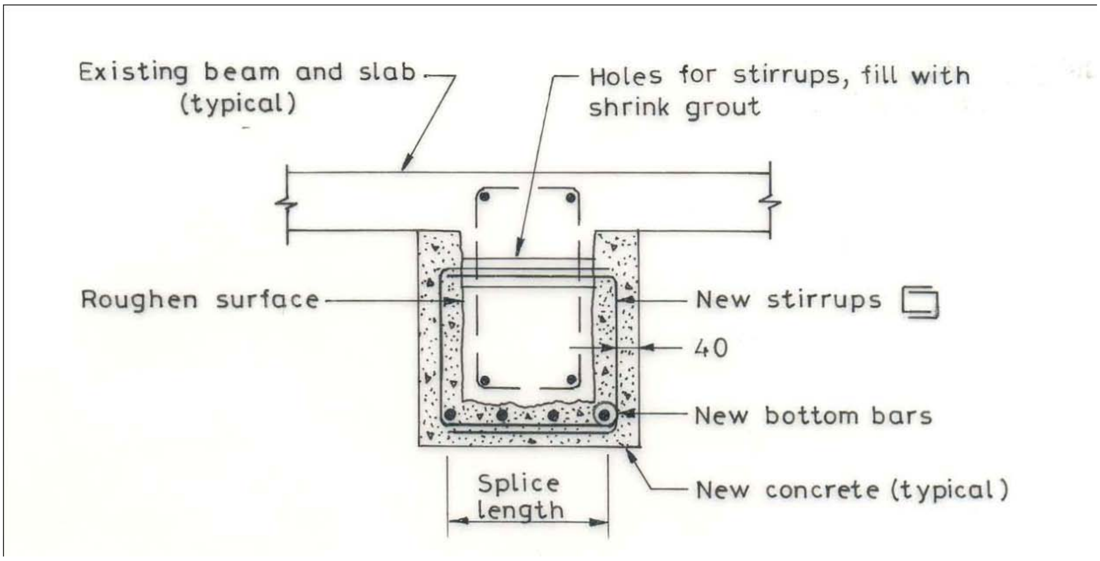


Figure 21
Enlarging a Section of an Existing Concrete Beam
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

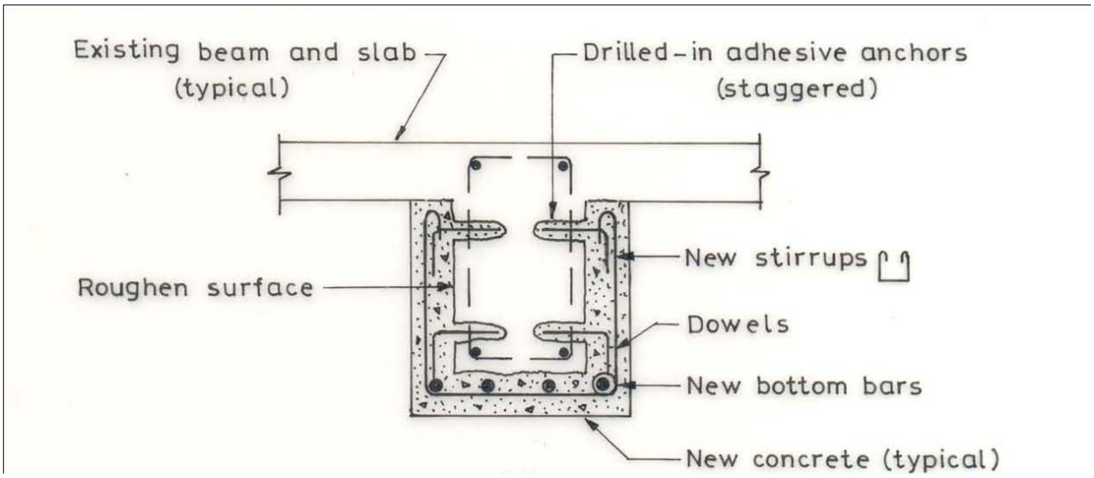


Figure 22
Enlarging a Section of an Existing Concrete Beam
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

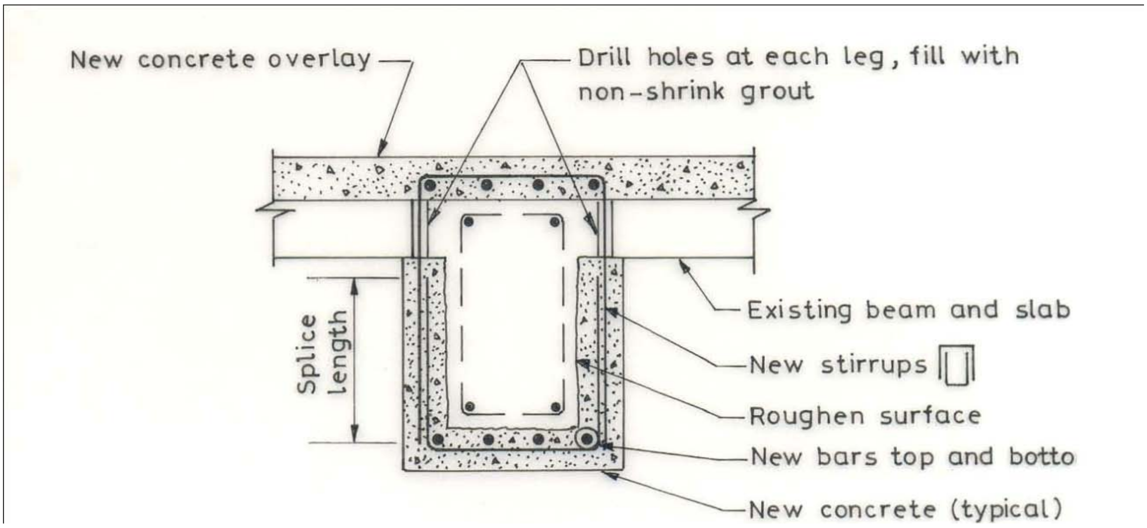


Figure 23
Enlarging a Section of an Existing Concrete Beam
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

When the beam lacks moment capacity it can be reinforced with structural steel tension plates bolted to the beam (see Figure 24). A welded U-bracket can be used if substantial additional steel is required. Differing damages can also be mitigated as shown in Figures 25, 26, and 27.

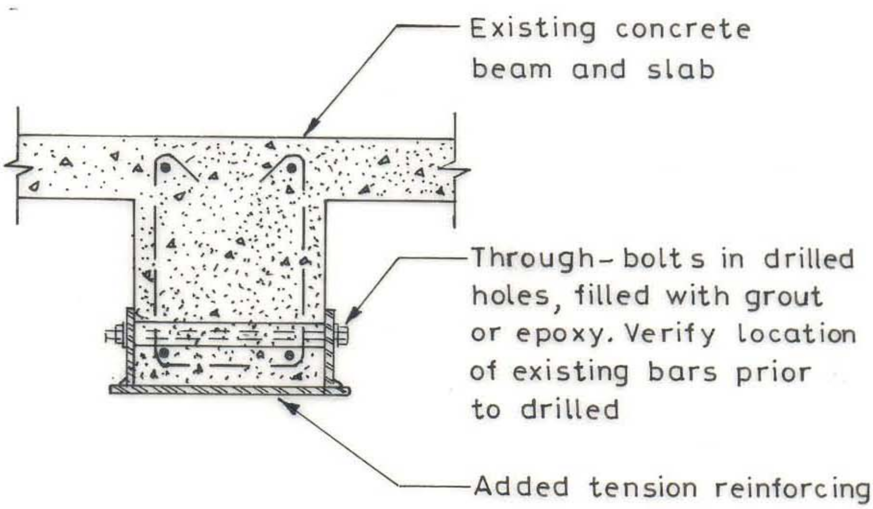


Figure 24
Addition of Steel Member to Improve Moment Capacity
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

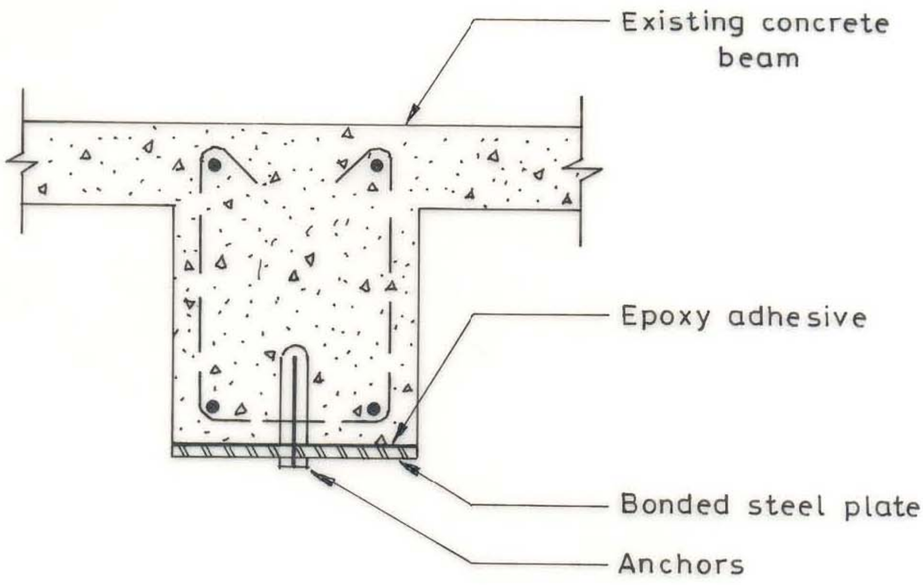


Figure 25
Concrete Damage Repair
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

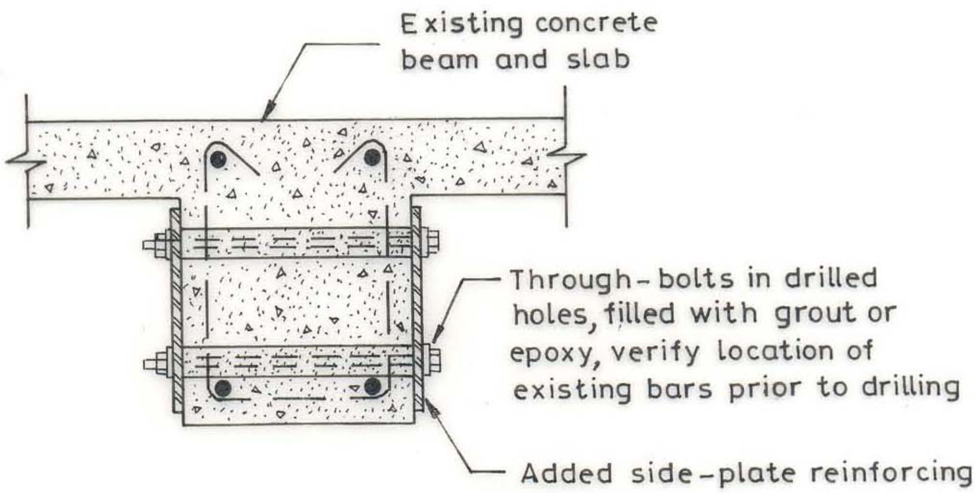


Figure 26
Concrete Damage Repair
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

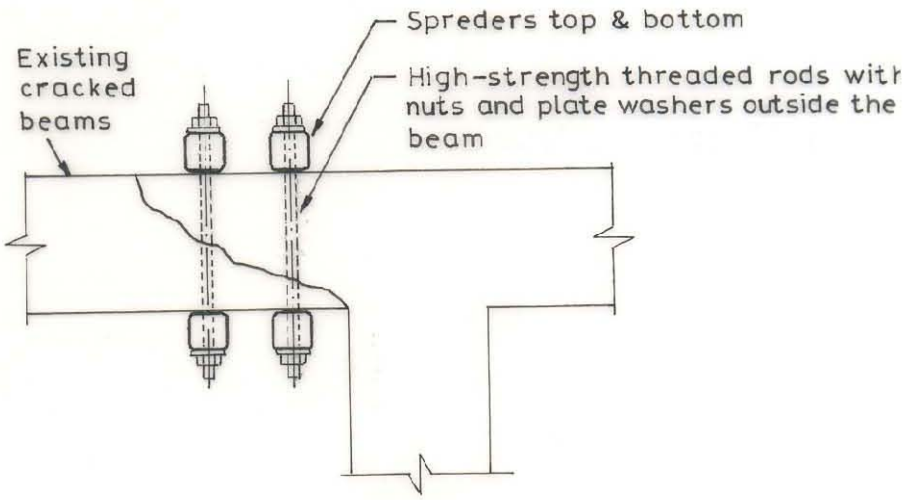


Figure 27
Concrete Damage Repair
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

Cracks can be generated in concrete due to earthquakes. This can be 'stitched' with dowels (see Figure 28 and 29). Epoxy injection or grouting can 'glue' the concrete together, or sealant can be applied to mitigate cracking also.

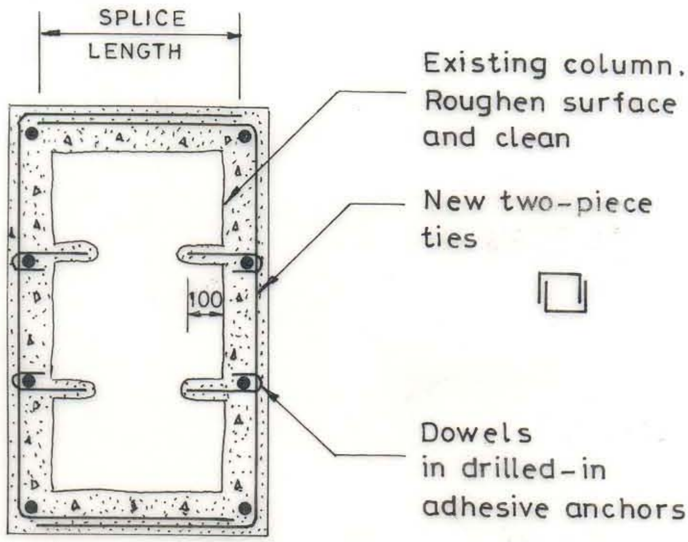


Figure 28
Retrofitting Concrete Columns
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

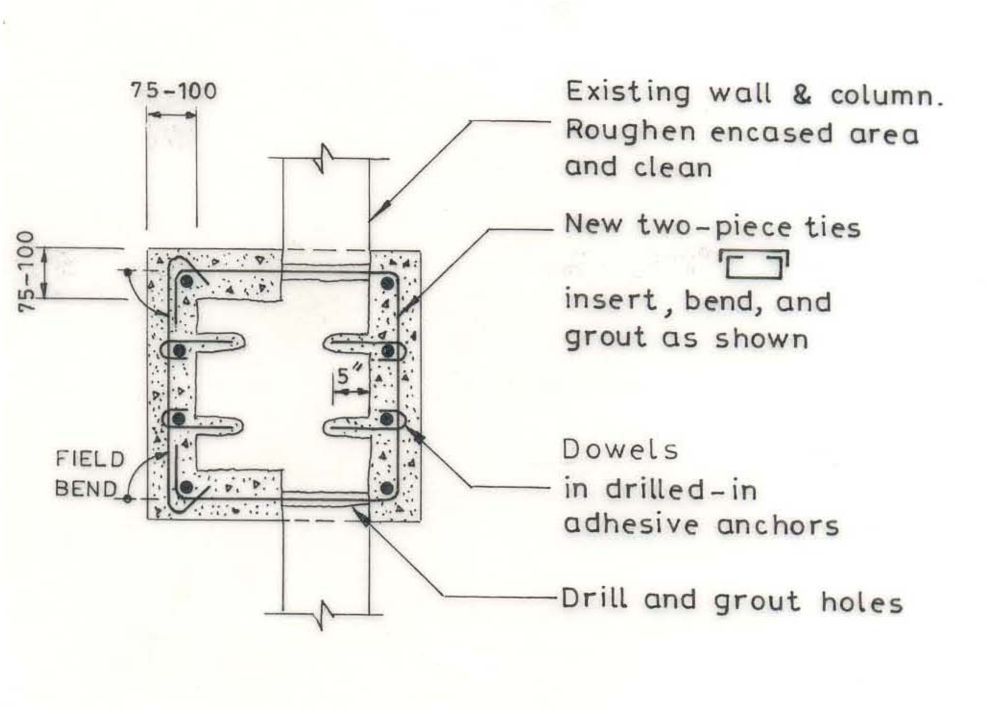


Figure 29
Retrofitting Concrete Columns
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

Although Professor Bhattacharyya's solutions do not specifically relate to subfloor and foundation detailing, some retrofit measures presented may be relevant in the retrofit of concrete piled foundations or where concrete is damages or cracked and in need of repair and attention.

Full Piled Foundation:

This consists of a piled foundation where piles are constructed from concrete or timber, and there is no differentiation between perimeter and interior piles.[f]

Many of the details relevant to internally piled foundations may also apply to full piled foundations, hence these details have been included in the section on internally piled foundations.

[f] Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 47.

Partial Foundation Wall:
This consists of lengths of concrete foundation wall, commonly located at the corners of the dwelling. The concrete foundation wall is frequently connected to the subfloor framing with reinforcing bars penetrating through a timber plate, or with bolts.[g]

Many details relevant to the partial foundation wall foundation type are also relevant to the full foundation wall foundation type and have thus been included in the later section. Please refer to this for additional details.

As James Irvine explains in his thesis, *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading*, the connection between plate and foundation wall is often inadequate in New Zealand dwellings. This connection requires a bolt or similar fixing to connect a brace to the wall. Packing may also be required if the concrete foundation wall is greater in width than the timber foundation wall plate. This detail is outlined below.

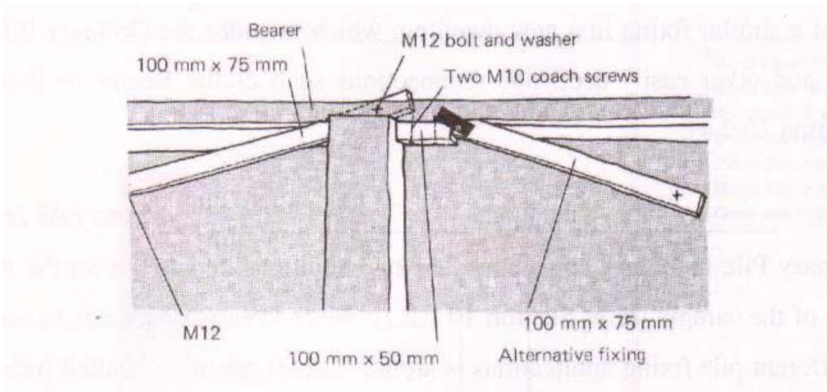


Figure 30
Remedial Connection for Plate to Foundation Wall
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 171.

[g] Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 50.

Full Foundation Wall:
This consists of an enclosing reinforced concrete wall following the perimeter of the dwelling. The wall supports both lateral loads from the superstructure and lateral loads from the floor diaphragm.[h]

A full foundation wall foundation, in addition to the internally piled foundation type, is often accompanied by jack studs atop the wall. The sheet cladding on the outside of the jack studs is commonly brittle and provides little bracing resistance. The remedial measures than can be employed, as outlined by Graeme Beattie of BRANZ, include removing the bracing material and replacing it with modern fibre cement sheet at least 7.5mm thick nailed at 150mm centres and around its perimeter, or using fibre cement sheet materials or 7mm thick D-D grade plywood. This is detailed below.

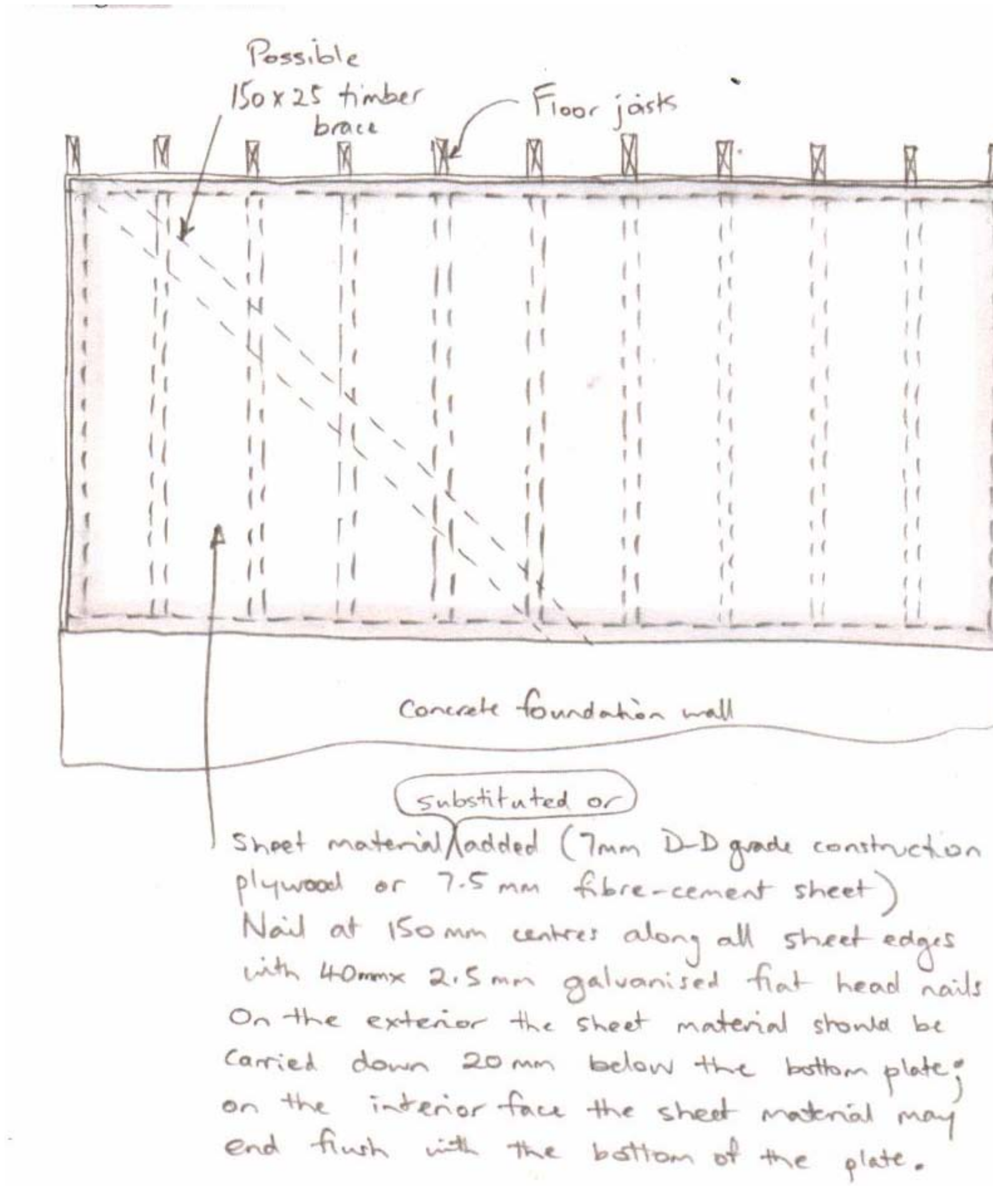


Figure 31
System for Strengthening Jack Stud Walls against Earthquakes
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 13.

[h] Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 52.

For a perimeter foundation wall with jack studs atop, the California Earthquake Retrofitting Information Center, a non-profit organisation set up by architects and civil engineers, explains the process of retrofitting the home to meet California State Building and Engineering Codes as follows. The first step is to install plates bolting down the sill plate using a 2 x 3inch piece of steel (see Figure 32). The steel anchor plates are specifically designed for this application (see Figure 33). The bolt is a concrete expansion anchor bolt (see Figure 34) and are used around the perimeter (see Figure 35). This is the common retrofit measure in California to remedially prepare the dwelling for a seismic event.

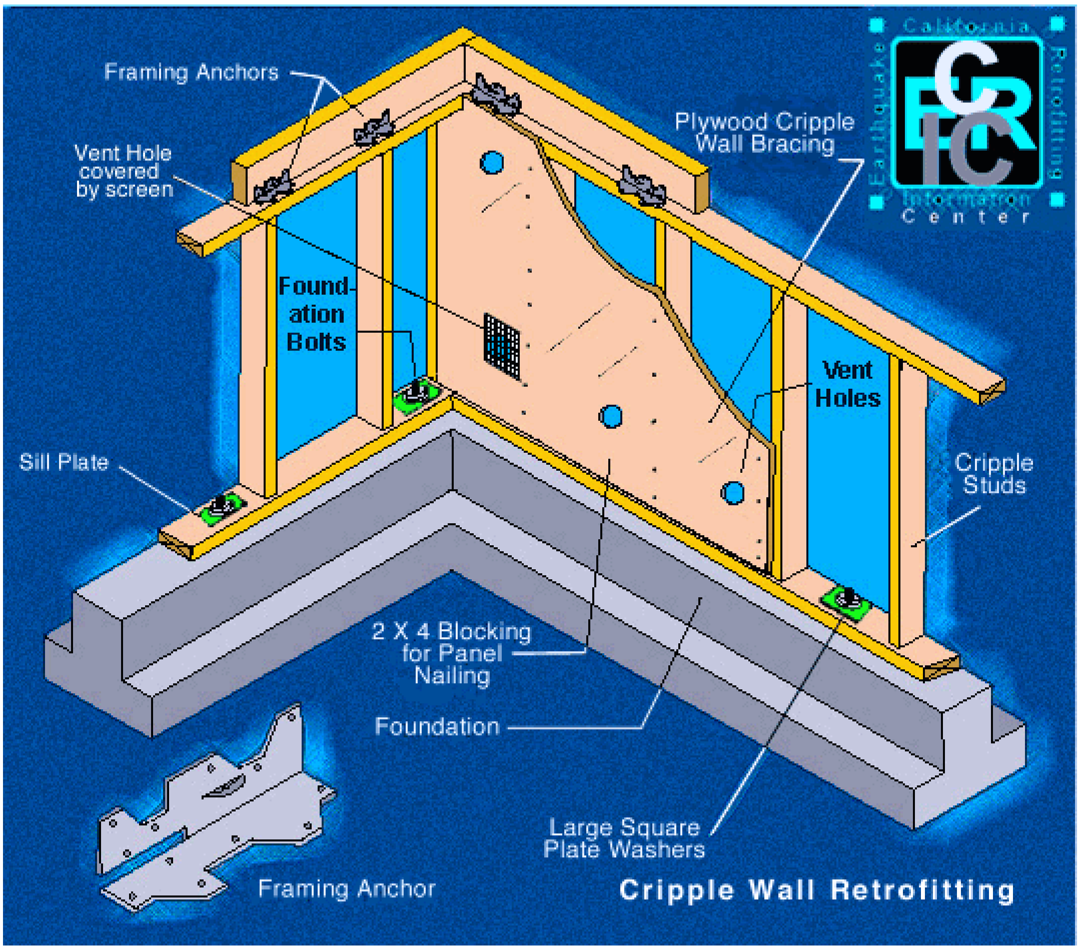


Figure 32
Cripple Wall (Jack Stud) Retrofitting
Source: http://housebolting.com

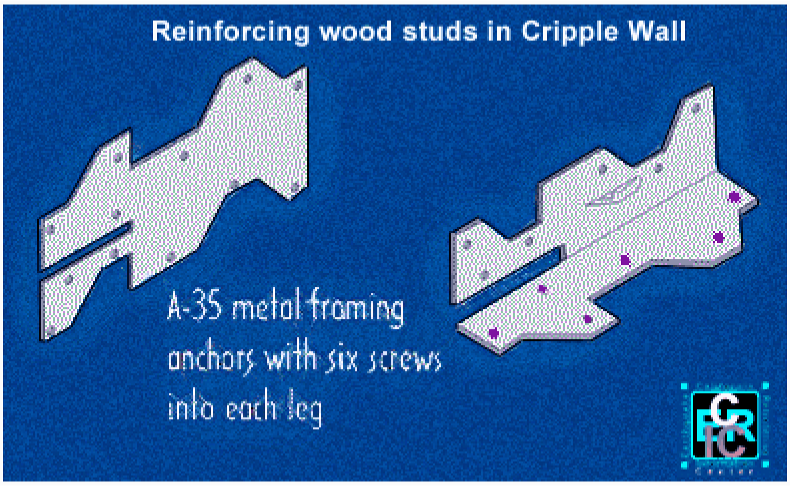


Figure 33
Retrofitting Steel Plates
Source: http://housebolting.com

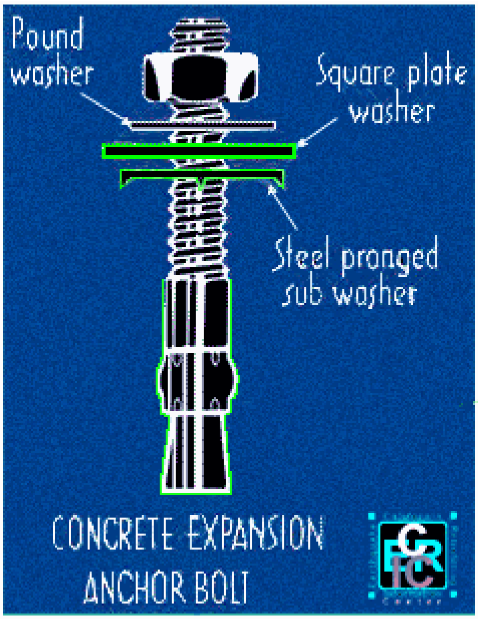


Figure 34
Concrete Expansion Anchor Bolt
Source: http://housebolting.com

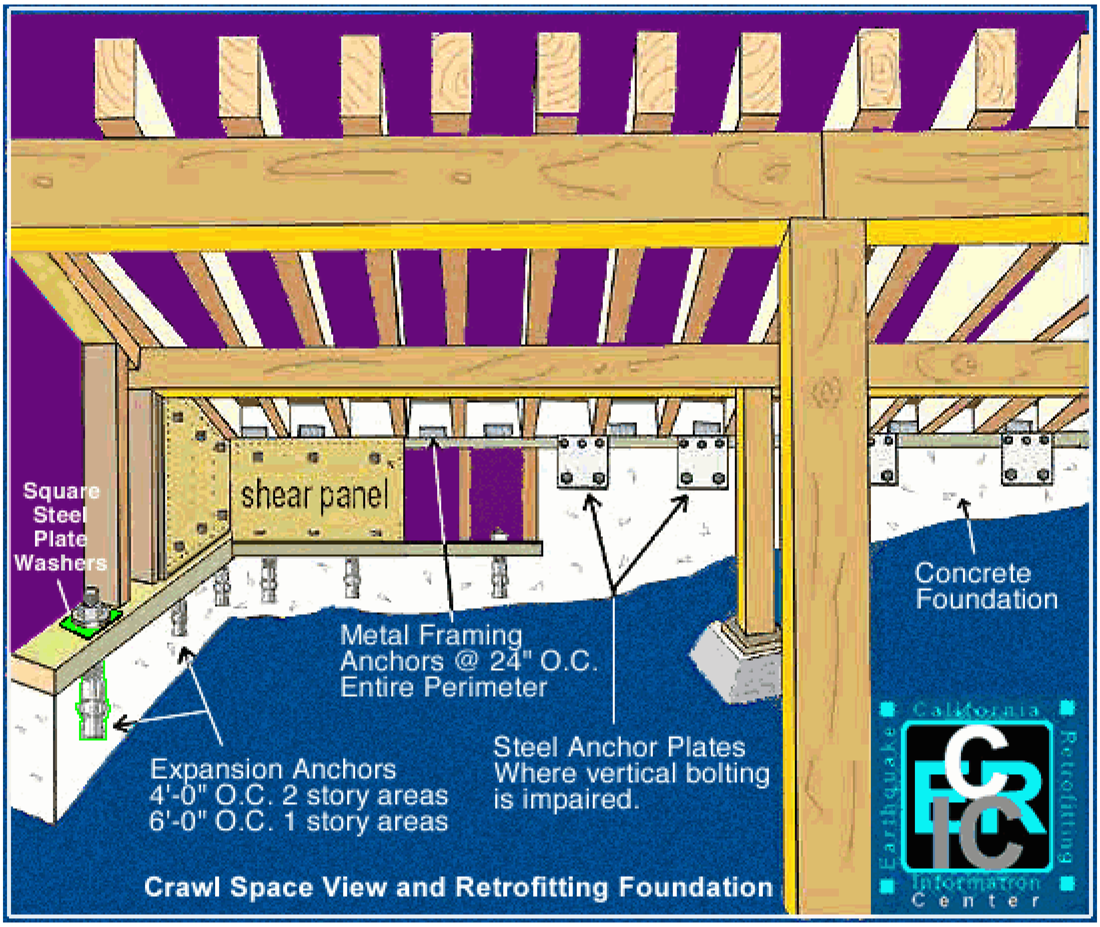


Figure 35
Placement of Concrete Expansion Anchor Bolt
Source: http://housebolting.com

The Los Angeles Department of Building and Safety has also developed retrofit diagrams which illustrate how retrofit details are to be carried out in the Los Angeles area. This is a similar process to the one outlined above in this report, aimed at full foundation walls with jack studs (or cripple walls). This is a series of figures, covering from replacement of concrete footing and stem wall, to cripple wall details (see Figures 36, 37, 38, 39, 40, 41, 42, 43 and 44). The details for the cripple wall are most applicable for New Zealand jack stud foundations.

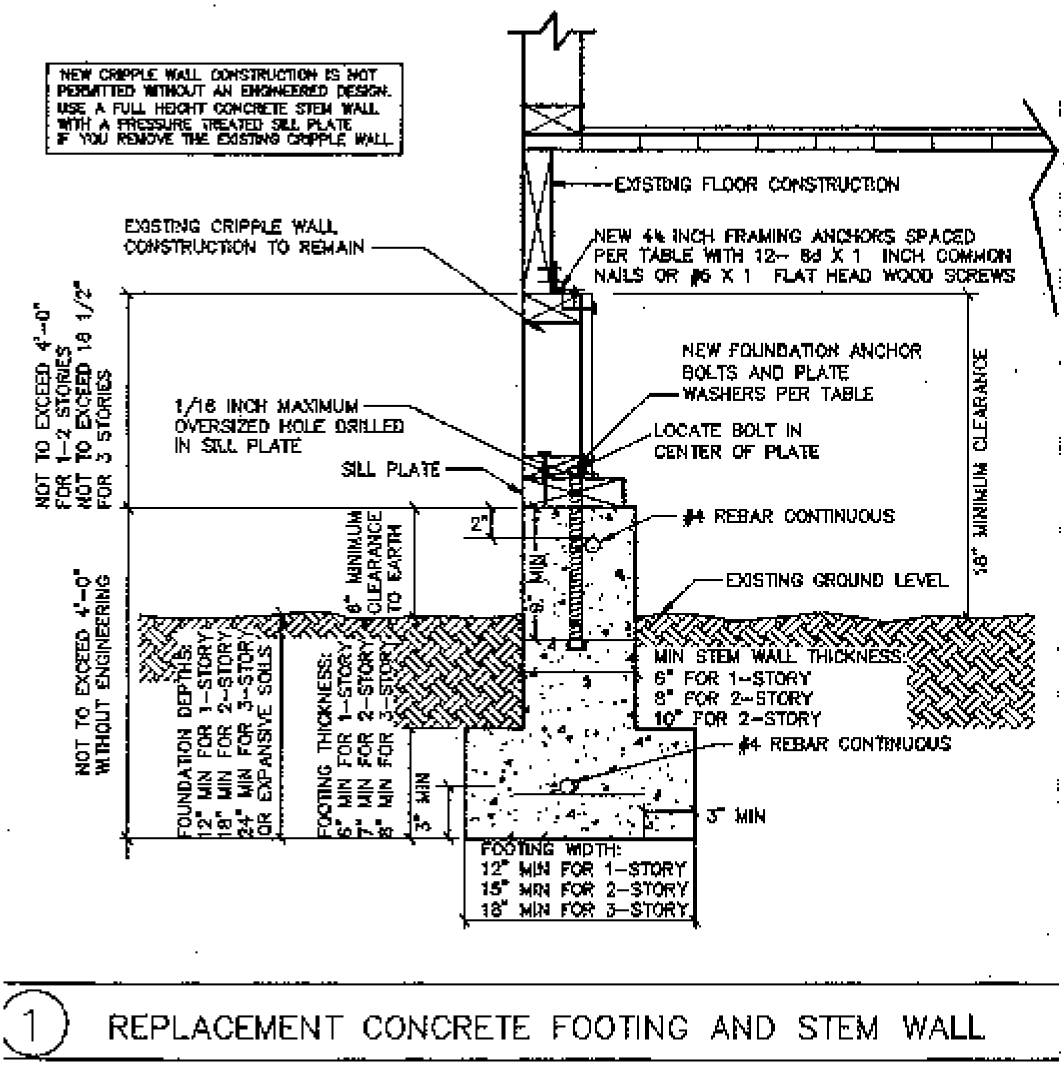


Figure 36
Replacement Concrete Footing and Stem Wall
Source: http://www.foundationbolting.com

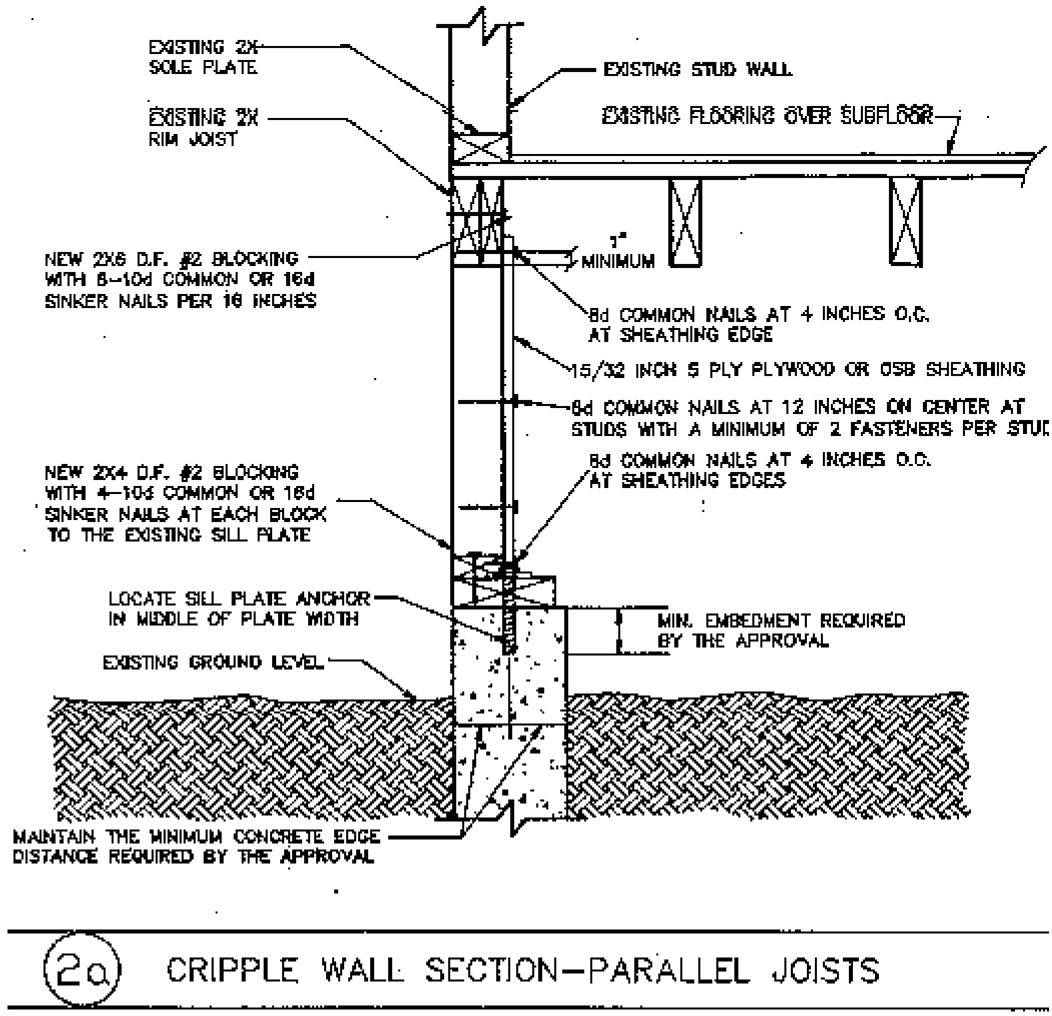


Figure 37
Cripple Wall Section – Parallel Joists
Source: http://www.foundationbolting.com

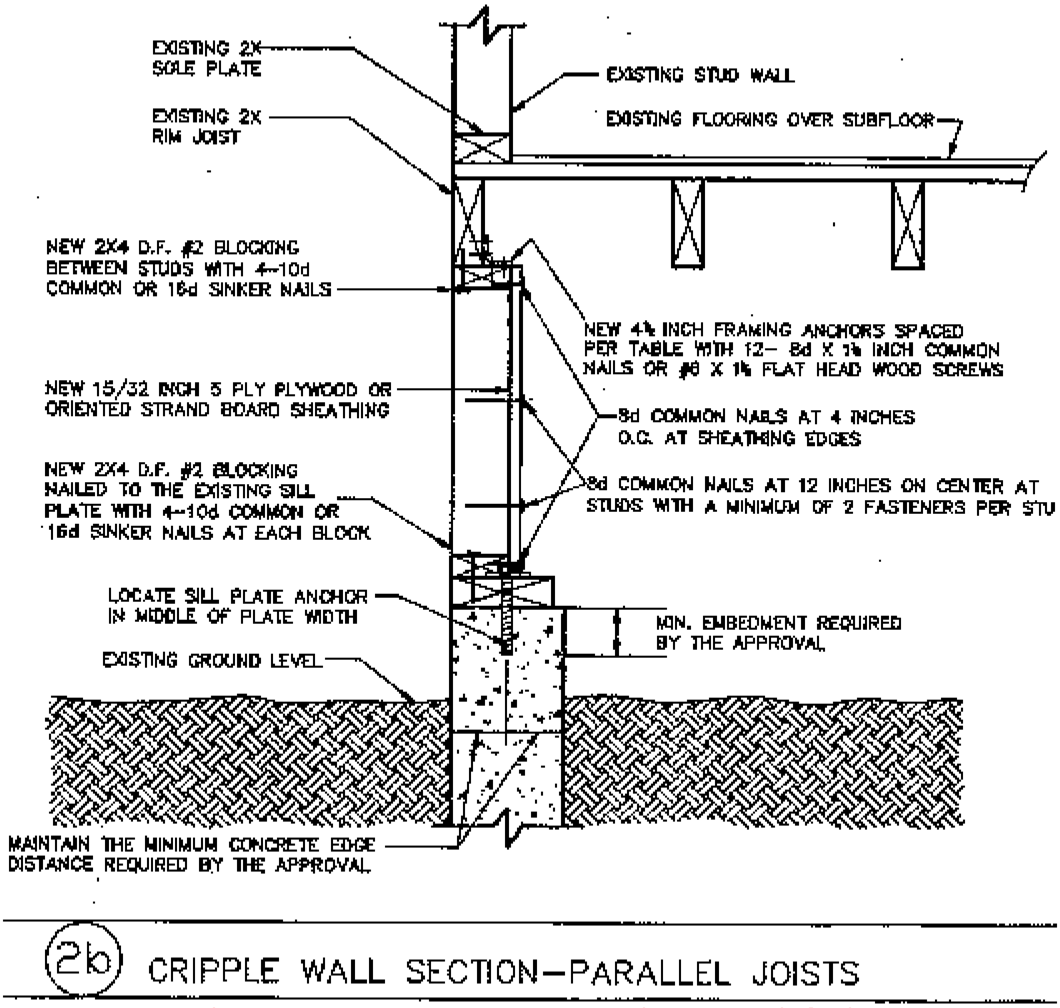


Figure 38
Cripple Wall Section – Parallel Joists
Source: http://www.foundationbolting.com

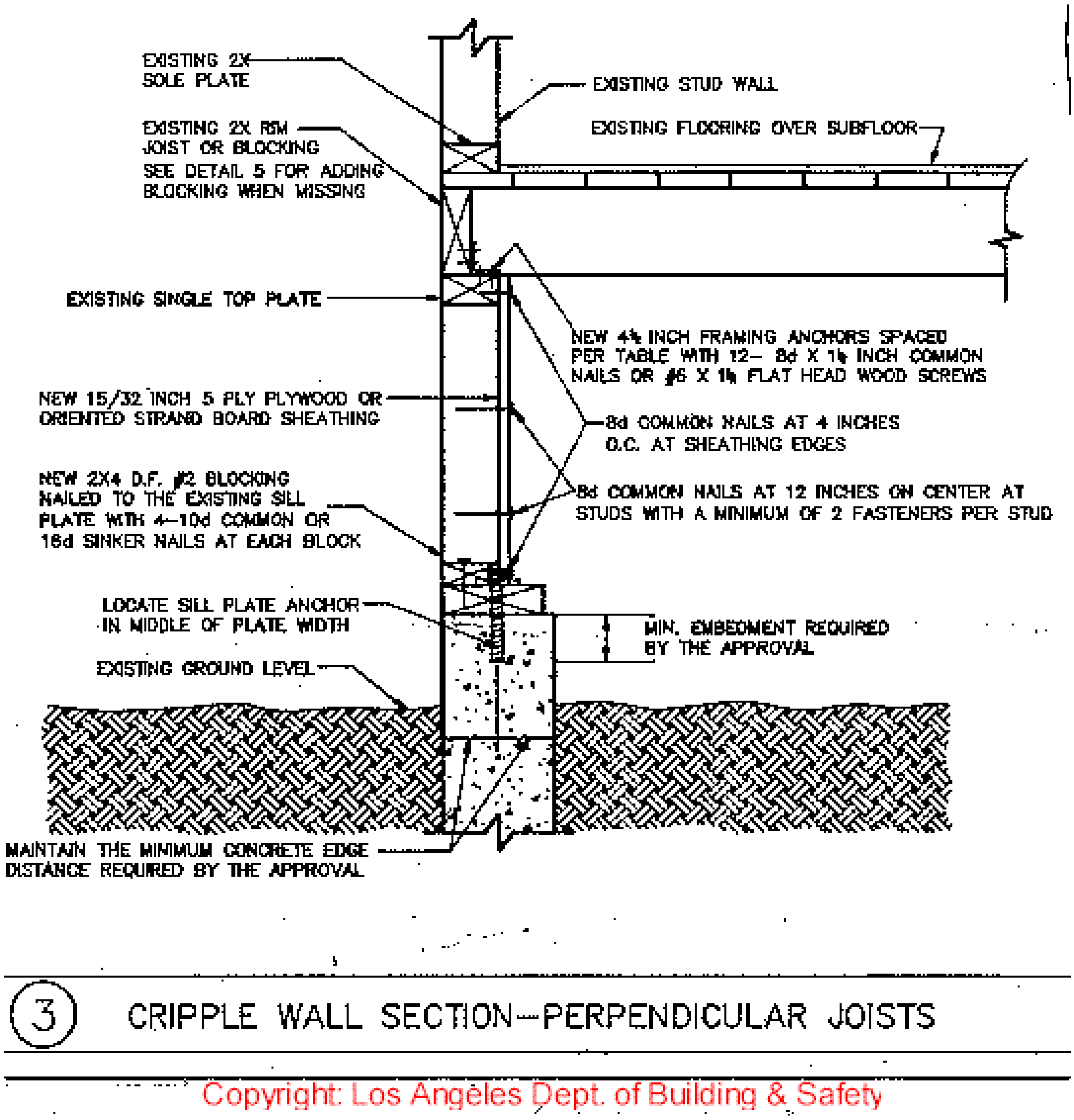


Figure 39
Cripple Wall Section – Perpendicular Joists
Source: http://www.foundationbolting.com

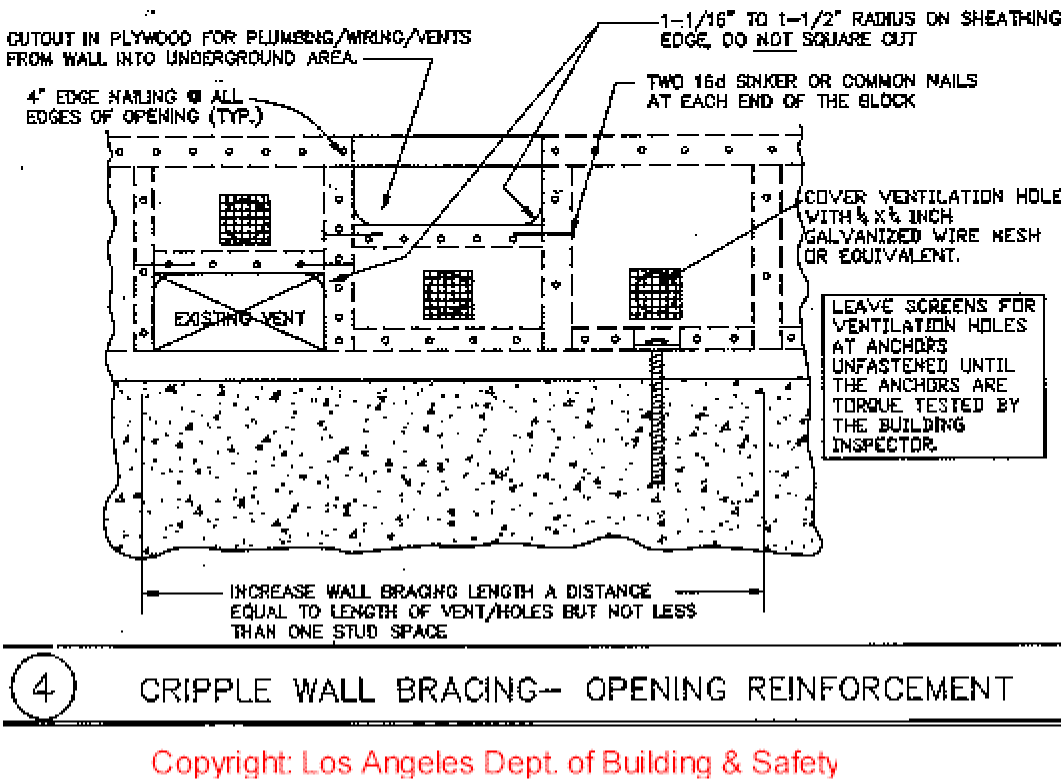


Figure 40
Cripple Wall Bracing – Opening Reinforcement
Source: http://www.foundationbolting.com

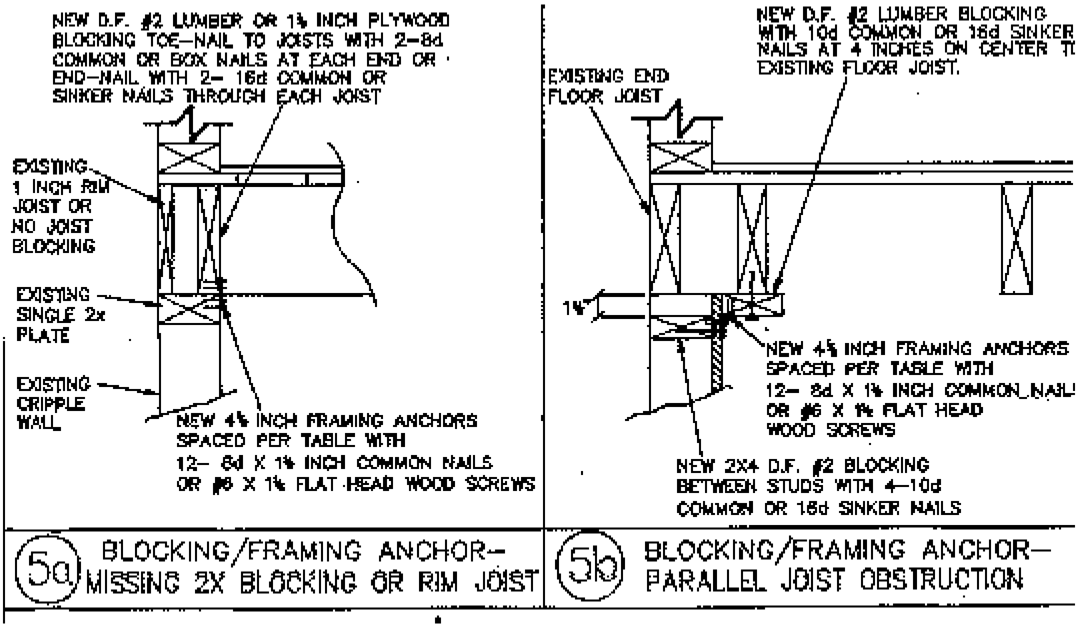


Figure 41
Blocking/Framing Anchor
Source: http://www.foundationbolting.com

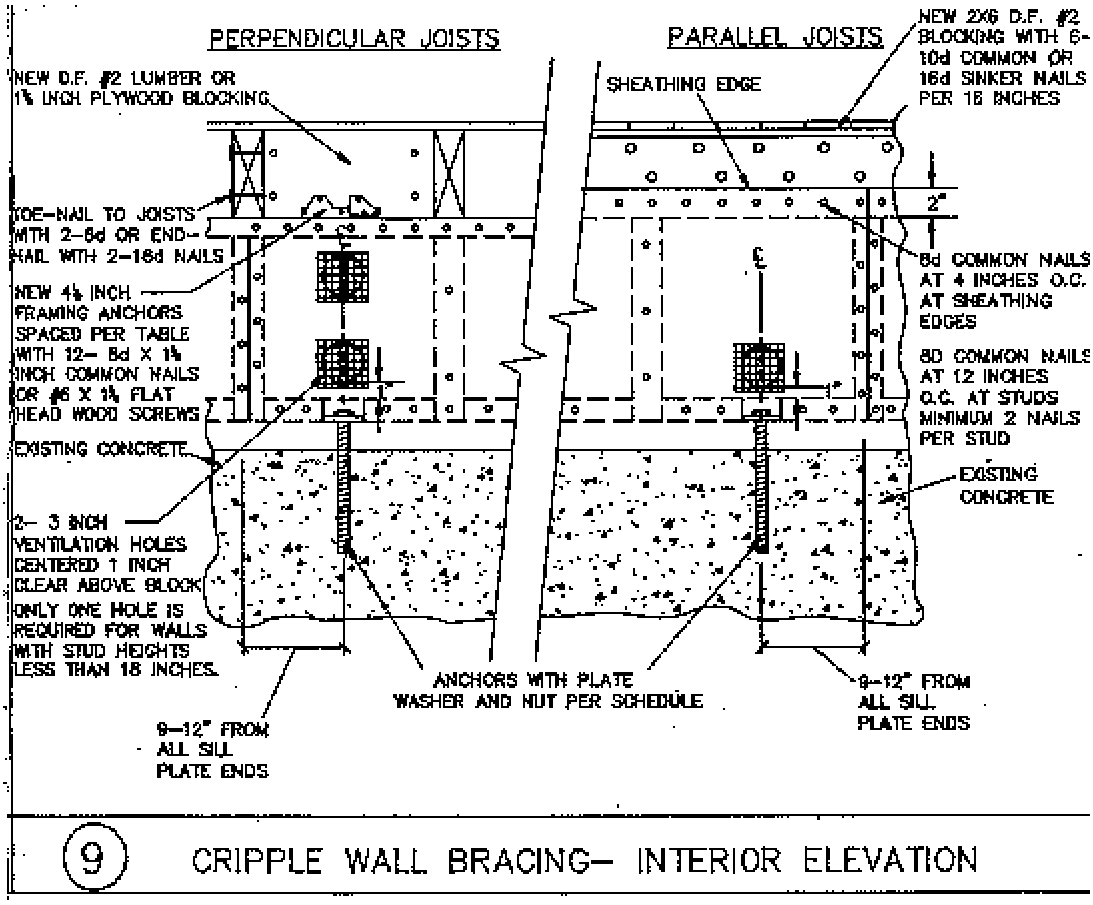


Figure 42
Cripple Wall Bracing
Source: http://www.foundationbolting.com

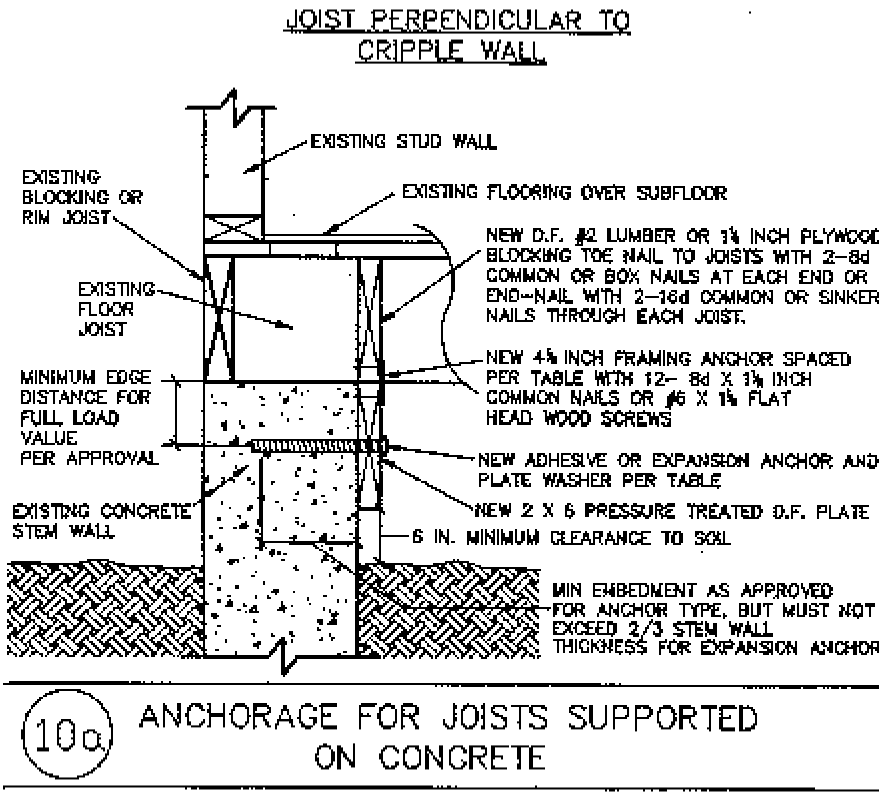


Figure 43
Anchorage for Joists Supported on Concrete
Source: http://www.foundationbolting.com

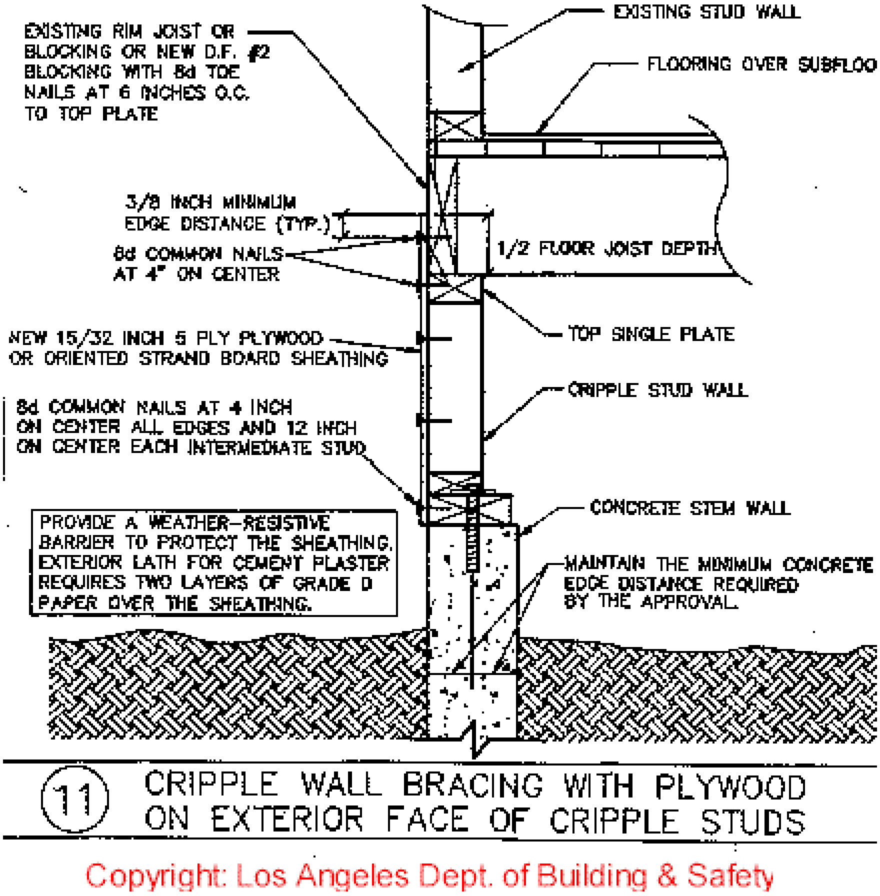


Figure 44
Cripple Wall Bracing with Plywood
Source: http://www.foundationbolting.com

A common practice occurring in areas of the United States involves cripple wall bracing. Typical bracing of a cripple wall is detailed (see Figure 45) showing also how the subfloor appears before (see Figure 46) and after the retrofit (see Figure 46) which involved plywood bracing panels and improved connections from the foundations, through the walls, and into the overhead framing of the floor.

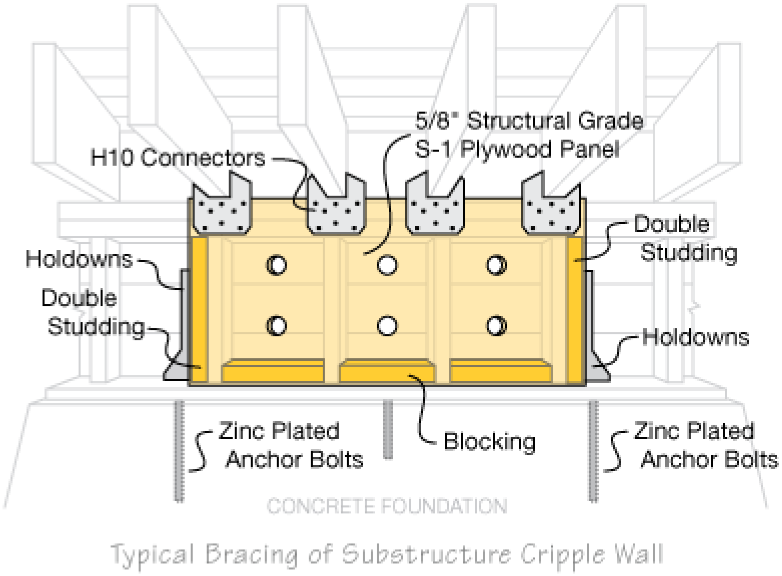


Figure 45
Typical Bracing of Substructure Cripple Wall
Source: http://earthquakesafety.com/retrofitting

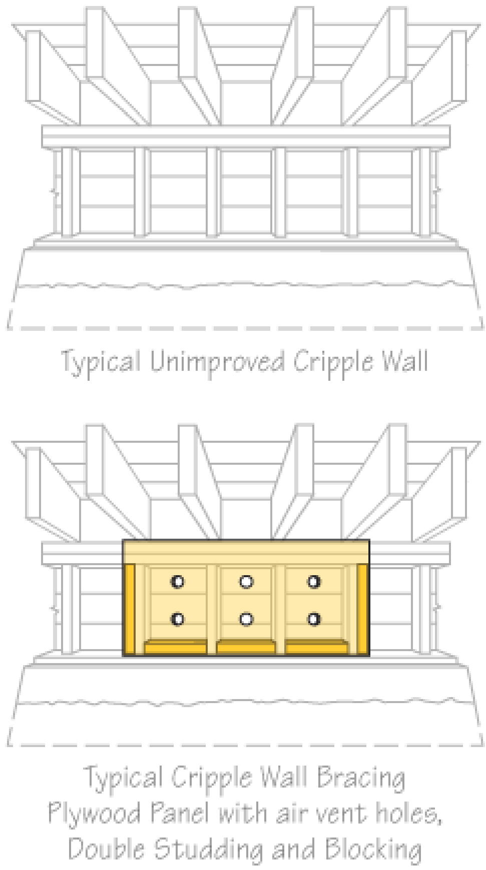


Figure 46
Top: Cripple Wall, Bottom: Retrofitted Cripple Wall
Source: http://earthquakesafety.com/retrofitting

Some houses require additional hold down brackets to anchor the shear walls (see Figure 47), usually installed at the ends of the shear walls. Installation is carried out with a long, deeply set epoxy anchored bolt.

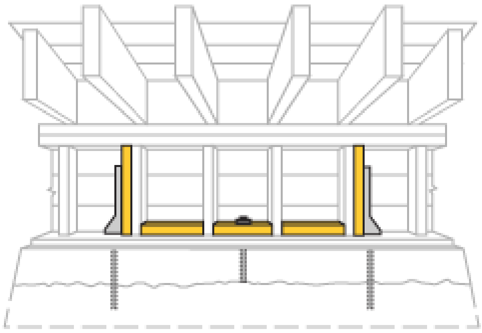
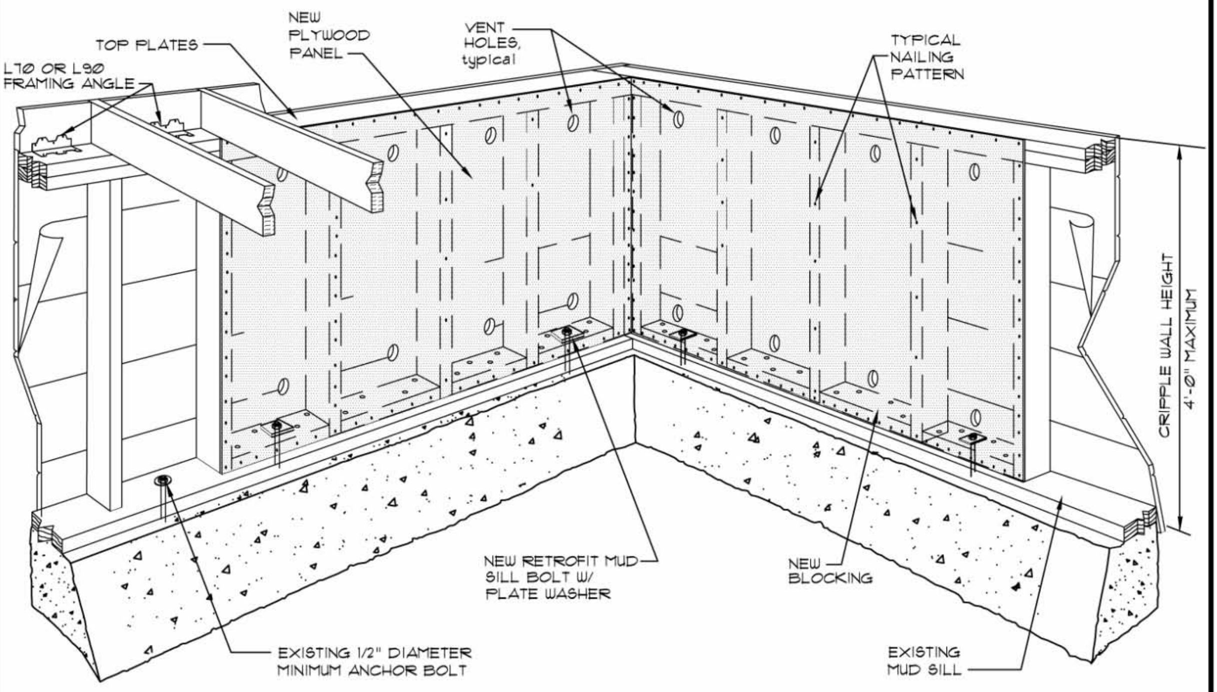


Figure 47
Foundation Hold Down Brackets
Source: http://earthquakesafety.com/retrofitting

The city of San Leandro, California has developed a residential seismic strengthening plan (see Appendix 1). This illustrates cripple wall bracing details (see Figure 48) as well as floor to mud sill connections (see Figure 49), further cripple wall bracing details (see Figure 50) and typical floor to cripple wall connections (see Figure 51). This resource is relevant to this report as it has produced details which may be applicable in New Zealand, and has been developed following research and input from the California Building Officials Seismic Safety Committee, the Earthquake Engineering Institute of Northern California and the Structural Engineers Association of Northern California. Again, this process is similar to those outlined above, and is closely linked to perimeter foundation walls with jack studs (or cripple walls) as may appear in New Zealand dwellings to be retrofitted.



(A) TYPICAL CRIPPLE WALL BRACING DETAIL

NOTES:

1. THIS DETAIL SHOWS A SAMPLE CRIPPLE WALL WHICH HAS UNDERGONE A TYPICAL SEISMIC STRENGTHENING.
2. THIS DETAIL IS NOT INTENDED TO SUPERSEDE REQUIREMENTS CONTAINED IN THE SPECIFIC INSTALLATION DETAILS ON SHEET 2 OR THE PLAN SET BOOKLET.

Figure 48
Cripple Wall Bracing Detail
Source: http://www.ci.san-leandro.ca.us

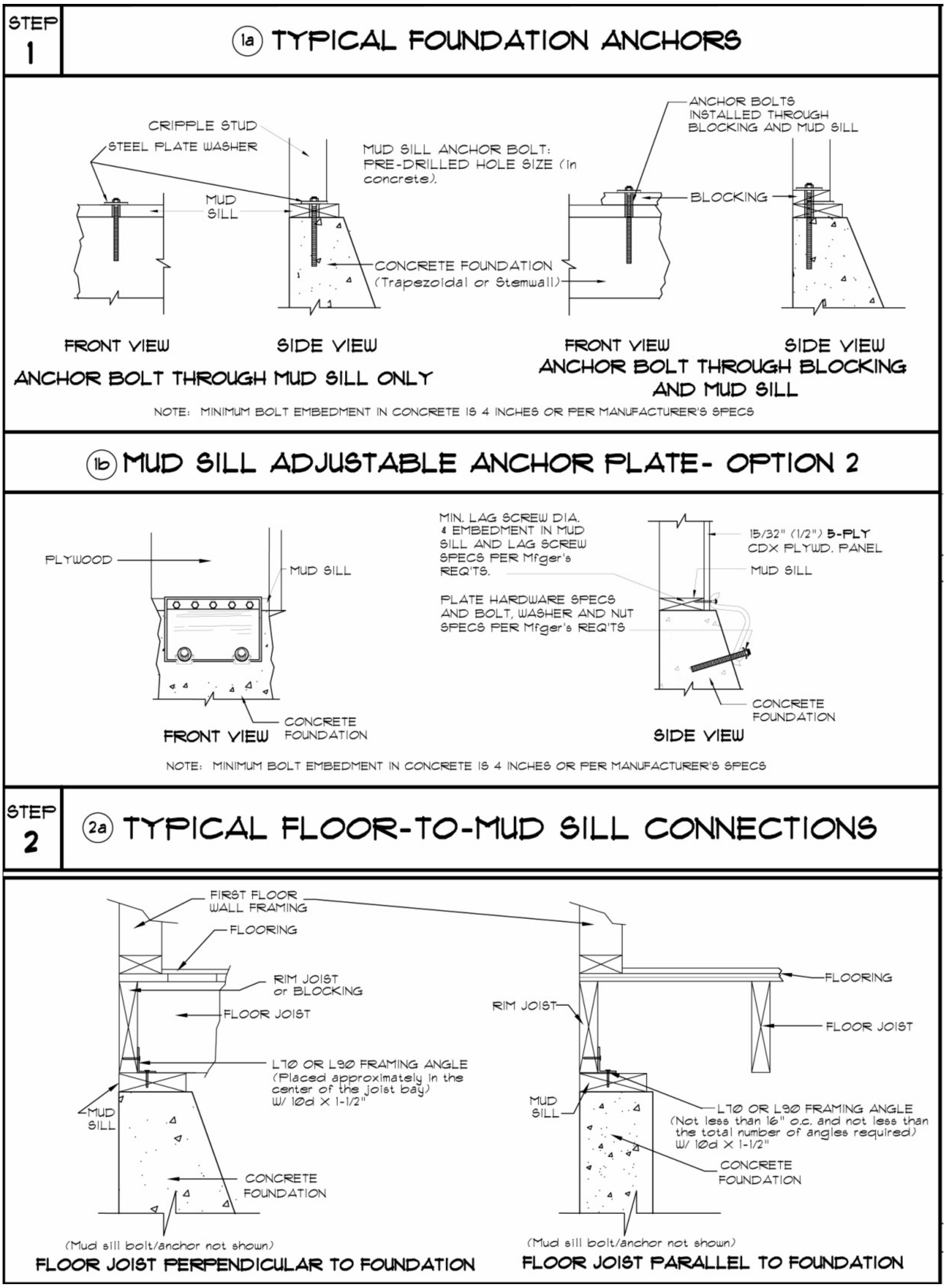


Figure 49
Floor to Mud Sill Connections
Source: http://www.ci.san-leandro.ca.us

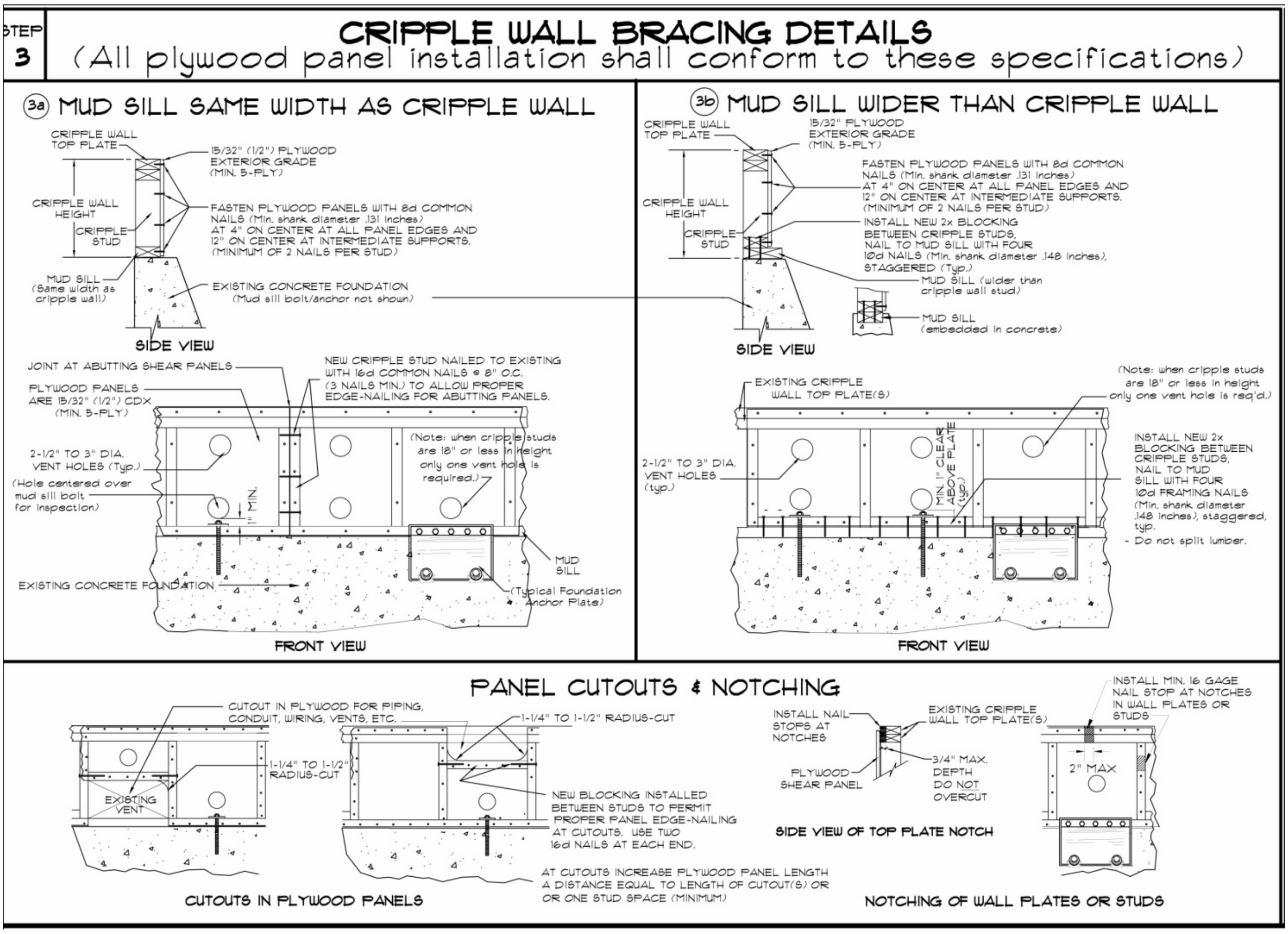


Figure 50
Cripple Wall Bracing Details
Source: http://www.ci.san-leandro.ca.us

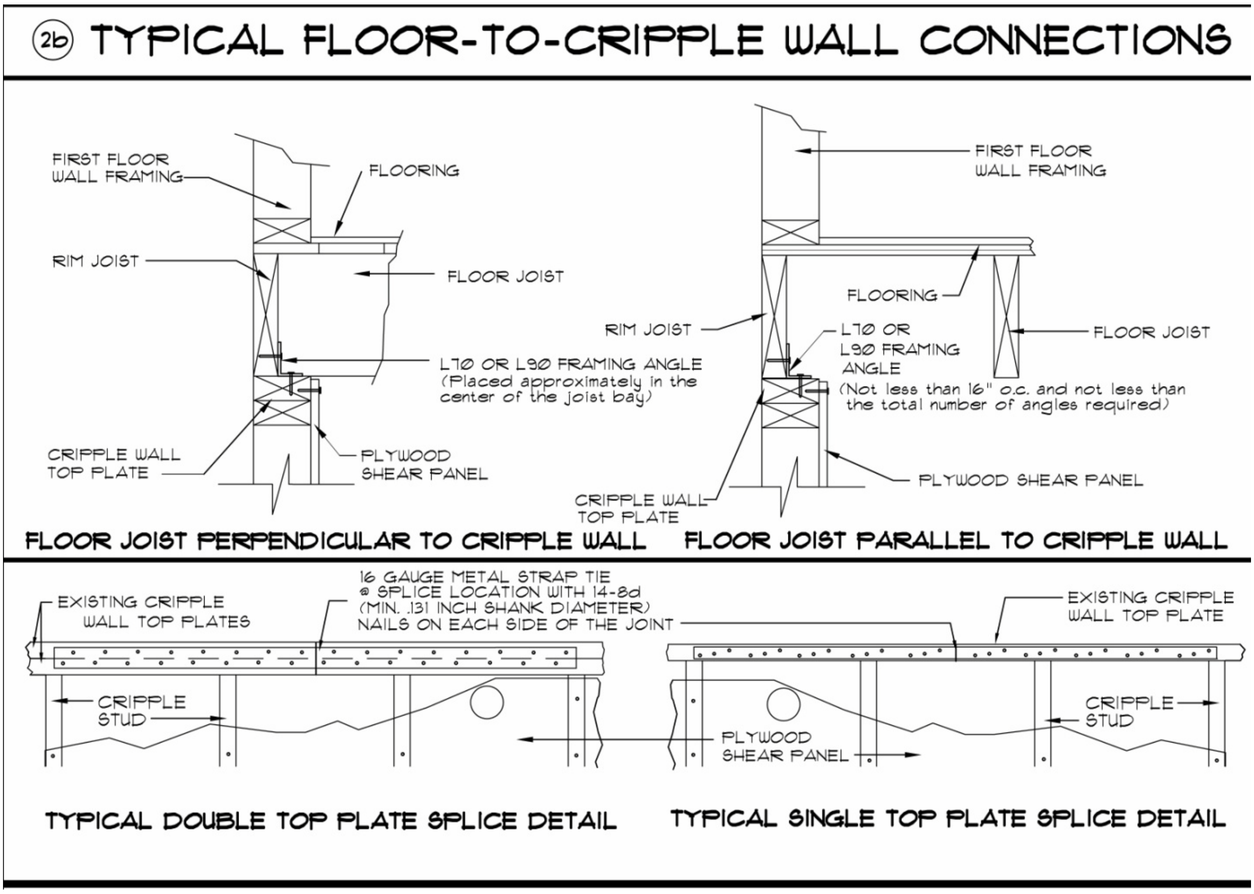


Figure 51
Floor to Cripple Wall Connections
Source: http://www.ci.san-leandro.ca.us

As John Scoggins, a practitioner of seismic retrofit, explains, jack studs on perimeter foundation walls California are first evaluated by drilling a test whole in the concrete, block, brick or stone to test if the material is strong enough to support a bolt. Connections are then examined, followed by damage to wooden members. If a cripple wall is present it must have panel sheathing for bracing and adequate connections. Selection of connectors for retrofit is important. A firm masonry foundation that has good accessibility but poor anchors may be retrofitted by drilling holes through the plates into the foundation, inserting lengths of steel rod, epoxied into place (see Figure 52). Epoxy is ideal as expansion bolts may crack the older, more brittle concrete.

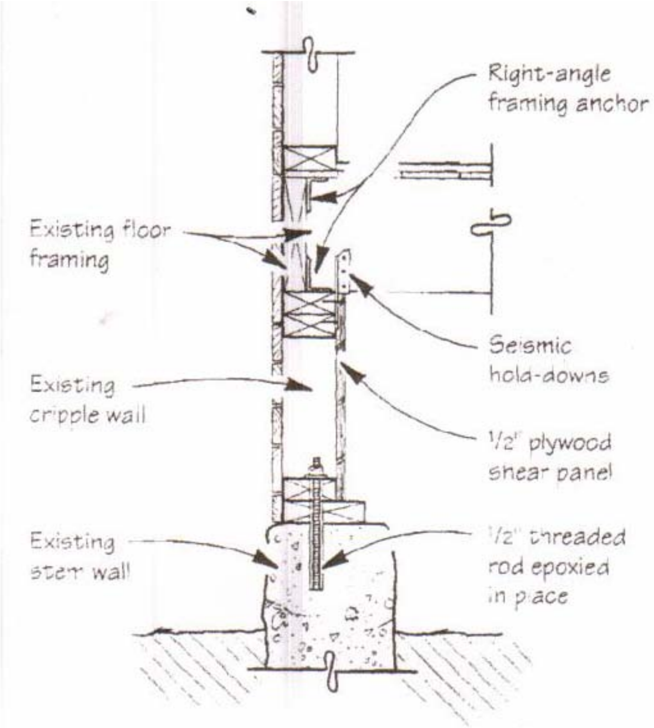


Figure 52
Where there is good access, the least expensive retrofit involves threaded rod anchors epoxied into place, plywood shear panelling, and framing anchors between the top of the cripple wall and the floor framing
Source: Scoggins, John. *Seismic Support for Old Foundations*. In Journal of Light Construction, Builderburg Partnership, Washington, DC, 1991, p 43.

Once the anchors and bolts are in place, structural sheathing can be installed around the cripple wall and at the sides of any access doors or vent openings, in accordance with guidelines provided by the city of Santa Barbara.[i] The length of each panel should also be at least twice its height. Three-inch holes are then drilled into the plywood at the top and bottom of each bay for ventilation. These are covered with hardware cloth. A Simpson H1s or H5s is then installed to secure the cripple wall to every second joist.

In limited access retrofits, where 2x12 joists are used there will be enough space to use a Hilti TE15 right angle hammer drill. A Simpson RFB retrofit bolt or epoxied threaded rod anchor can then be installed. Where the joists are smaller, a Simpson FA6 or FA8 can be used, an "L-shaped 12-gauge steel connector that rests on top of the plate and laps over the side of the stem wall."[j]

When the foundation is not strong enough to hold bolts, a new concrete stem wall will be poured (see Figure 53). Four rebar dowels are drilled and places in the old stem wall at 4' centres. New cripple walls can then be installed around the perimeter and bolted to the foundation. Metal brackets connect the floor joists to the cripple walls.

[i] Scoggins, John. *Seismic Support for Old Foundations*. In Journal of Light Construction, Builderburg Partnership, Washington, DC, 1991, p 44.
[j] Scoggins, John. *Seismic Support for Old Foundations*. In Journal of Light Construction, Builderburg Partnership, Washington, DC, 1991, p 44.

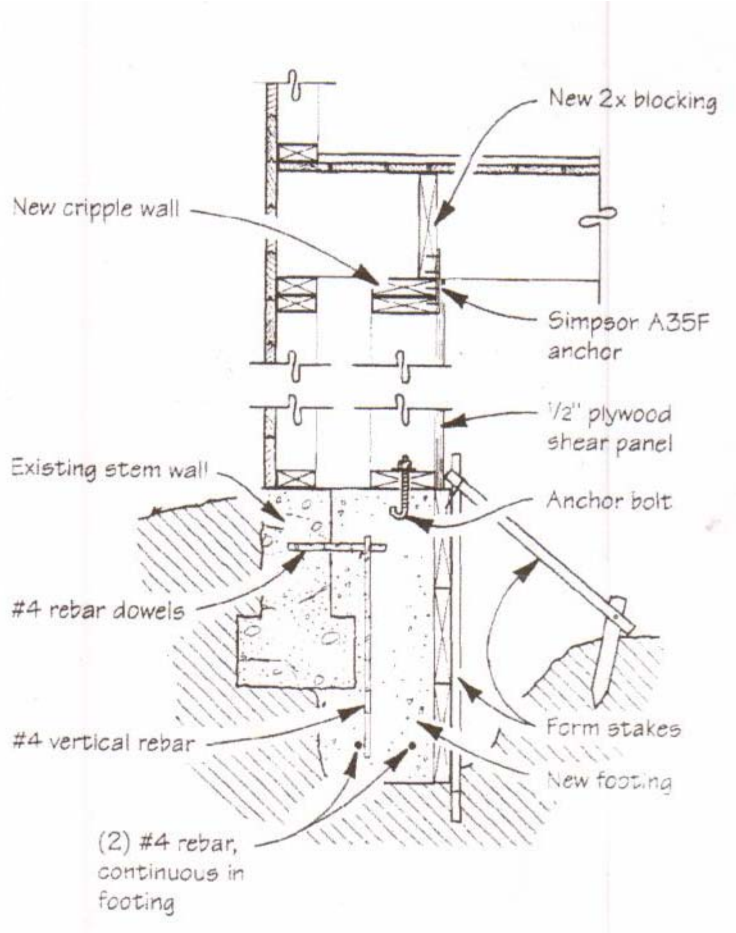


Figure 53
Pouring a New Stem Wall
Source: Scoggins, John. *Seismic Support for Old Foundations.* In Journal of Light Construction, Builderburg Partnership, Washington, DC, 1991, p 44.

When a dwelling is supported on posts and piers, anchors are rarely present and posts attached to the above girders with only nails. Here, a possible retrofit measure is to install new pier footings between existing posts and replace any posts located under girder splices (see Figure 54). Simpson H-series clips are used to tie the floor joists to the girders.

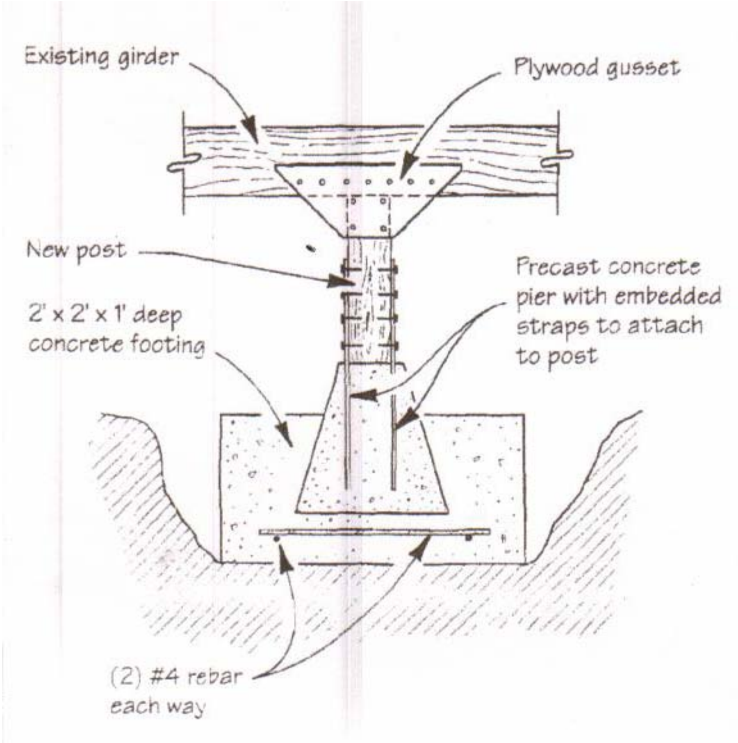


Figure 54
Reinforced Post Footing
Source: Scoggins, John. *Seismic Support for Old Foundations*. In Journal of Light Construction, Builderburg Partnership, Washington, DC, 1991, p 45.

Full foundation walls are at risk of degradation over time. Cracks may appear and reduce the strength of the wall. Small cracks can be repaired with pressure injection of epoxy (see Figure 55). This may be of use in a retrofit where foundation walls are damaged or ill-prepared for seismic activity.

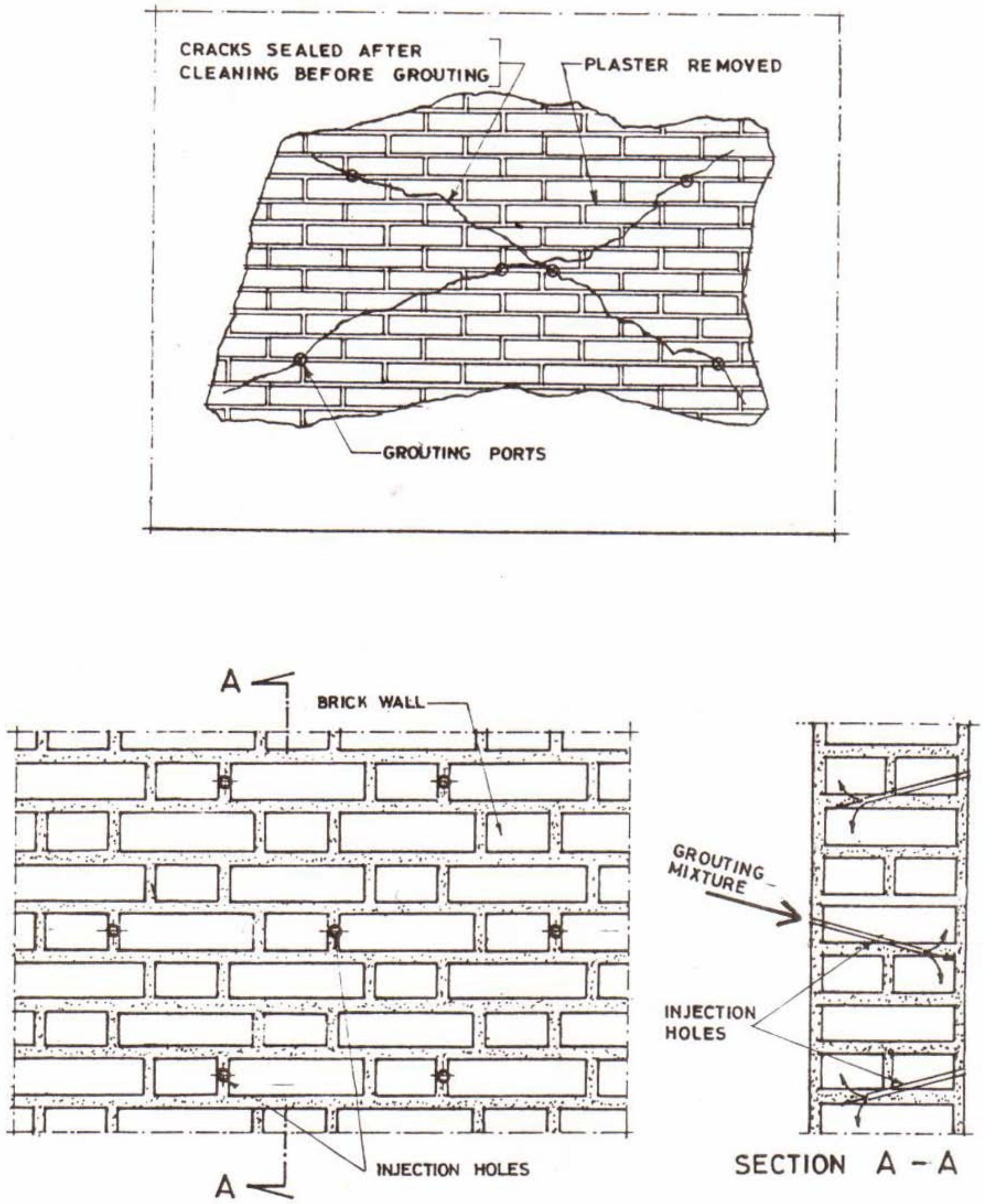


Figure 55
Strengthening of Existing Masonry Wall by Grouting
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 61.

Large cracks can be mitigated with a cover of mortar for protection and reinforcement, or with steel mesh nailed or bolted to the wall.[k]

Where foundation walls may have poor connections, two steel meshes can be placed on either side of the wall and thick cement mortar applied over top to improve the connection of these walls (see Figure 56).

[k] The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 62.

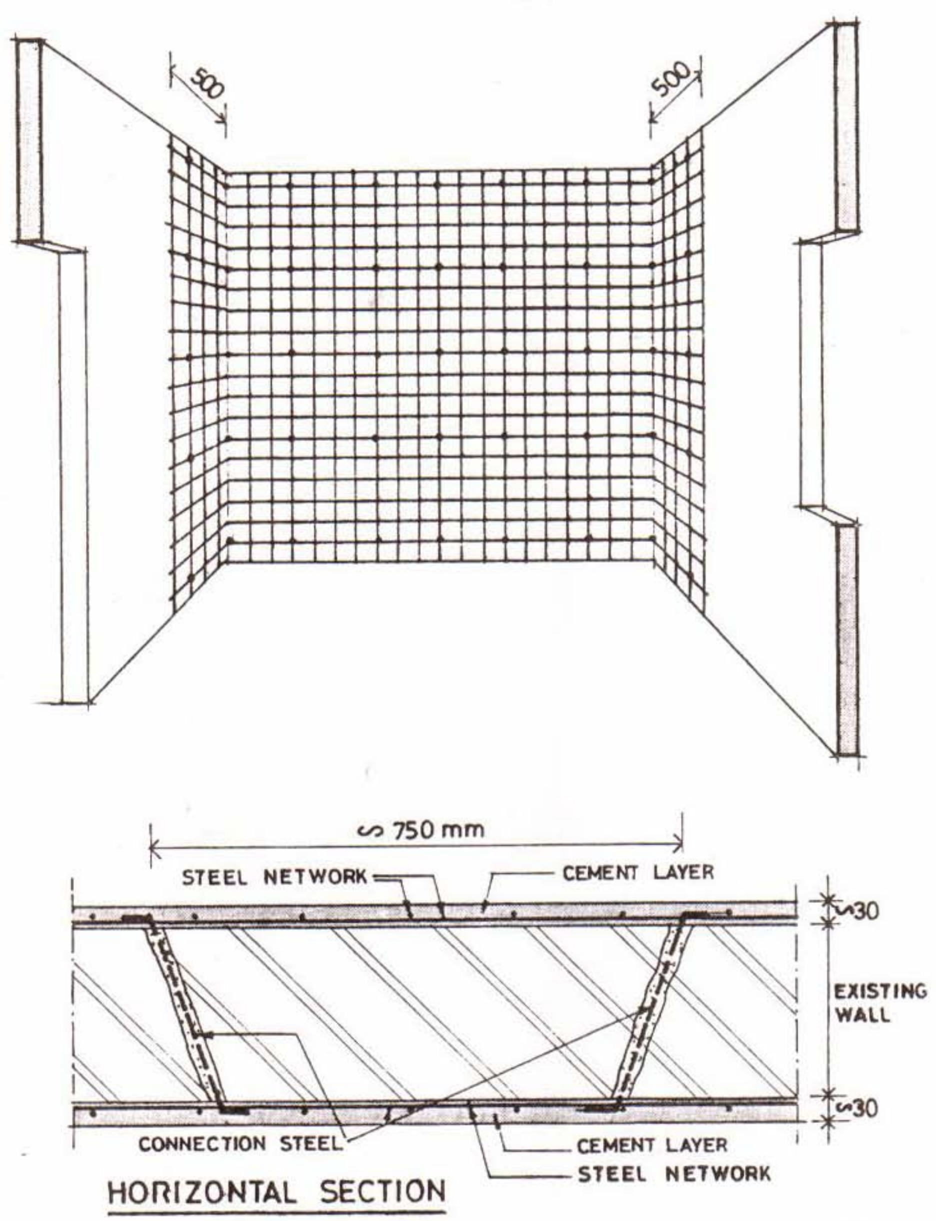


Figure 56
Vertical Reinforced Concrete Covering Plates
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 74.

Prestressing may also be useful to increase shear strength of walls, carried out by placing two steel rods on the two sides of the wall and stretching them by turnbuckles (see Figure 57).

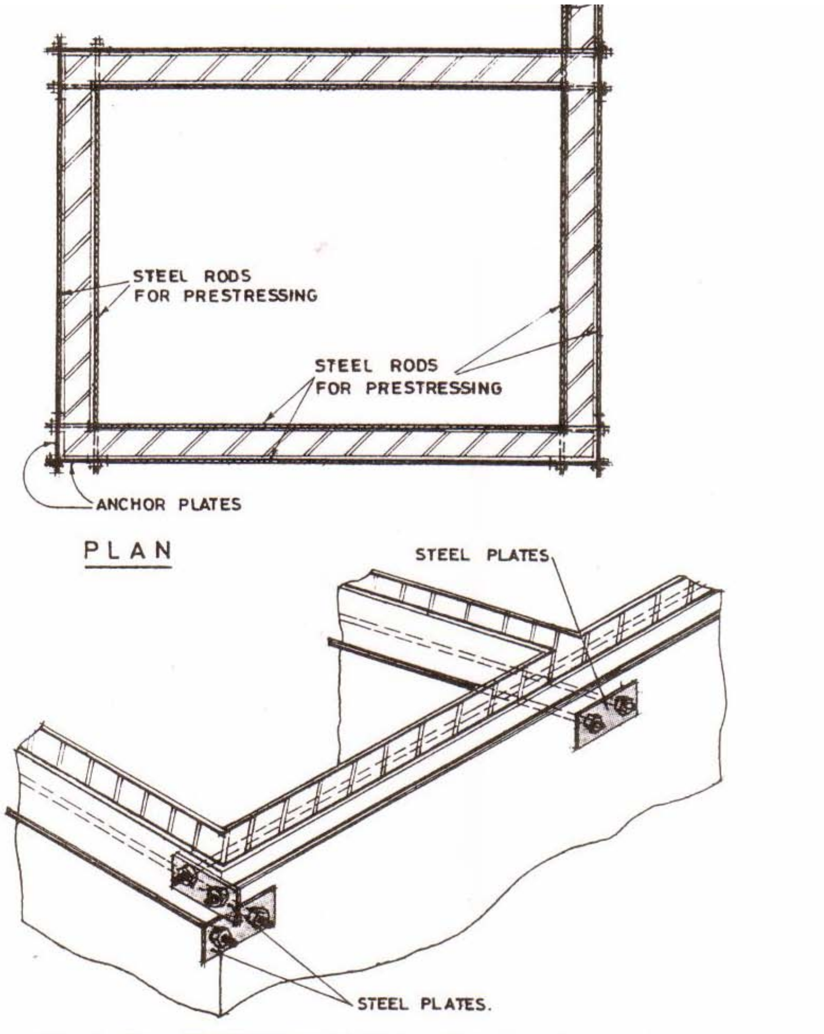


Figure 57
Strengthening of Walls by Prestressing
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes*. Association for Science Documents and Information, Tokyo, 1980, vol 1, p 75.

Foundation walls may also be strengthened with reinforced concrete strips (see Figures 58 and 59).

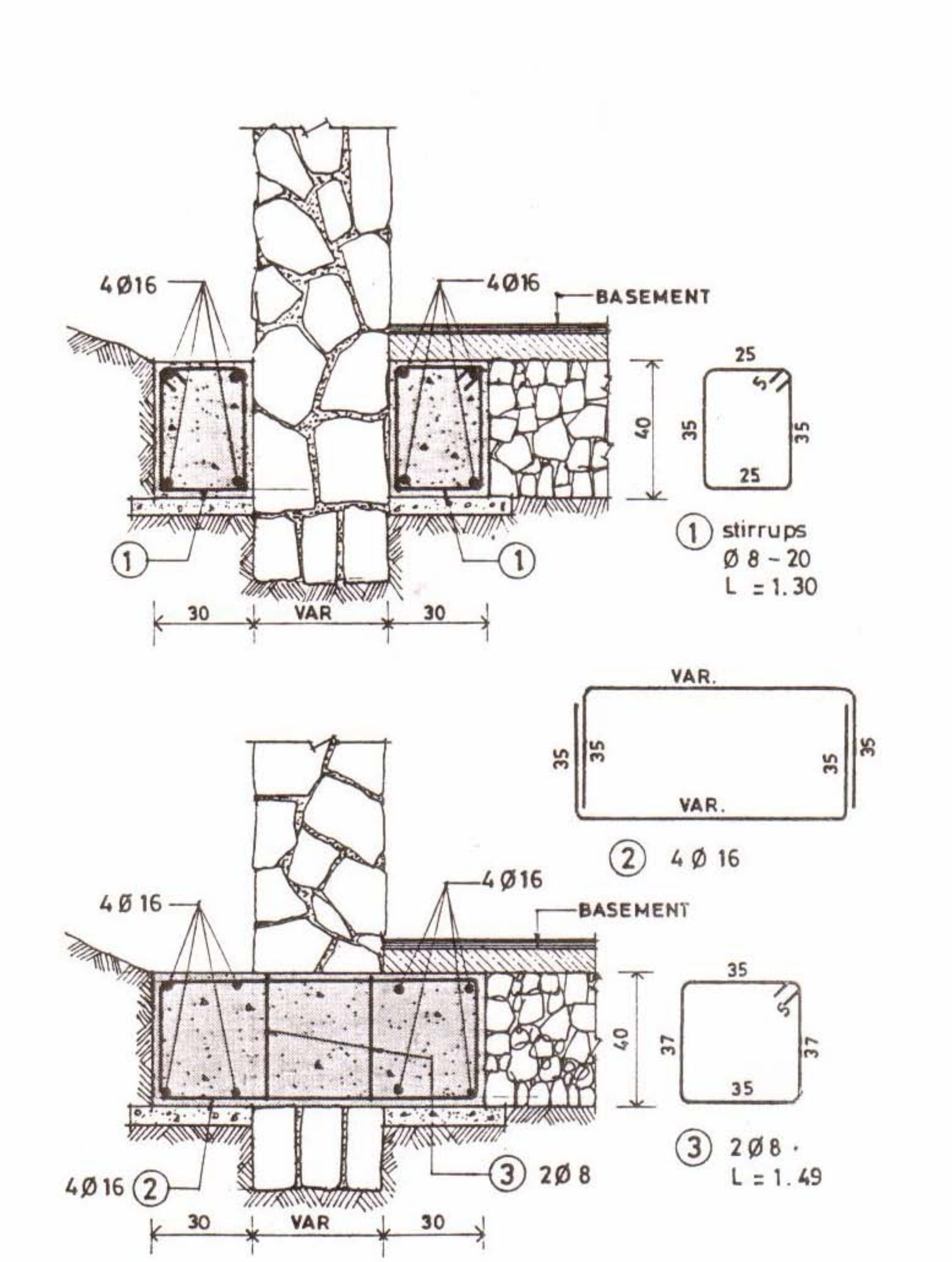


Figure 58
Strengthening of Existing Foundation
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 81.

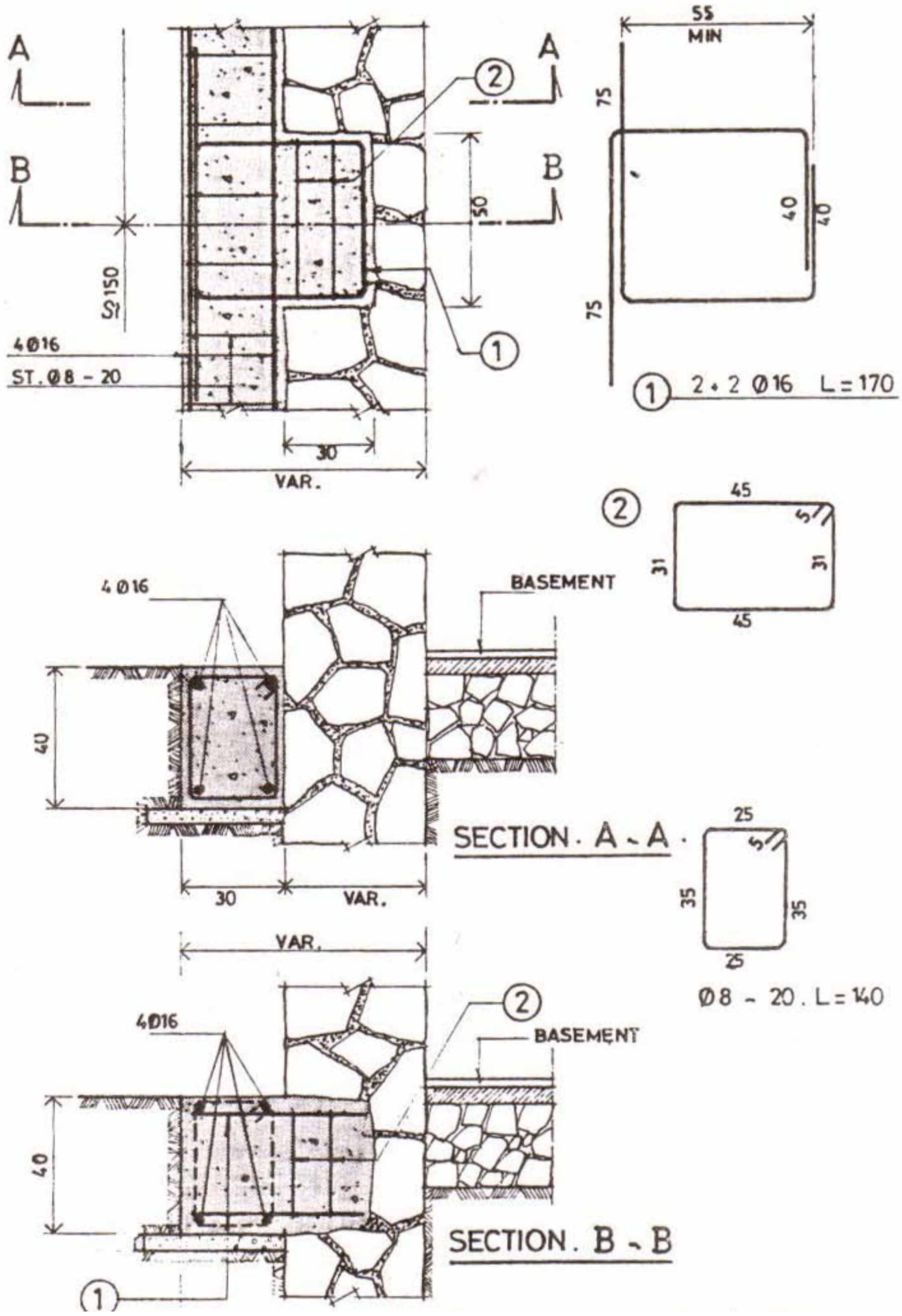


Figure 59
Strengthening of Existing Foundation: Strip on Outside Only
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 82.

A single layer of carbon fabric overlay applied to each side of the structural walls may also be applied to a concrete foundation wall which can contribute "significantly to doubling the inelastic deformation capacity."[1] Shear deformations have the potential to be halved following repair. Composite material jackets are extremely effective in both retrofit and repair situations as well as being economically competitive. This may prove useful at a smaller scale in dwelling retrofit, where foundation walls would be inadequate in their performance in a seismic event.

[1] Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 375.

A reactive powder mortar with a flow value of 200% and a compressive strength of 75MPa, may also be relevant in the retrofit of foundation walls. The reactive powder mortar is composed of "type II Portland Cement, quartz sand, quartz powder, silica fume, super-plasticizer and water."[m] This mortar has a slant shear strength comparable to epoxy resin, provides a higher rebar pull out force and a higher tensile strength.[n] This mortar is relevant to this report as it has the possibility to be used in the seismic retrofit of dwelling foundation and is proven to be an adequate repair material for concrete structures.

A new technique to retrofit masonry walls, which increases its shear strength and stiffness has been developed, involving deep repointing of the wall. The new technique uses deep repointing to replace mortar to a depth of 70-80mm, then confines the wall externally.[o] This method produces a "significant increase of the shear strength and especially of the shear stiffness…compared to the virgin masonry."[p] Shear stiffness was noted to increase by up to 300%, thus this technique has strong potential for use in seismic retrofit of dwelling foundations, where masonry walls need to be strengthened to withstand a seismic event.

Similar subfloor and foundation construction to New Zealand dwellings occurs in Turkey's traditional housing. Timber construction makes up a large majority of Turkey's historic buildings, and although considered very earthquake resistant, these historic timber buildings continue to be seriously damaged in earthquakes. Two or three storied traditional timber constructions are typically formed consisting of a timber framework on a basement wall or masonry ground floor, very similar to New Zealand's own full or partial foundation wall foundation types. Strengthening of these structures is considered in terms of maintenance and technique. Continuous maintenance is emphasised to ensure the longevity of the structure. Strengthening techniques are then outlined. Strapping of a building involves bolting the structure to the foundation, or strapping the timber frame together with cable and protecting the elements with wooden angle plates. Walls must be connected to each other using braces of timber, steel or synthetic fibre and plywood stiffeners between building and strapping cables may give increased strength. This system can be applied to masonry buildings also and allows the building to perform structurally as a whole. Infill openings may be used to provide structural continuity. Bracing can be used to repair weakened wooden structural systems; it should be added to have minimum impact and not overload the existing structural system. Reinforcing joints and connections in the timber is ideal, by using anchor ties or bolts, or metal or glass fibre reinforced plastic. Missing areas in the timber members may be filled with epoxy resins.

These methods have been suggested as low cost, practical approaches to retrofit timber structures without compromising their character or integrity. This relates very closely to the retrofitting of timber dwellings in New Zealand.

Helifix is a company producing high performance stainless steel helical wall ties, fixings and masonry repair and reinforcement systems.q This relates closely to this foundation type and Helifix

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[m] Liu, Chin-Tsung, and Huang, Jong-Shin. *Highly Flowable Reactive Powder Mortar as a Repair Material.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 1044.

[n] Liu, Chin-Tsung, and Huang, Jong-Shin. *Highly Flowable Reactive Powder Mortar as a Repair Material.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, pp 1049-1050.

[o] Corradi, M and Tedeschi, C and Binda, L and Borri, A. *Experimental Evaluation of Shear and Compression Strength of Masonry Wall Before and After Reinforcement: Deep Repointing.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 465.

[p] Corradi, M and Tedeschi, C and Binda, L and Borri, A. *Experimental Evaluation of Shear and Compression Strength of Masonry Wall Before and After Reinforcement: Deep Repointing.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 471.

[q] http://www.helifix.com.au

have explored several techniques for several areas of remedial construction. Their specialist area devoted to masonry repair relates closely to the retrofit of partial or full foundation wall foundation types in New Zealand dwellings. The following set of figures detail methods of masonry repair using Helifix products (the figures are also printed in full size in Appendix 2). The first figure details crack stitching a cavity wall using HeliBars, a reinforcing bar set into place with grout (see Figure 60). Concrete patching can be carried out using patchpins (see Figure 61), a stainless steel pin for concrete patching. This is driven into the concrete and mortar applied over to conceal the remedial work, which is ideal. Crack stitching a rendered cavity wall can be done using HeliBars (see Figure 62). The stainless steel reinforcement bar is set into place with grout. Grout is applied over the bar to conceal it. HeliBars can be used to repair a crack near a corner in a cavity wall (see Figure 63). Here the bar is cut to the required length and bent to fit in the slots and grouted into place. The repair of a crack near the corner of a cavity wall can also be carried out using CemTies (see Figure 64). Here a stainless steel structural pin is inserted into the wall at the required spacing and set with grout. DryFix may also be used for this repair (see Figure 65). This is where a dry stainless steel pining system is used. Cross stitching of a cracked solid wall may be done using CemTies (see Figure 66). This uses stainless steel structural pins, grouted into a wall, and CemTies wound into the grout filled hole.

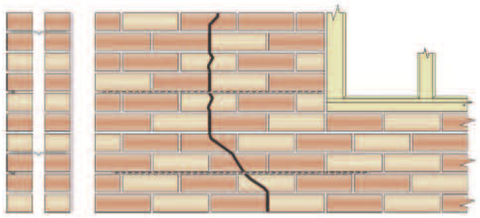
The repair of a crack near a corner in a solid wall may be done using HeliBars (see Figure 67). Again this utilizes a stainless steel reinforcement bar, grouted into place. CemTies can also be used (see Figure 68). The repair of a crack near a corner in a stone wall cane be done with HeliBars (see Figure 69) or the bars may be used to crack stitch a solid wall (see Figure 70). Repair of a crack near a corner in a stone wall may also be carried out using CemTies (see Figure 71.)

REPAIR DETAIL BCS01 HELIFIX

BCS01

Crack stitching a cavity wall using HeliBars

Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB



METHOD STATEMENT

1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing.* Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
6. Push the HeliBar into the grout to obtain good coverage.
7. Inject a second bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for new pointing.
8. Point up the remaining slot with a suitable matching mortar and make good the crack using an appropriate Helifix bonding agent or filler, depending on the width of the crack.
9. Clean tools with clean, fresh water.

NOTE ***Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.***

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***

RECOMMENDED TOOLING

For cutting slots up to 40mm deep ....Wall chaser, mortar saw or angle grinder with vacuum attachment

For mixing HeliBond ....Drill with mixing paddle

For injection of HeliBond into slots ....Helifix Pointing Gun with mortar nozzle

For smoothing pointing ....Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

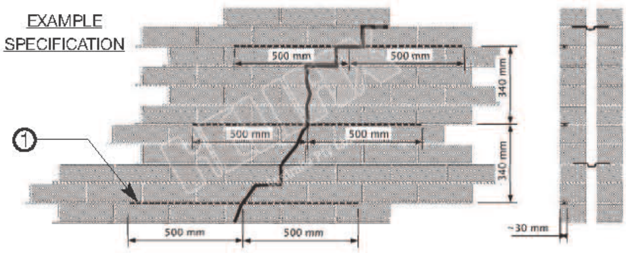
- **A.** Depth of slot into the masonry to be 25mm to 35mm.
- **B.** Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
- **C.** HeliBar to be long enough to extend a minimum of 500mm either side of the crack or 500mm beyond the outer cracks if two or more adjacent cracks are being stitched using one rod.
- **D.** Normal vertical spacing is 340mm (4 brick courses).
- **E.** Where a crack is less than 500mm from the end of a wall or an opening the HeliBar is to be continued for at least 100mm around the corner and bonded into the adjoining wall or bent back and fixed into the reveal, avoiding any DPC.
- **F.** Install Helifix remedial wall ties if existing ties are defective in any way. Refer to Repair Details BRT01–03 for details on Helifix remedial wall tie installation.
- **G.** In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

EXAMPLE SPECIFICATION



CRACK STITCHING A CRACKED BRICK WALL

Material: HELIBAR 6 X 1000
Product code: **HBR6x1000**

CRACK TO BE STITCHED BY BONDING 1M LENGTHS OF 6MM DIA. HELIBAR (HBR6) INTO CUT SLOTS USING HELIBOND GROUT (HLB). HELIBARS TO EXTEND 500MM PAST EITHER SIDE OF THE CRACK AND TO BE INSTALLED AT A VERTICAL SPACING OF NOT MORE THAN 4 BRICK COURSES APART. SLOTS TO BE CUT INTO THE HORIZONTAL MORTAR JOINTS TO A DEPTH OF 25-35MM AND TO A HEIGHT EQUAL TO THE MORTAR JOINT HEIGHT.

ITEM	CODE	DESCRIPTION				
1	HBR	HELIBAR	HELIFIX	HELIFIX (AUSTRALIA) PTY LTD		
				TYPICAL WALL TYPE AND HELIBAR APPLICATION		
				SCALE 1:20	DWG No. BCS01-EXS	SHEET 1 of 1

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Figure 60

Source: http://www.helifix.com.au/masonry_repair_details.html

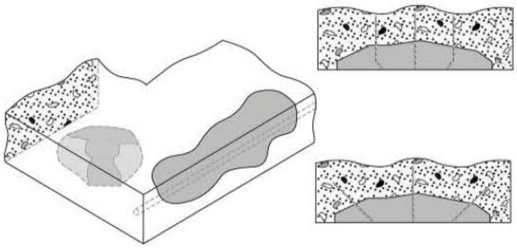
REPAIR DETAIL BCR01

HELIFIX

BCR01

Concrete patching using PatchPins

Product	Description	Code
PatchPin	Stainless steel pin for concrete patching	HPP



METHOD STATEMENT

1. Clean the area to be patched. Remove all loose material and leave the surface ready to accept the patching material in accordance with the manufacturer's instructions.
2. Clean and treat any exposed, embedded steel.
3. Drill 6.5mm diameter holes into the concrete to the specified depth and at the specified spacing.
4. Attach the PatchPin support tool to an SDS hammer drill set to a slow speed and light hammer only.
5. Load the PatchPin into the support tool.
6. Drive the PatchPin into the pre-drilled pilot hole. Check that the exposed end of the pin finishes below the intended face of the finished concrete. The pin end may be bent if the straight length is too long.
7. Apply the patching mortar in accordance with the manufacturer's instructions.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***

RECOMMENDED TOOLING

For drilling .... SDS rotary hammer drill 650/800w
For installation of StarTie .... SDS rotary hammer drill and PatchPin support tool

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Depth of hole to be 30-50mm depending on the hardness of the material, with harder materials requiring less embedment.

B. Pin spacing and position may be varied at the discretion of the specifier to suit site conditions. Typically, placing pins 50mm in from the edge with intermediate pins to keep centres within 150-200mm will prove adequate.

C. Generally, pins should be applied at not less than two pins per patch.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on **1300 66 70 71**.

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Figure 61

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS02 HELIFIX

BCS02

Crack stitching a rendered cavity wall using HeliBars

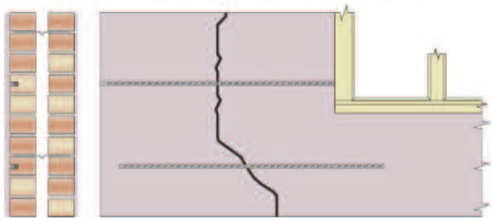
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Using an appropriate power cutting tool with vacuum attachment, cut slots through the render and into the masonry to the specified depth and at the required vertical spacing.* Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
6. Push the HeliBar into the grout to obtain good coverage.
7. Inject a second bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for making good the render.
8. The crack within the wall should be waterproofed using an appropriate Helifix bonding agent or filler, e.g. HeliBond or CrackBond, depending on the width of the crack, and the crack and remaining slots at the surface made good with a suitable matching render or mortar.
9. Clean tools with clean, fresh water.

***NOTE.** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For cutting slots up to 40mm deep .... Wall chaser, mortar saw or angle grinder with vacuum attachment

To achieve final depth of slot beyond 40mm .... Hand or Helifix Power Chisel

For mixing HeliBond .... Drill with mixing paddle

For injection of HeliBond into slots .... Helifix Pointing Gun with mortar nozzle

For smoothing pointing .... Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Depth of slot into the masonry to be 25mm to 35mm + the thickness of the render.

B. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.

C. HeliBar to be long enough to extend a minimum of 500mm either side of the crack or 500mm beyond the outer cracks if two or more adjacent cracks are being stitched using one rod.

D. Normal vertical spacing is 340mm (4 brick courses).

E. Where a crack is less than 500mm from the end of a wall or an opening the HeliBar is to be continued for at least 100mm around the corner and bonded into the adjoining wall or bent back and fixed into the reveal, avoiding any DPC.

F. Install Helifix remedial wall ties if existing ties are defective in any way. Refer to Repair Details BRT01–03 for details on Helifix remedial wall tie installation.

G. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 62

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS03 HELIFIX

BCS03

Repair of a crack near a corner in a cavity wall using HeliBars

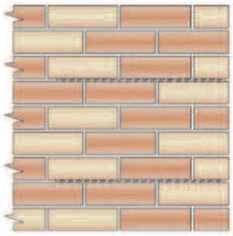
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

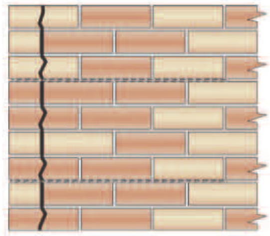
1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing.* Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond. If the wall is rendered and the mortar joints are not visible, cut the horizontal slots through the render and into the masonry.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 6.
3. Cut the 6mm HeliBar to the required length and bend to fit in the slots.
4. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
5. Fit the mortar nozzle to the gun.
6. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
7. Push the 6mm HeliBar into the grout to obtain good coverage.
8. Inject a second bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for new pointing.
9. Point up the remaining slot with a suitable matching mortar and make good the crack using an appropriate Helifix bonding agent or filler, depending on the width of the crack.
10. Clean tools with clean, fresh water.

***NOTE** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

⚠ Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.



ELEVATION A



ELEVATION B

RECOMMENDED TOOLING

For cutting slots up to 40mm deep..................Wall chaser, mortar saw or angle grinder with vacuum attachment

To achieve final depth of slot beyond 40mm......................Hand or Helifix Power Chisel

For mixing HeliBond ....Drill with mixing paddle

For injection of HeliBond into slots............................Helifix Pointing Gun with mortar nozzle

For smoothing pointing...Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Depth of slot into the masonry to be 25mm to 35mm + thickness of any render.

B. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.

C. HeliBar to be long enough to extend a minimum of 500mm either side of the crack or 500mm beyond the outer cracks if two or more adjacent cracks are being stitched using one rod.

D. Normal vertical spacing is 340mm (4 brick courses).

E. Where a crack is less than 500mm from the end of a wall or an opening the HeliBar is to be continued for at least 100mm around the corner and bonded into the adjoining wall or bent back and fixed into the reveal, avoiding any DPC.

F. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 63

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS04 HELIFIX

BCS04

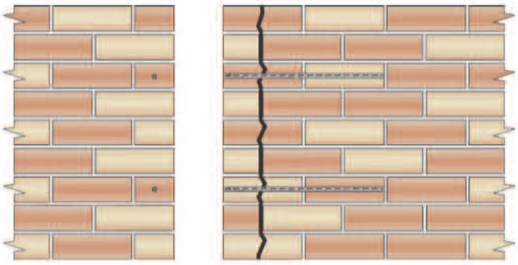
Repair of a crack near a corner in a cavity wall using CemTies

Product	Description	Code
CemTie	Grade 316 stainless steel structural pin	HCT
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Mark the locations for the CemTie pins onto the face of the wall at the required spacing.*
2. Drill a 16mm Ø clearance hole through the outer wall to the required depth.*
3. Clean out all dust from the hole and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the hole is damp or primed prior to commencing step 8.
4. Attach the required length of CemTie pinning nozzle to the Helifix Pointing Gun.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the gun.
6. Pump grout to fill the nozzle.
7. Wind the CemTie into the nozzle and ensure that it is fully covered in grout. (Alternatively, fill the hole with grout and wind the CemTie into the grout-filled hole.)
8. Insert the nozzle to the full depth of the drilled hole and pump the grout. Slowly withdraw the nozzle while pumping. The CemTie will be carried out with the HeliBond grout as it is forced through the nozzle. Back pressure will help to push the nozzle back out of the hole.
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings. Make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.
10. Clean tools with clean, fresh water.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling .... SDS rotary hammer drill 650/700w
For mixing HeliBond .... Drill with mixing paddle
For insertion of the CemTies .... Helifix Pointing Gun with CemTie Pinning Nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

- **A.** CemTies are to be installed at a vertical spacing of 425mm.
- **B.** CemTies are to extend at least 250mm past the crack.
- **C.** Depth of hole to be CemTie length + 25mm.
- **D.** Ensure the CemTies are installed into solid brick and not the mortar joints or loose rubble within the wall.
- **E.** If cracking occurs on both elevations consider using HeliBar crack stitching around the corner (see Repair Detail BCS03). If CemTies are to be used, they should be staggered between each elevation.
- **F.** In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the hole, or priming with HeliPrimer WB, should be carried out just prior to inserting the CemTie.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 64
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS05 HELIFIX

BCS05

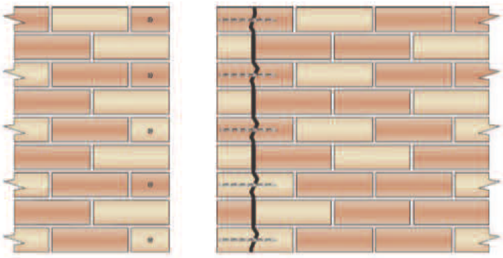
Repair of a crack near a corner in a cavity wall using DryFix

Product	Description	Code
DryFix	Stainless steel dry pinning system	HDF

METHOD STATEMENT

1. Mark the locations for the DryFix ties onto the face of the wall at the required spacing. (Refer to the Specification Notes for typical spacing requirements.)
2. Drill a 5mm Ø pilot hole through the near skin and into the remote skin to the specified depth using a light-weight SDS hammer drill set to a slow speed and light hammer only. A rotary percussion 3-jaw chuck drill may be preferred if the masonry is particularly soft. A 6mm or 6.5mm Ø pilot hole size may be preferred if the masonry is particularly hard. (Refer to the Specification Notes for typical depth requirements.)
3. Attach the Helifix Power Driver attachment to an SDS hammer drill set to a slow speed and light hammer only. (DryFix ties are self-tapping and will work themselves into the wall following the hammer action of the drill.)
4. Load the DryFix tie into the power driver attachment.
5. Support the power driver attachment with one hand, while using the other to work the drill, and drive the DryFix tie into the pre-drilled pilot hole to approximately 10mm beyond the surface of the near skin.
6. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings. Make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



ELEVATION SECTION A

RECOMMENDED TOOLING

For drilling ....Rotary percussion or SDS rotary hammer drill 650/700w

For installation of DryFix ....SDS rotary hammer drill and DryFix Power Driver attachment

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. DryFix ties are to be installed at a vertical spacing of 170mm (every 2 brick courses).

B. DryFix ties are to extend at least 70mm past the crack.

C. Depth of pilot hole to be DryFix tie length + 10mm.

D. DryFix ties are to be installed at least 25mm in from the brick edge.

E. If cracking occurs on both elevations consider using HeliBar crack stitching around the corner (see Repair Detail BCS03). If DryFix ties are to be used, they should be staggered between each elevation.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 65

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS08 HELIFIX

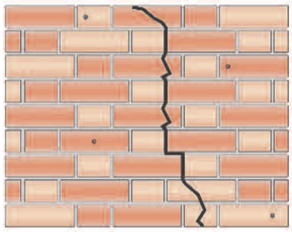
BCS08 Cross stitching a cracked solid wall using CemTies

Product	Description	Code
CemTie	Grade 316 stainless steel structural pin	HCT
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Mark the locations for the CemTie pins onto the face of the wall at the required spacing. (Refer to the Specification Notes for typical spacing requirements.)
2. Drill a 12–14mm Ø clearance hole, or 16mm Ø if the CemTie is longer than 450mm, at the required location and angle, and to the specified depth.*
3. Clean out all dust from the hole and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the hole is damp or primed prior to commencing step 8.
4. Attach the required length of CemTie pinning nozzle to the Helifix Pointing Gun.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the gun.
6. Pump grout to fill the nozzle.
7. Wind the CemTie into the nozzle and ensure that it is fully covered in grout. (Alternatively, fill the hole with grout and wind the CemTie into the grout-filled hole.)
8. Insert the nozzle to the full depth of the drilled hole and pump the grout. Slowly withdraw the nozzle while pumping. The CemTie will be carried out with the HeliBond grout as it is forced through the nozzle. Back pressure will help to push the nozzle back out of the hole.
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings. Make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.
10. Clean tools with clean, fresh water.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling ....SDS Rotary hammer drill 650/700w
For mixing HeliBond ....Drill with mixing paddle
For insertion of the CemTies................................Helifix Pointing Gun with CemTie Pinning Nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. CemTies are to be installed perpendicular to the direction of the plane of the crack (e.g. in the horizontal plane for vertical cracks and in the vertical plane for horizontal cracks).
B. CemTies are to start a minimum of 225mm away from the crack.
C. Depth of hole to be CemTie length + 25mm.
D. Angle of drilling to be such that the CemTies will pass through the crack within the centre third of the wall.
E. CemTies are to start from alternate sides of the crack and to be at 225mm spacing measured along the length of the crack.
F. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the hole, or priming with HeliPrimer WB, should be carried out just prior to inserting the CemTie.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 66
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS09 HELIFIX

BCS09

Repair of a crack near a corner in a solid wall using HeliBars

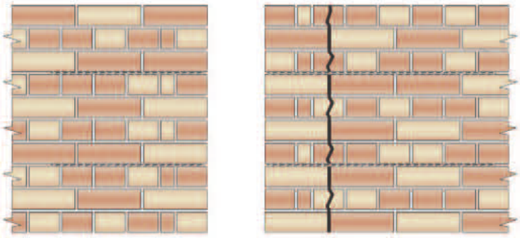
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing. (Refer to the Specification Notes for typical depth and spacing requirements.) Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond. If the wall is rendered and the mortar joints are not visible, cut the horizontal slots through the render and into the masonry.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
6. Push the 6mm HeliBar into the grout to obtain good coverage.
7. Repeat steps 5 and 6 as required to install all specified HeliBar into the slot.
8. Inject a final bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond grout as necessary, leaving 10-15mm for new pointing.
9. Point up the remaining slot with a suitable matching mortar and make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.
10. Clean tools with clean, fresh water.

***NOTE.** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.



RECOMMENDED TOOLING

For cutting slots up to 40mm deep	Wall chaser, mortar saw or angle grinder with vacuum attachment
To achieve final depth of slot beyond 40mm	Hand or Helifix Power Chisel
For mixing HeliBond	Drill with mixing paddle
For injection of HeliBond into slots	Helifix Pointing Gun with mortar nozzle
For smoothing pointing	Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Allow for the installation of one HeliBar for each skin of brickwork into each cut slot. By example, a common 230mm solid wall construction (equivalent to two skins of tied brickwork) will require the installation of two HeliBars per slot. A solid wall equivalent in depth to three skins of bonded masonry will require three HeliBars per slot.

B. Depth of slot into the masonry to be 35mm to 40mm + thickness of any render, assuming a 230mm solid wall. Add 10mm for each additional skin of brickwork.

C. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.

D. HeliBar to be long enough to extend a minimum of 500mm either side of the crack or 500mm beyond the outer cracks if two or more adjacent cracks are being stitched using one rod.

E. Normal vertical spacing is 340mm (4 brick courses).

F. Where a crack is less than 300mm from the end of a wall or an opening the HeliBar is to be continued for at least 100mm around the corner and bonded into the adjoining wall or bent back and fixed into the reveal, avoiding any DPC.

G. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 67

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS10 **HELIFIX**

BCS10

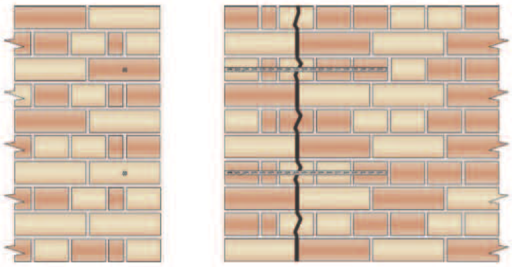
Repair of a crack near a corner in a solid wall using CemTies

Product	Description	Code
CemTie	Grade 316 stainless steel structural pin	HCT
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Mark the locations for the CemTie pins onto the face of the wall at the required spacing.*
2. Drill a 16mm Ø clearance hole through the outer wall to the required depth.*
3. Clean out all dust from the hole and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the hole is damp or primed prior to commencing step 8.
4. Attach the required length of CemTie pinning nozzle to the Helifix Pointing Gun.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the gun.
6. Pump grout to fill the nozzle.
7. Wind the CemTie into the nozzle and ensure that it is fully covered in grout. (Alternatively, fill the hole with grout and wind the CemTie into the grout-filled hole.)
8. Insert the nozzle to the full depth of the drilled hole and pump the grout. Slowly withdraw the nozzle while pumping. The CemTie will be carried out with the HeliBond grout as it is forced through the nozzle. Back pressure will help to push the nozzle back out of the hole.
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings. Make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.
10. Clean tools with clean, fresh water.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



ELEVATION SECTION A

RECOMMENDED TOOLING

For drilling ....SDS rotary hammer drill 650/700w
For mixing HeliBond ....Drill with mixing paddle
For insertion of the CemTies ....Helifix Pointing Gun with CemTie Pinning Nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. CemTies are to be installed at a maximum vertical spacing of 425mm.
B. CemTies are to extend an equal distance, and typically to not more than 500mm, either side of the crack.
C. Depth of hole to be CemTie length + 25mm.
D. Ensure the CemTies are installed into solid brick and not the mortar joints or loose rubble within the wall.
E. If cracking occurs on both elevations consider using HeliBar crack stitching around the corner. If CemTies have to be used, they should be staggered between each elevation.
F. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the hole, or priming with HeliPrimer WB, should be carried out just prior to inserting the CemTie.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 68

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS11 — HELIFIX

BCS11

Repair of a crack near a corner in a stone wall using HeliBars

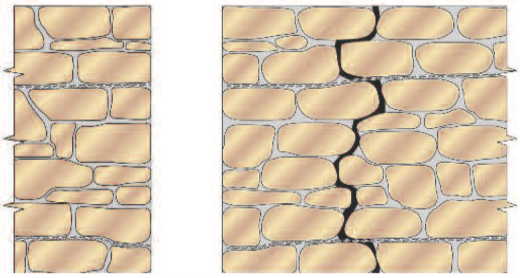
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing. (Refer to the Specification Notes for typical depth and spacing requirements.) Ensure that as much mortar is removed as possible from the exposed surfaces in order to provide a good masonry/grout bond. This operation may require the use of hand tools to remove the mortar due to the random nature of the stone.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
6. Push the 6mm HeliBar into the grout to obtain good coverage.
7. Repeat steps 5 and 6 as required to install all specified HeliBars into the slot.
8. Inject a final bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond grout as necessary, leaving 10-15mm for new pointing.
9. Point up the remaining slot with a suitable matching mortar and make good the crack using an appropriate Helifix bonding agent or filler, depending on the width of the crack.
10. Clean tools with clean, fresh water.

***NOTE:** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For cutting slots up to 40mm deep.......................Wall chaser, mortar saw or angle grinder with vacuum attachment
To achieve final depth of slot beyond 40mm Hand or Helifix Power Chisel
For mixing HeliBond ....Drill with mixing paddle
For injection of HeliBond into slots.............................Helifix Pointing Gun with mortar nozzle
For smoothing pointing...Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Allow for the installation of one HeliBar for each 100mm of wall thickness into each cut slot. By example, a common 200mm solid stone wall construction will require the installation of two HeliBars per slot. A 300mm solid wall construction will require three Helibars per slot.
B. Depth of slot into a common 200mm stone wall to be 35mm to 40mm. Add 10mm for each additional 100mm of wall thickness.
C. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
D. HeliBar to be long enough to extend a minimum of 500mm either side of the crack or 500mm beyond the outer cracks if two or more adjacent cracks are being stitched using one rod.
E. Normal vertical spacing is 425mm.
F. Where a crack is less than 300mm from the end of a wall or an opening the HeliBar is to be continued for at least 100mm around the corner and bonded into the adjoining wall or bent back and fixed into the reveal, avoiding any DPC.
G. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 69
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS06 /BCS07 HELIFIX

BCS06 BCS07

Crack stitching a solid wall using HeliBars

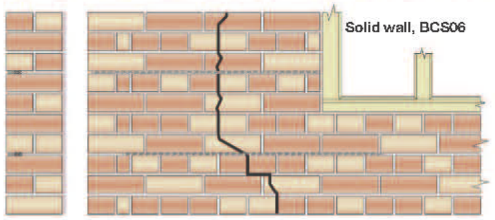
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

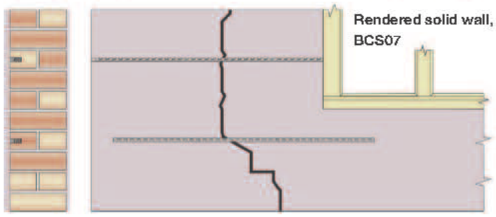
METHOD STATEMENT

1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the brick or horizontal mortar joints, to the specified depth and at the required vertical spacing. (Refer to the Specification Notes for typical depth and spacing requirements.) Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond. If the wall is rendered and the mortar joints are not visible, cut the horizontal slots through the render and into the masonry.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use a suitable primer. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
6. Push the 6mm HeliBar into the grout to obtain good coverage.
7. Repeat steps 5 and 6 as required to install all specified HeliBar into the slot.
8. Inject a final bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for new pointing.
9. Point up the remaining slot with a suitable matching mortar and make good the crack using an appropriate Helifix bonding agent or filler, depending on the width of the crack.
10. Clean tools with clean, fresh water.

***NOTE:** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***





RECOMMENDED TOOLING

For cutting slots up to 40mm deep ....Wall chaser, mortar saw or angle grinder with vacuum attachment
To achieve final depth of slot beyond 40mm Hand or Helifix Power Chisel
For mixing HeliBond ....Drill with mixing paddle
For injection of HeliBond into slots...........................Helifix Pointing Gun with mortar nozzle
For smoothing pointing...Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Allow for the installation of one HeliBar for each skin of brickwork into each cut slot. By example, a common 230mm solid wall construction (equivalent to two skins of tied brickwork) will require the installation of two HeliBars per slot. A solid wall equivalent in depth to three skins of bonded masonry will require three HeliBars per slot.
B. Depth of slot into the masonry to be 35mm to 40mm + thickness of any render, assuming a 230mm solid wall. Add 10mm for each additional skin of brickwork.
C. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
D. HeliBar to be long enough to extend a minimum of 500mm either side of the crack or 500mm beyond the outer cracks if two or more adjacent cracks are being stitched using one rod.
E. Normal vertical spacing is 340mm (4 brick courses).
F. Where a crack is less than 500mm from the end of a wall or an opening the HeliBar is to be continued for at least 100mm around the corner and bonded into the adjoining wall or bent back and fixed into the reveal, avoiding any DPC.
G. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 70
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS12/BCS13 HELIFIX

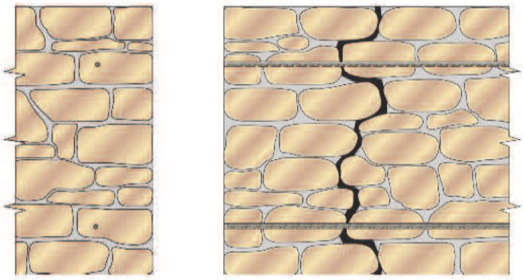
BCS12 BCS13 Repair of a crack near a corner in a stone wall using CemTies

Product	Description	Code
CemTie	Grade 316 stainless steel structural pin	HCT
HeliBond	Injectable cementitious grout	HLB

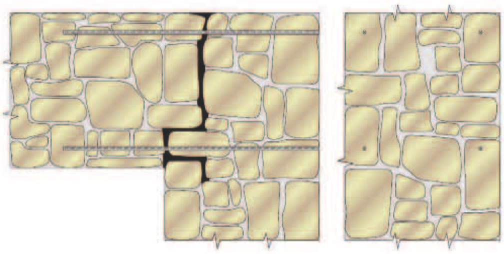
METHOD STATEMENT

1. Mark the locations for the CemTie pins onto the face of the wall at the required spacing. (Refer to the Specification Notes for typical spacing requirements.)
2. Drill a 16mm Ø clearance hole through the outer wall to the required depth. (Refer to the Specification Notes for typical depth requirements.)
3. Clean out all dust from the hole and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the hole is damp or primed prior to commencing step 8.
4. Attach the required length of CemTie Pinning Nozzle to the Helifix Pointing Gun.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the gun.
6. Pump grout to fill the nozzle.
7. Wind the CemTie into the nozzle and ensure that it is fully covered in grout. (Alternatively, fill the hole with grout and wind the CemTie into the grout-filled hole.)
8. Insert the nozzle to the full depth of the drilled hole and pump the grout. Slowly withdraw the nozzle while pumping. The CemTie will be carried out with the HeliBond grout as it is forced through the nozzle. Back pressure will help to push the nozzle back out of the hole.
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings. Make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.
10. Clean tools with clean, fresh water.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



Repair of a crack near a corner, BCS12



Repair of internal and external cracks near a corner, BCS13

RECOMMENDED TOOLING

For drilling .... SDS rotary hammer drill 650/700w
For mixing HeliBond .... Drill with mixing paddle
For insertion of the CemTies .... Helifix Pointing Gun with CemTie Pinning Nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. CemTies are to be installed at a vertical spacing of 425mm.
B. CemTies are to extend an equal distance, and typically to not more than 500mm, either side of the crack.
C. Depth of hole to be CemTie length + 25mm.
D. Ensure the CemTies are installed into solid stone and not the mortar joints or loose rubble within the wall.
E. If cracking occurs on both elevations consider using HeliBar crack stitching around the corner (see Repair Detail BCS11). If CemTies have to be used, they should be staggered between each elevation.
F. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the hole, or priming with HeliPrimer WB, should be carried out just prior to inserting the CemTie.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

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Figure 71
Source: http://www.helifix.com.au/masonry_repair_details.html

Helifix have also developed procedures for creating load bearing beams in cavity or solid walls using HeliBars (see Figures 72 and 73). This is where two of the stainless steel reinforcement bars are grouted into a wall, one on top of another and concealed with a matching mortar.
Helibars may also be used for lintel stabilisation. Slots are cut into the horizontal mortar joints and HeliBars grouted into place until all slots have been filled (see Figure 74).

REPAIR DETAILS BLB01/02/04 HELIFIX

BLB01
BLB02
BLB04

Creating load-bearing beams in cavity or solid walls using HeliBars, external and/or internal Beaming

Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

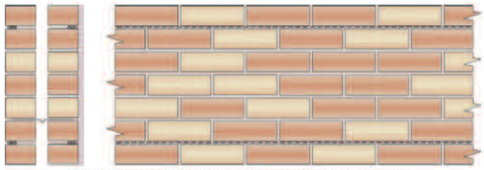
1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing. (Refer to the Specification Notes for typical depth and spacing requirements.) If the wall is plastered/rendered and the mortar joints are not visible, cut the horizontal slots through any plaster/render and into the masonry. Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond cementitious grout, 10-15mm deep, into the back of the slot.
6. Push the first 6mm HeliBar into the grout to obtain good coverage.
7. Inject a second bead of HeliBond grout over the exposed HeliBar.
8. Push the second 6mm HeliBar into the grout to obtain good coverage.
9. Inject a third bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for new pointing.
10. Point up the remaining slot with a suitable matching mortar.
11. Clean tools with clean, fresh water.

***NOTE.** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

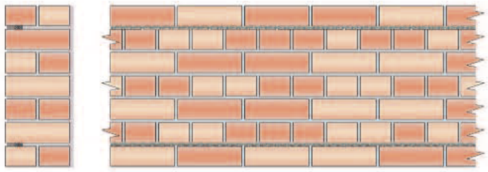
⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.



Cavity wall, BLB01 (external) and BLB02 (internal)



Solid wall, BLB04

RECOMMENDED TOOLING

For cutting slots up to 40mm deep........................Wall chaser, mortar saw or angle grinder with vacuum attachment
To achieve final depth of slot beyond 40mm Hand or Helifix Power Chisel
For mixing HeliBond ....Drill with mixing paddle
For injection of HeliBond into slots............................Helifix Pointing Gun with mortar nozzle
For smoothing pointing...Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. A minimum of two HeliBars should be installed into each cut slot. Allow for the installation of one additional HeliBar per slot for each additional skin of brickwork over the standard two when creating beams in deep solid walls.
B. Depth of slot into the masonry of a CAVITY WALL to be 40mm to 55mm + the thickness of any plaster (internal) or render (external). Depth of slot into the masonry of a SOLID WALL (230mm) to be 55mm to 70mm + the thickness of any plaster or render. Add 10mm for each additional skin of brickwork.
C. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
D. If HeliBars are to be joined in a straight run, overlap the bars by a minimum of 500mm.
E. Top and bottom reinforcements should be positioned as far apart as practicable, up to a maximum distance equivalent to 10 brick courses (approx. 850mm).
F. Any fractures in the masonry within the 'beam zone' MUST be stabilised by crack stitching (see Repair Detail BCS01), CrackBond TE or replacement of the masonry.
G. Any missing or very poor quality masonry MUST be replaced.
H. Install Helifix remedial wall ties if existing ties are defective in any way. Refer to Repair Details BRT01–03 for details on Helifix remedial tie installation.
I. Multiple Helibeams should be installed starting at the top and working down to the bottom.
J. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

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Figure 72
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAILS BLB01/02/04 HELIFIX

BLB01 BLB02 BLB04

Creating load-bearing beams in cavity or solid walls using HeliBars, external and/or internal Beaming

Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

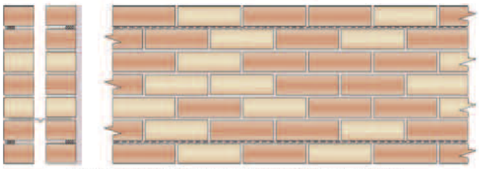
1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing. (Refer to the Specification Notes for typical depth and spacing requirements.) If the wall is plastered/rendered and the mortar joints are not visible, cut the horizontal slots through any plaster/render and into the masonry. Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond cementitious grout, 10-15mm deep, into the back of the slot.
6. Push the first 6mm HeliBar into the grout to obtain good coverage.
7. Inject a second bead of HeliBond grout over the exposed HeliBar.
8. Push the second 6mm HeliBar into the grout to obtain good coverage.
9. Inject a third bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for new pointing.
10. Point up the remaining slot with a suitable matching mortar.
11. Clean tools with clean, fresh water.

***NOTE** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

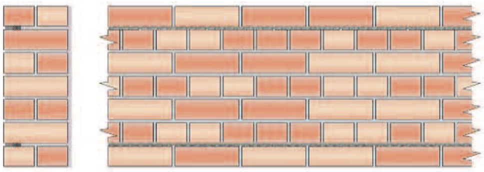
⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.



Cavity wall, BLB01 (external) and BLB02 (internal)



Solid wall, BLB04

RECOMMENDED TOOLING

For cutting slots up to 40mm deep......................Wall chaser, mortar saw or angle grinder with vacuum attachment
To achieve final depth of slot beyond 40mm Hand or Helifix Power Chisel
For mixing HeliBond ....Drill with mixing paddle
For injection of HeliBond into slots............................Helifix Pointing Gun with mortar nozzle
For smoothing pointing...Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. A minimum of two HeliBars should be installed into each cut slot. Allow for the installation of one additional HeliBar per slot for each additional skin of brickwork over the standard two when creating beams in deep solid walls.
B. Depth of slot into the masonry of a CAVITY WALL to be 40mm to 55mm + the thickness of any plaster (internal) or render (external). Depth of slot into the masonry of a SOLID WALL (230mm) to be 55mm to 70mm + the thickness of any plaster or render. Add 10mm for each additional skin of brickwork.
C. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
D. If HeliBars are to be joined in a straight run, overlap the bars by a minimum of 500mm.
E. Top and bottom reinforcements should be positioned as far apart as practicable, up to a maximum distance equivalent to 10 brick courses (approx. 850mm).
F. Any fractures in the masonry within the 'beam zone' MUST be stabilised by crack stitching (see Repair Detail BCS01), CrackBond TE or replacement of the masonry.
G. Any missing or very poor quality masonry MUST be replaced.
H. Install Helifix remedial wall ties if existing ties are defective in any way. Refer to Repair Details BRT01–03 for details on Helifix remedial tie installation.
I. Multiple Helibeams should be installed starting at the top and working down to the bottom.
J. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

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Figure 73
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BLRD1 HELIFIX

BLRD1

Stabilising failed lintels in cavity walls using HeliBars

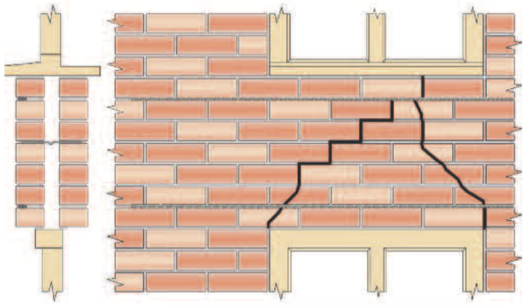
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing.* If the wall is plastered/rendered and the mortar joints are not visible, cut the horizontal slots through any plaster/render and into the masonry. Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot are damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond cementitious grout, 10-15mm deep, into the back of the slot.
6. Push the first 6mm HeliBar into the grout to obtain good coverage.
7. Inject a second bead of HeliBond grout over the exposed HeliBar.
8. Push the second 6mm HeliBar into the grout to obtain good coverage.
9. Inject a third bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for new pointing.
10. Repeat steps 5 to 9 for remaining slots.
11. Point up the remaining slots with a suitable matching mortar. Make good the cracks with an appropriate Helifix bonding agent depending on the width of the crack.
12. Clean tools with clean, fresh water.

***NOTE.** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

⚠ Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.



RECOMMENDED TOOLING

- For cutting slots up to 40mm deep .... Wall chaser, mortar saw or angle grinder with vacuum attachment
- For drilling .... SDS rotary hammer drill 650/700w
- For mixing HeliBond .... Drill with mixing paddle
- For injection of HeliBond into slots .... Helifix Pointing Gun with mortar nozzle
- For insertion of the CemTies .... Helifix Pointing Gun with CemTie Pinning Nozzle
- For smoothing pointing .... Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Depth of slot into masonry to 40mm to 55mm.
B. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
C. Top and bottom reinforcements should be positioned as far apart as practicable, up to a maximum distance equivalent to 10 brick courses (approx. 850mm).
D. HeliBar to be long enough to extend a minimum of 500mm beyond each side of the opening.
E. Any fractures in the masonry within the 'beam zone' MUST be stabilised by Crack Stitching, CrackBond or masonry replacement.
G. Any missing or very poor quality masonry MUST be replaced.
H. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slots and holes, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 74
Source: http://www.helifix.com.au/masonry_repair_details.html

HeliBars can be used to create movement joints in masonry walls. A movement sleeve is placed over one half of the HeliBar and grouted into place, ensuring no grout comes into contact with the area of bar encased by the sleeve to protect its movement capability (see Figures 75 and 76). BowTies, stainless steel remedial wall ties, can be used to restrain a bowed wall by driving the tie into joist ends. Resin is injected to secure the tie (see Figures 77 and 78).

REPAIR DETAIL BMJ01

HELIFIX

BMJ01

Creating movement joints in cavity walls using HeliBars

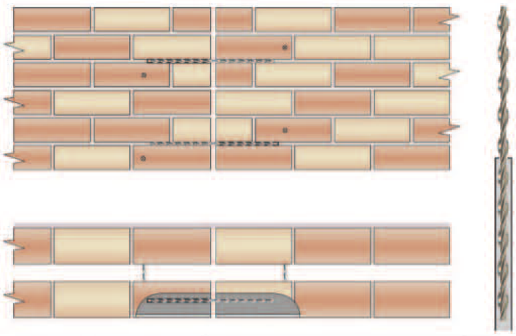
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Mark the position on the wall for the movement joint.
2. Install the specified number of appropriate Helifix wall ties adjacent to the location of the movement joint.*
3. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints either side of the movement joint, to the specified depth and at the required vertical spacing.* Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond. If the wall is rendered and the mortar joints are not visible, cut the horizontal slots through the render and into the masonry.
4. Cut the movement joint to the specified width and at the required location.
5. Clean out all dust and mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 8.
6. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
7. Fit the mortar nozzle to the pointing gun.
8. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
9. Fit the movement sleeve over one half of the 6mm HeliBar and push the complete assembly into the grout ensuring a good bond between the HeliBar and the sleeve in the slot. Ensure that no grout comes into contact with the end of the HeliBar covered by the sleeve, as this end must be free to move.
10. Inject a second bead of HeliBond grout up against the HeliBar and sleeve assembly to obtain good coverage of both.
11. Point up the remaining slot with a suitable matching mortar.
12. Seal the joint with a suitable flexible mastic type material.
13. Clean tools with clean, fresh water.

***NOTE:** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For cutting slots up to 40mm deep	Wall chaser, mortar saw or angle grinder with vacuum attachment
To achieve final depth of slot beyond 40mm	Hand or Helifix Power Chisel
For drilling wall tie pilot holes	Light-weight SDS rotary hammer drill or rotary percussion drill 650/700w
For installation of DryFix wall ties	SDS rotary hammer drill 650/700w and SDS power driver attachment
For mixing HeliBond	Drill with mixing paddle
For injection of HeliBond into slots	Helifix Pointing Gun with mortar nozzle
For smoothing pointing	Standard finger trowel

* Specification Notes

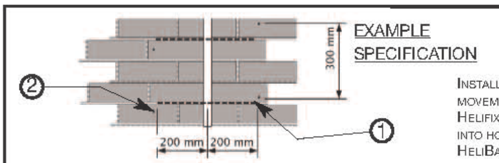
The following criteria are to be used unless specified otherwise:

- **A.** Depth of slot to accommodate the HeliBar and sleeve assembly to be 40mm + the thickness of any render.
- **B.** Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
- **C.** HeliBar should extend a minimum of 200mm either side of the expansion joint.
- **D.** Alternate the position of the sleeve on adjacent HeliBars.
- **E.** HeliBars to be installed at a maximum 300mm vertical spacing.
- **F.** Suitable Helifix wall ties to be installed on each side of the newly formed movement joint not more than 225mm back from the joint and at a maximum of 300mm vertical spacing. Refer to Repair Details BRT01–03 for details on Helifix remedial tie installation.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.



EXAMPLE SPECIFICATION

EXPANSION JOINT CUT INTO NEAR LEAF OF 270mm CAVITY BRICK WALL

Material: DRYFIX 8 x 220 and HELIBAR 6
Product code: **HDF8x220** and **HBR 6mm**

INSTALL DRYFIX 8MM DIA. X 220MM L. (HDF8x220) TIES EITHER SIDE OF THE LOCATION OF THE MOVEMENT JOINT AT 300MM VERTICAL CTS AND AT NOT MORE THAN 225MM BACK FROM THE JOINT (SEE HELIFIX REPAIR DETAIL BRT01). CUT THE JOINT AND BOND SLEEVED HELIBARS 6MM DIA. X 400MM L. INTO HORIZONTAL SLOTS CUT ACROSS THE JOINT AT 300MM VERTICAL CTS. USING HELIBOND GROUT. HELIBAR MOVEMENT TIES SHOULD EXTEND A MINIMUM OF 200MM EITHER SIDE OF THE JOINT.

ITEM	CODE	DESCRIPTION		
1	HBR	HELIBAR	HELIFIX	HELIFIX (AUSTRALIA) PTY LTD
2	HDF	DRYFIX		TYPICAL WALL TYPE AND HELIBAR MOVEMENT TIE APPLICATION
				SCALE 1:20 · DWG No. BMJ01-EXS · SHEET 1 of 1

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Figure 75
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BMJ02 HELIFIX

BMJ02

Creating movement joints in solid walls using HeliBars

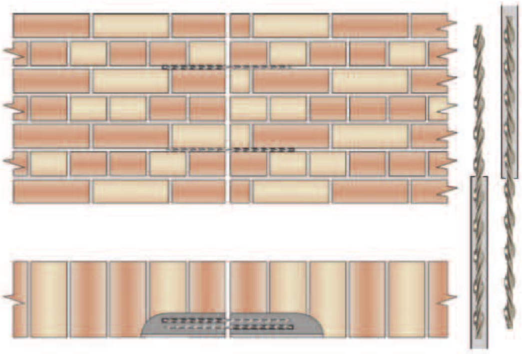
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Mark the position on the wall for the movement joint.
2. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints either side of the movement joint, to the specified depth and at the required vertical spacing. (Refer to the Specification Notes for typical depth and spacing requirements.) Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond. If the wall is rendered and the mortar joints are not visible, cut the horizontal slots through the render and into the masonry.
3. Cut the movement joint to the specified width and at the required location.
4. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 7.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
6. Fit the mortar nozzle to the gun.
7. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
8. Fit the movement sleeve over one half of the first 6mm HeliBar and push the complete assembly into the grout ensuring a good bond between the HeliBar and the sleeve in the slot. Ensure that no grout comes into contact with the end of the HeliBar covered by the sleeve, as this end must be free to move.
9. Inject a second bead of grout over the HeliBar and tube assembly. Again, ensure that no grout comes into contact with the end of the HeliBar covered by the sleeve.
10. Push a second 6mm HeliBar and sleeve assembly into the grout.
11. Inject a third bead of HeliBond grout up against the HeliBar and sleeve assembly to obtain good coverage of both.
12. Point up the remaining slot with a suitable matching mortar.
13. Seal the joint with a suitable flexible mastic type material.
14. Clean tools with clean, fresh water.

***NOTE**. Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For cutting slots up to 40mm deep........................Wall chaser, mortar saw or angle grinder with vacuum attachment
To achieve final depth of slot beyond 40mm ....Hand or Helifix Power Chisel
For mixing HeliBond ....Drill with mixing paddle
For injection of HeliBond into slots ....Helifix Pointing Gun with mortar nozzle
For smoothing pointing..Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

- **A.** Allow for the installation of one HeliBar/sleeve assembly for each skin of brickwork into each cut slot. By example, a common 230mm solid wall construction (equivalent to two skins of tied brickwork) will require the installation of two HeliBar/sleeve assemblies per slot. A solid wall equivalent in depth to three skins of bonded masonry will require three Helibar/sleeve assemblies per slot.
- **B.** Depth of slot to accommodate the HeliBar and sleeve assembly to be 70mm + the thickness of any render.
- **C.** Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
- **D.** HeliBar should extend a minimum of 200mm either side of the movement joint.
- **E.** Alternate the position of the sleeve on adjacent HeliBars.
- **F.** HeliBar/sleeve assemblies to be installed at a maximum 300mm vertical spacing.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 76
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAILS BRB01/03/04 HELIFIX

BRB01
BRB03
BRB04

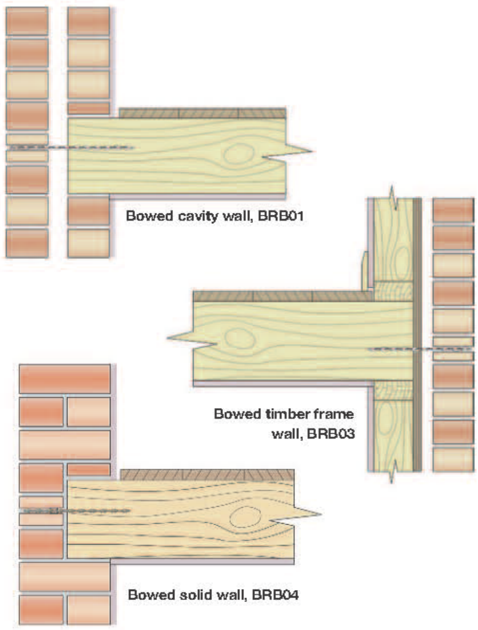
Restraining a bowed cavity, timber frame or solid wall using BowTies into joist ends

Product	Description	Code
BowTie	Grade 316 stainless steel remedial wall tie	HBT
EpoxyPlus	High performance pure epoxy resin	HTE

METHOD STATEMENT

1. Mark the positions of the joists on the external wall.
2. Drill the clearance holes for the BowTies (normally 12mm Ø) through the masonry only and in line with the centre of the joists.
3. Clean out the hole to clear any dust or debris.
4. Insert the BowTie power support tool into an SDS rotary hammer drill and place the BowTie into the support tool.
5. Drive the BowTie into the timber to the required depth. (Refer to the Specification Notes for typical depth requirements.)
6. Place the end of the nozzle of the resin applicator over the exposed end of the BowTie. Masking tape may be placed around the hole to protect the surface of the wall from resin spillage. Cloth may also be wrapped around the nozzle to help seal the opening during installation and protect the wall face from resin spillage.
7. Pump the resin applicator to inject Helifix EpoxyPlus resin into the hole. The resin will track down the tie, following its helical profile. Inject resin until the hole in the near skin is filled completely.
8. Allow the resin to gel (normally 15 to 20 minutes).
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling and insertion of BowTies...SDS rotary hammer drill 650/700w
For installation of BowTies ....BowTie support tool
For injection of Helifix EpoxyPlus resin............Applicator gun with nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. BowTie penetration into the end grain of the timber joist must be a minimum of 70mm.
B. Each joist in the area of concern is to be secured with a BowTie (i.e. spacing of BowTies is to correspond with the original joist spacing).
C. Ensure that all joists into which BowTies are to be installed are both sound and secure.
D. Install Helifix remedial wall ties if existing ties are defective in any way. Refer to Repair Details BRT01–03 for details on Helifix remedial tie installation.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 77
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAILS BRB01/03/04 HELIFIX

BRB01 BRB03 BRB04

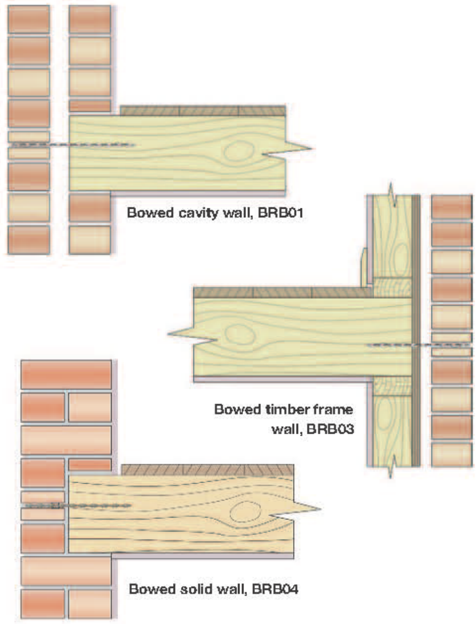
Restraining a bowed cavity, timber frame or solid wall using BowTies into joist ends

Product	Description	Code
BowTie	Grade 316 stainless steel remedial wall tie	HBT
EpoxyPlus	High performance pure epoxy resin	HTE

METHOD STATEMENT

1. Mark the positions of the joists on the external wall.
2. Drill the clearance holes for the BowTies (normally 12mm Ø) through the masonry only and in line with the centre of the joists.
3. Clean out the hole to clear any dust or debris.
4. Insert the BowTie power support tool into an SDS rotary hammer drill and place the BowTie into the support tool.
5. Drive the BowTie into the timber to the required depth. (Refer to the Specification Notes for typical depth requirements.)
6. Place the end of the nozzle of the resin applicator over the exposed end of the BowTie. Masking tape may be placed around the hole to protect the surface of the wall from resin spillage. Cloth may also be wrapped around the nozzle to help seal the opening during installation and protect the wall face from resin spillage.
7. Pump the resin applicator to inject Helifix EpoxyPlus resin into the hole. The resin will track down the tie, following its helical profile. Inject resin until the hole in the near skin is filled completely.
8. Allow the resin to gel (normally 15 to 20 minutes).
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling and insertion of BowTies...SDS rotary hammer drill 650/700w
For installation of BowTies ....BowTie support tool
For injection of Helifix EpoxyPlus resin............Applicator gun with nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. BowTie penetration into the end grain of the timber joist must be a minimum of 70mm.
B. Each joist in the area of concern is to be secured with a BowTie (i.e. spacing of BowTies is to correspond with the original joist spacing).
C. Ensure that all joists into which BowTies are to be installed are both sound and secure.
D. Install Helifix remedial wall ties if existing ties are defective in any way. Refer to Repair Details BRT01–03 for details on Helifix remedial tie installation.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 78

Source: http://www.helifix.com.au/masonry_repair_details.html

Repair of delaminated or separating masonry is a rubble-filled or solid wall may also be carried out using CemTies (see Figure 79). These can also be used to repair brick faced random stone walls through the brick faces or mortar joints (see Figure 80).

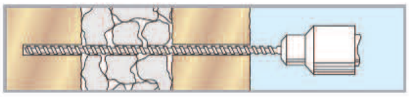
DryFix, a stainless steel dry pinning system, can be used to replace worn or absent wall ties (see Figure 81). These can be hidden from view with sand, cement and oxide mix or with silicone sealant. Retroties may also be used to do this, where a stainless steel remedial wall tie is set into the wall with high performance pure epoxy resin (see Figure 82).

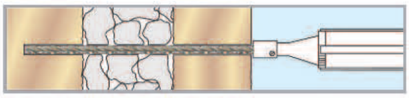
REPAIR DETAIL BRF01 HELIFIX

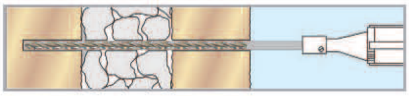
BRF01

Repair of delaminated or separating masonry in a rubble-filled or solid wall using CemTies

Product	Description	Code
CemTie	Grade 316 stainless steel structural pin	HCT
HeliBond	Injectable cementitious grout	HLB







METHOD STATEMENT

1. Mark the locations for the CemTie pins onto the face of the wall at the required spacing.*
2. Drill a 12–14mm Ø clearance hole, or a 14-16mm Ø hole if the CemTie is longer than 450mm, at the required location and to the specified depth.*
3. Clean out all dust from the hole and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the hole is damp or primed prior to commencing step 8.
4. Attach the required length of CemTie Pinning Nozzle to the Helifix Pointing Gun.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the gun.
6. Pump grout to fill the nozzle.
7. Wind the CemTie into the nozzle and ensure that it is fully covered in grout. (Alternatively, fill the hole with grout and wind the CemTie into the grout-filled hole.)
8. Insert the nozzle to the full depth of the drilled hole and pump the grout. Slowly withdraw the nozzle while pumping. The CemTie will be carried out with the HeliBond grout as it is forced through the nozzle. Back pressure will help to push the nozzle back out of the hole.
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings.
10. Clean tools with clean, fresh water.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***

RECOMMENDED TOOLING

For drilling ....SDS rotary hammer drill 650/700w
For mixing HeliBond..Drill with mixing paddle
For insertion of the CemTies ....Helifix Pointing Gun with CemTie Pinning Nozzle

* Specification Notes

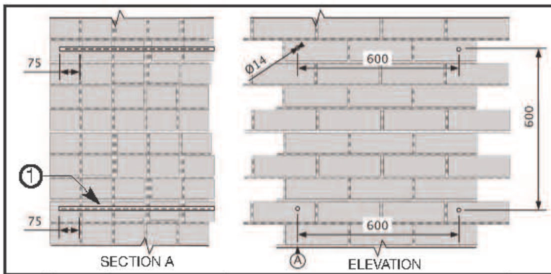
The following criteria are to be used unless specified otherwise:

A. CemTies are to be installed at a minimum density of approx. 2.8 ties/m² (approx. 600mm horizontal and 600mm vertical spacing).
B. The density is to be increased around openings with ties placed at a maximum 300mm vertical spacing and 225mm back from the opening.
C. Depth of hole to be CemTie length + 25mm. CemTies should be embedded to a minimum depth of 75mm into the far leaf.
D. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the hole should be carried out just prior to inserting the CemTie.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on **1300 66 70 71**.



EXAMPLE SPECIFICATION

STABILISING A SOLID WALL
Material: CEMTIE 8
Product code: **HCT8**

8MM DIA. CEMTIES (HCT8) TO BE INSTALLED INTO CLEARANCE HOLES USING HELIBOND INJECTABLE CEMETITIOUS GROUT (HLB). CEMTIES TO BE SUFFICIENTLY LONG TO EXTEND 75MM INTO THE FAR LEAF. CEMTIES TO BE INSTALLED AT A VERTICAL AND HORIZONTAL SPACING OF NOT MORE 600MM CTS. CLEARANCE HOLES TO MEASURE 12-14MM IN DIAMETER.

1	HCT	CEMTIE	HELIFIX	HELIFIX (AUSTRALIA) PTY LTD
				TYPICAL SOLID WALL TYPE AND CEMTIE APPLICATION
ITEM	CODE	DESCRIPTION		SCALE 1:20 / DWG No. BRF01-EXS / SHEET 1 of 1

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Figure 79
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BRF02/BRF03 HELIFIX

BRF02
BRF03

Repair of brick-faced random stone walls using CemTies through brick faces or mortar joints

Product	Description	Code
CemTie	Grade 316 stainless steel structural pin	HCT
HeliBond	Injectable cementitious grout	HLB

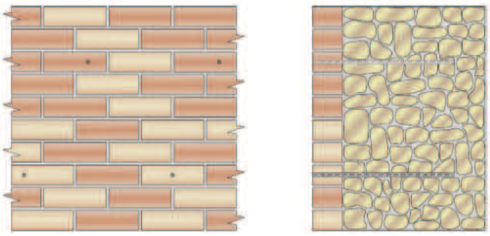
METHOD STATEMENT

1. Mark the positions for the holes on the outer face of the wall. (Refer to the Specification Notes for typical spacing requirements.)
2. Drill a 12–14mm Ø clearance hole, or 16mm Ø if the CemTie is longer than 450mm, at the required location, through the brick face of the wall and into the back-up material to the specified depth. (Refer to the Specification Notes for typical depth requirements.)

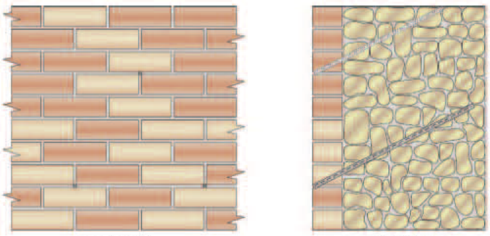
   Alternatively, to avoid marking the brick faces, the hole should be drilled through the perpendicular mortar joint between two adjacent bricks. The hole should be angled either upwards (as shown) or downwards to pass through the brick and then continue into the back-up material.
3. Clean out all dust from the hole and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the hole is damp or primed prior to commencing step 8.
4. Attach the required length of CemTie Pinning Nozzle to the Helifix Pointing Gun.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the gun.
6. Pump grout to fill the nozzle.
7. Wind the CemTie into the nozzle and ensure that it is fully covered in grout. (Alternatively, fill the hole with grout and wind the CemTie into the grout-filled hole.)
8. Insert the nozzle to the full depth of the drilled hole and pump the grout. Slowly withdraw the nozzle while pumping. The CemTie will be carried out with the HeliBond grout as it is forced through the nozzle. Back pressure will help to push the nozzle back out of the hole.
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings. Make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.
10. Clean tools with clean, fresh water.

***NOTE** If diamond core drilling is used, the internal surface of the hole must be roughened to ensure a good bond.*

⚠ Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.



ELEVATION Brick face repair, BFR02 SECTION



ELEVATION Hidden repair, BFR03 SECTION

RECOMMENDED TOOLING

For drilling .... SDS rotary hammer drill 650/700w
For mixing HeliBond .... Drill with mixing paddle
For insertion of the CemTies .... Helifix Pointing Gun with CemTie Pinning Nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. The density of the ties will depend upon the condition of the masonry and the loading that it is expected to withstand. Typically, CemTies should be installed at a minimum density of 2.8 ties/m2 (approx. 600mm horizontal and 600mm vertical spacing).
B. The depth of fixing into the back-up material must be sufficient to provide a secure connection (prior testing may be required).
C. Depth of hole to be CemTie length + 25mm.
D. CemTies are to be installed at an angle of 30° to 40° when following the hidden repair detail to allow sufficient fixing in the brick facing.
E. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the hole should be carried out just prior to inserting the CemTie.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 80
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BRT01 — HELIFIX

BRT01

Replacing wall ties using DryFix

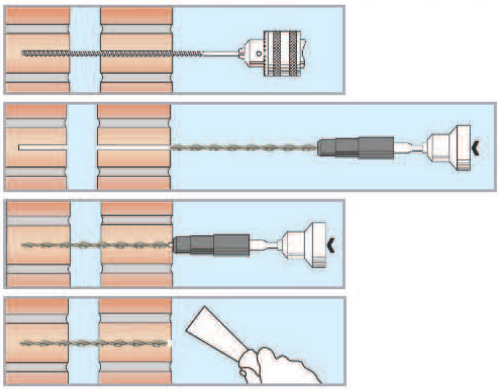
Product	Description	Code
DryFix	Stainless steel dry pinning system	HDF

METHOD STATEMENT

1. Mark the locations for the DryFix ties onto the face of the wall at the required spacing.* Wherever possible, the holes should be drilled directly into the masonry, but they may also be driven into the existing mortar provided that this is strong and in good condition.
2. Drill a 5mm Ø pilot hole through the near leaf and into the remote leaf to the specified depth using a light-weight SDS hammer drill set to a slow speed and light hammer only.* A rotary percussion 3-jaw chuck drill may be preferred if the masonry is particularly soft or thin and prone to excessive spalling. A 6mm or 6.5mm Ø pilot hole size may be preferred if the masonry is particularly hard.
3. Attach the Helifix Power Driver attachment to an SDS hammer drill set to a slow speed and light hammer only. (DryFix ties are self-tapping and will work themselves into the wall following the hammer action of the drill.)
4. Load the DryFix tie into the power driver attachment.
5. Support the power driver attachment with one hand, while using the other to work the drill, and drive the DryFix tie into the pre-drilled pilot hole to approximately 10mm beyond the surface of the near leaf.
6. Make good the hole using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings.

***NOTE.** Avoid leaning or pushing heavily on the drill during operation to ensure the accuracy of the hole's diameter and to limit spalling of the near leaf as the drill breaks into the cavity.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling ....Rotary percussion or SDS rotary hammer drill 650/700w

For installation of DryFix ....SDS rotary hammer drill and DryFix Power Driver attachment

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. DryFix ties are to be installed at 600mm vertical and horizontal centres into continuous brickwork. Ties are to be installed at 300mm centres around openings (e.g. around windows).

B. Depth of pilot hole to be DryFix tie length + 10mm.

C. DryFix length to equal near brick width less 10mm + cavity width + far leaf embedment depth. Typically, ties should be sufficiently long to embed 35-70mm into the remote leaf depending on its hardness, with harder materials requiring less embedment. Typically, an embedment of 60-70mm isto be achieved when installing into common, dry-pressed or extruded brickwork.

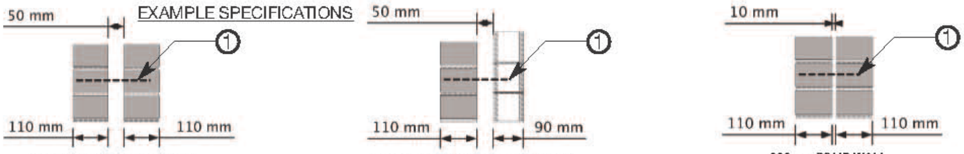
D. Ties may be installed from either side of the wall.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

EXAMPLE SPECIFICATIONS



270mm CAVITY BRICK WALL	250mm CAVITY BRICK/BLOCK WALL	230mm SOLID WALL
Material: DRYFIX 8 X 220 Product code: HDF8x220	Material: DRYFIX 8 x 195 Product code: HDF8x195	Material: DRYFIX 8 x 170 Product code: HDF8x170
DryFix 8mm dia. x 220mm l. (HDF8x220) ties to be installed at 600mm vertical and horizontal cts on open brick faces, and 300mm cts around openings. Ties to be driven 60-70mm into the remote leaf and recessed 10mm below the face of the near leaf.	DryFix 8mm dia. x 195mm l. (HDF8x195) ties to be installed at 600mm vertical and horizontal cts on open brick faces, and 300mm cts around openings. Ties to connect with the near web of the block and to be recessed 10mm below the face of the brick leaf.	DryFix 8mm dia. x 170mm l. (HDF8x170) ties to be installed at 600mm vertical and horizontal cts on open brick faces, and 300mm cts around openings. Ties to be driven 60-70mm into the remote leaf and recessed 10mm below the face of the near leaf.

ITEM	CODE	DESCRIPTION	HELIFIX (AUSTRALIA) PTY LTD		
1	HDF	DRYFIX	TYPICAL WALL TYPES AND DRYFIX APPLICATIONS		
			SCALE 1:20	DWG No. BRT01-EXS	SHEET 1 of 1

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Figure 81

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BRT02 HELIFIX

BRT02

Replacing wall ties using RetroTies

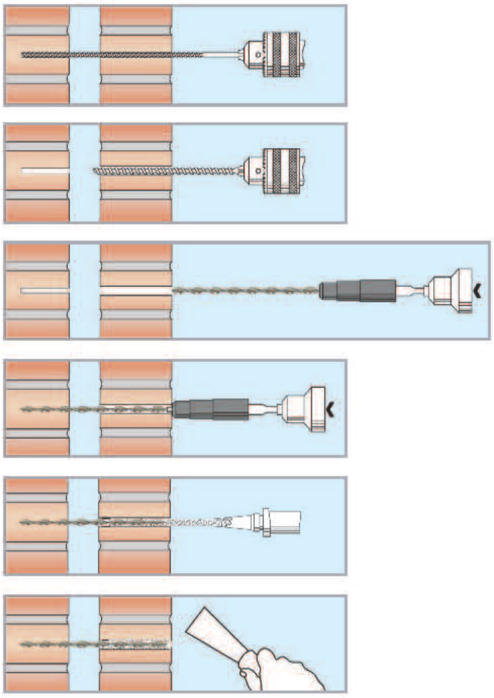
Product	Description	Code
RetroTie	Grade 316 stainless steel remedial wall tie	HRT
EpoxyPlus	High performance pure epoxy resin	HTE

METHOD STATEMENT

1. Mark the positions for the RetroTie pilot/clearance holes on the outer face of the wall.* Wherever possible, the holes should be drilled directly into the masonry, but they may also be driven into the exisitng mortar provided that this is strong and in good condition.
2. Drill a 5mm Ø pilot hole through the near leaf and into the remote leaf to the specified depth using a light-weight SDS hammer drill set to a slow speed and light hammer only.* A rotary percussion 3-jaw chuck drill may be preferred if the masonry is particularly soft or thin and prone to excessive spalling. A 6mm or 6.5mm Ø pilot hole size may be preferred if the inner leaf is particularly hard.
3. Following the same path as the pilot hole, drill a 10mm Ø clearance hole through the near skin only.
4. Attach the Helifix Power Driver attachment or RetroTie support tool to an SDS hammer drill set to a slow speed and light hammer only. (RetroTies are self-tapping and will work themselves into the remote wall following the hammer action of the drill.)
5. Load the RetroTie into the power driver or support tool.
6. Push the RetroTie through the near skin to align the end of the tie with the opening to the pilot hole on the face of the remote leaf.
7. If using a power driver attachment, support the attachment with one hand, while using the other to work the drill, and drive the RetroTie into the pre-drilled pilot hole in the remote leaf to the specified depth. If using the RetroTie support tool, simply drive the tie into the pilot hole to the specified depth. (The RetroTie support tool does not require hand-held support during operation.)
8. Place the end of the nozzle of the resin applicator over the exposed end of the RetroTie in the near leaf. Masking tape may be placed around the hole to protect the surface of the wall from resin spillage. Cloth may also be wrapped around the nozzle to help seal the opening during injection and protect the wall face from spillage.
9. Pump the resin applicator to inject Helifix EpoxyPlus resin into the hole. The resin will track down the tie, following its helical profile. Inject resin until the hole in the near leaf is filled completely.
10. Allow the resin to gel (normally 15 to 20 minutes).
11. Make good the hole using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust/drillings.

***NOTE:** Avoid leaning or pushing heavily on the drill during operation to ensure the accuracy of the hole's diameter and to limit spalling of the near leaf as the drill breaks into the cavity.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling........Rotary percussion or SDS rotary hammer drill 650/700w

For installation of RetroTie........SDS rotary hammer drill and DryFix Power Driver attachment or RetroTie support tool

For injection of Helifix EpoxyPlus resin........Applicator gun with nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. RetroTies are to be installed at 600mm vertical and horizontal centres into continuous brickwork. Ties are to be installed at 300mm centres around openings (e.g. around windows).

B. Tie length to be selected according to the hardness and thickness of the masonry and the cavity width. Ties are to be embedded 35-70mm into the remote leaf depending on the hardness of the masonry, with harder materials requiring less embedment. By example, an embedment of 35mm will be sufficient when driving into reinforced concrete. Typically, an embedment of 60-70mm is to be achieved when installing into common, dry-pressed brickwork.

C. Depth of pilot hole to be RetroTie length + 10mm.

D. Ties may be installed from either side of the wall.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 82

Source: http://www.helifix.com.au/masonry_repair_details.html

Simpson Strong Tie Anchor Systems is a company specialising in the manufacture of anchors for cracked and uncracked concrete, and utilised in many retrofit projects. This is closely related to this foundation type here in New Zealand dwellings. These anchors will be specified in a project if conditions exist that may cause the concrete to crack, in line with the new 2006 International Building Code. These anchor systems include the Strong-Bolt, the IXP Anchor, the Titen HD anchor and SET-XP epoxy.
The Strong-Bolt is a wedge anchor, providing reliability in performance in cracked concrete under static and seismic loading (see Figure 83). It has a tri-segmented clip which may be attached and adjusted independently increasing follow-up expansion should the hole increase in size as a result of a crack. Dual embossments on each clip segment allows the clip to undercut into the concrete should a crack occur.

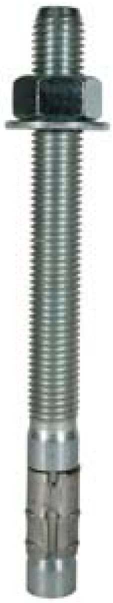


Figure 83
Strong-Bolt
Source: http://www.simpsonanchors.com

The IXP Anchor is a torque-controlled adhesive anchor, used with Simpson Strong Tie SET-XP epoxy. It has a conical shape (see Figure 84) which allows it to mimic the follow up expansion behaviour of a torque-controlled expansion anchor when tension-zone cracks occur in the base material and intersect with the placement of the anchor.[r] The shape also prevents the anchor from unscrewing.

[r] http://www.simpsonanchors.com

Figure 84
IXP Anchor
Source: http://www.simpsonanchors.com

Its test criteria are outlined, including:

- Seismic and wind loading in cracked and uncracked concrete
- Static tension and shear loading in cracked and uncracked concrete
- Horizontal and overhead applications
- Long-term creep
- Static loading at elevated-temperatures
- Damp holes
- Freeze-thaw conditions
- Critical and minimum edge distance and spacing [s]

Its suggested specifications are also included (see Figure 85).

[s] http://www.simpsonanchors.com

Characteristic	Symbol	Units	Nominal Anchor Diameter (inch)			
			⅜	½	⅝	¾
Installation Information						
Drill Bit Diameter	d	in.	½	⅝	¾	⅞
Baseplate Clearance Hole Diameter	d_c	in.	0.438	0.563	0.688	0.875
Installation Torque	T_{inst}	ft-lb	30	60	100	160
Embed. Depth & Eff. Embed Depth	h_{nom} & h_{ef}	in.	3⅜	4⅞	6⅝	8⅜
Critical Edge Distance	c_{ac}	in.	5	7¼	10	12½
Minimum Edge Distance	c_{min}	in.	3⅜	4⅞	6⅝	8⅜
Minimum Spacing	s_{min}	in.	5	4⅞	6⅝	8⅜
Minimum Concrete Thickness	h_{min}	in.	6¾	9¾	13¼	16¾
Additional Data						
Anchor Category	category	-	1			
Yield Strength	f_{ya}	psi	105,000			
Tensile Strength	f_{uta}	psi	125,000			
Minimum Tensile Stress Area	A_{se}	in^2	0.0494	0.0886	0.1414	0.2064

Figure 85
IXP Anchor Specifications
Source: http://www.simpsonanchors.com

The Titen-HD is a heavy duty screw anchor for concrete and masonry (see Figure 86). The non-expansive characteristics of this anchor make it ideal for structural applications, even at reduced distances and spacings. It has a high load capacity and vibration resistance as the mechanical interlock of the threads and the ratchet teeth on the underside of the head help prevent the anchor from loosening. Less spacing is required as the anchor does not exert expansion forces on the base material. Serrated teeth on the tip of this anchor facilitate cutting and reduce installation torque (see Figure 87).

Figure 86
Titen-HD Anchor
Source: http://www.simpsonanchors.com

Figure 87
Titen-HD Anchor Head
Source: http://www.simpsonanchors.com

SET-XP is a structural epoxy-tie anchoring adhesive, a high solids formula for cracked and uncracked concrete. It is used in tension and seismic zones where there is rick that a crack may intersect with where an anchor is placed. Its test criteria are outlined:

- Seismic and wind loading in cracked and uncracked concrete
- Static tension and shear loading in cracked and uncracked concrete
- Horizontal and overhead installations
- Long-term creep at elevated-temperatures
- Static loading at elevated-temperatures
- Damp holes
- Freeze-thaw conditions
- Critical and minimum edge distance and spacing[t]

Its specifications are also given (see Figure 88).

Characteristic		Symbol	Units	Nominal Anchor Diameter				
				½ / #4	⅝ / #5	¾ / #6	⅞ / #7	1 / #8
Installation Information								
Drill Bit Diameter		d	in.	⅝	¾	⅞	1	1⅛
Maximum Tightening Torque		T_{inst}	ft-lb	40	90	130	200	300
Permitted Embedment Depth (h_{ef}) Range[2]	Minimum	-	in.	2¾	3⅛	3½	3¾	4
	Maximum	-	in.	10	12½	15	17 1/2	20
Minimum Concrete Thickness		h_{min}	in.	2.25 x h_{ef}				
Critical Edge Distance		c_{ac}	in.	3 x h_{ef}				
Minimum Edge Distance		c_{min}	in.	1¾				
Minimum Anchor Spacing		s_{min}	in.	3				

Figure 88
SET-XP Specifications
Source: http://www.simpsonanchors.com

[t] http://www.simpsonanchors.com

Project Impact Seattle: Building Disaster Resistant Community has prescribed an earthquake retrofit plan which would relate closely to the retrofit of jack stud foundation in New Zealand dwellings, known as pony walls in Seattle. It is titled the Guide to Completing an Earthquake Retrofit Plan for Wood Frame Residential Buildings. It begins with a detailed introduction, covering if your home qualifies for this type of retrofit, if a building plan is needed and how to obtain a building permit. How to complete the retrofit plan is then explored. This is divided into five tasks: drawing the foundation outline, selecting the method of replacing sections of damaged concrete foundation wall if necessary, selecting the method of anchoring the sill plate to the foundation wall, selecting the method of strengthening the pony wall, and selecting the method of connecting the floor framing system to the pony wall on to the foundation wall. Figures are given to explain a retrofitted wall (see Figure 89) and the retrofitted subfloor area (see Figure 90). Each task is then described in depth.

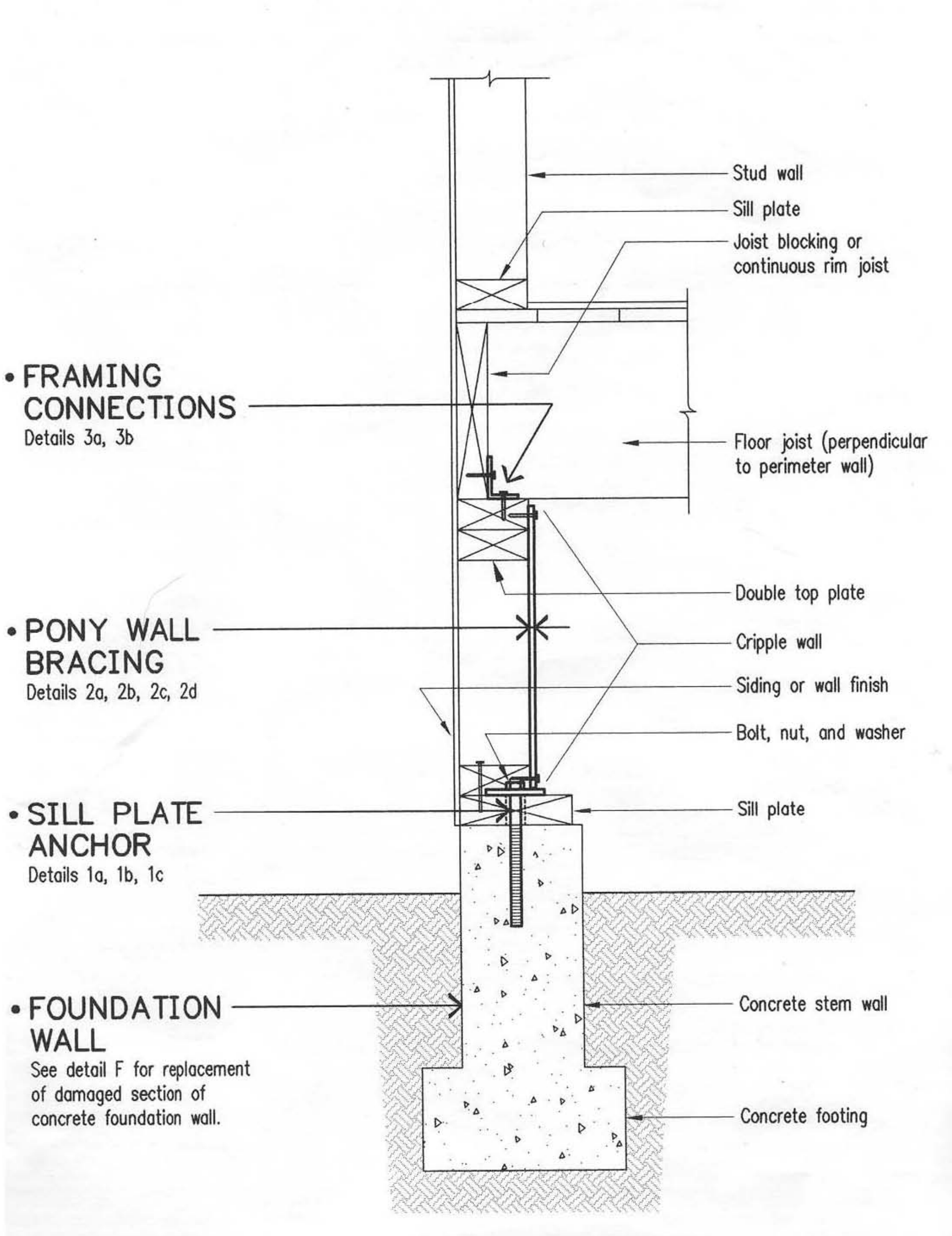


Figure 89
Side View of a Typical Wall Section
Source: http://www.soundseismic.com/live/page/project-impact

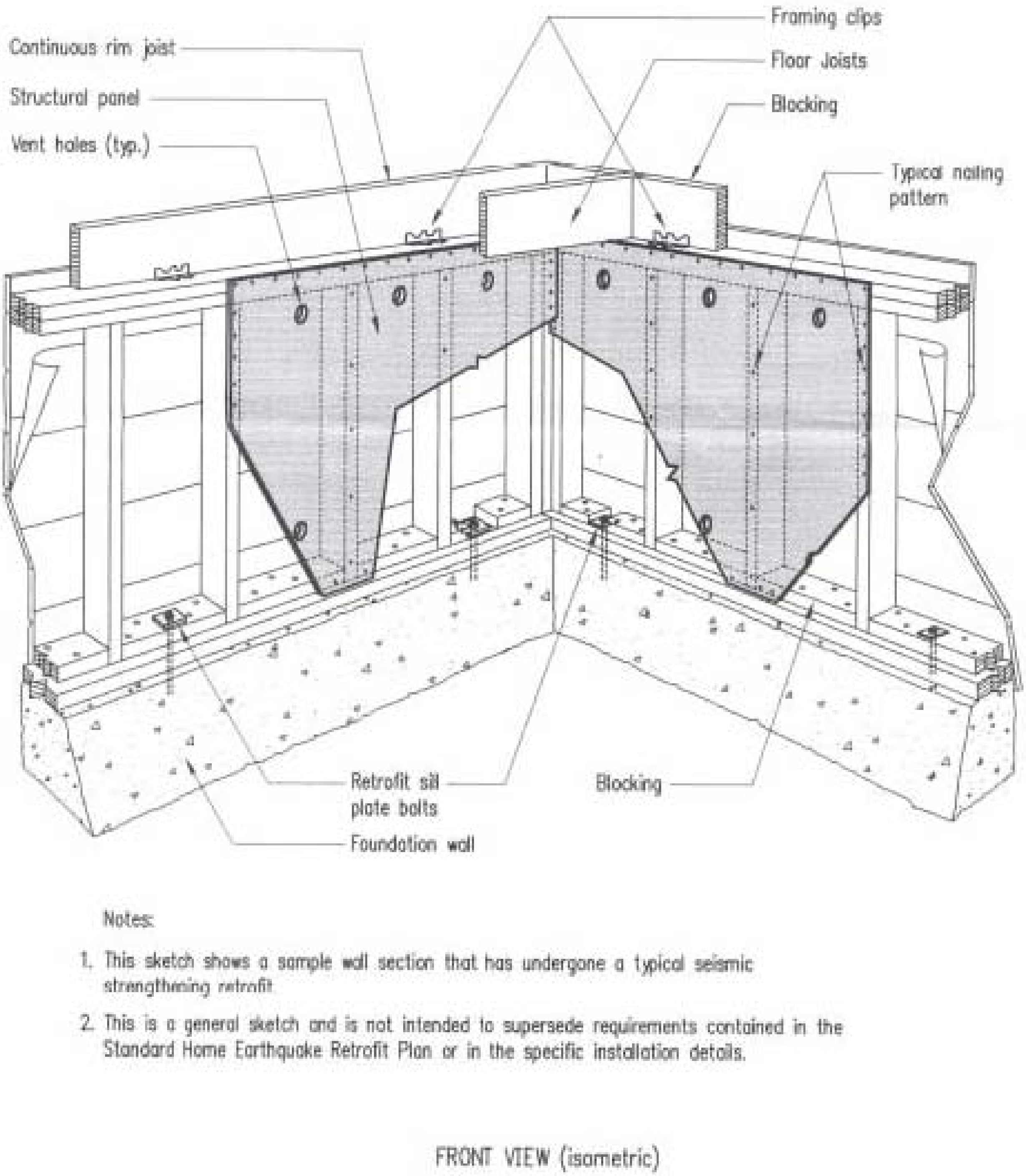
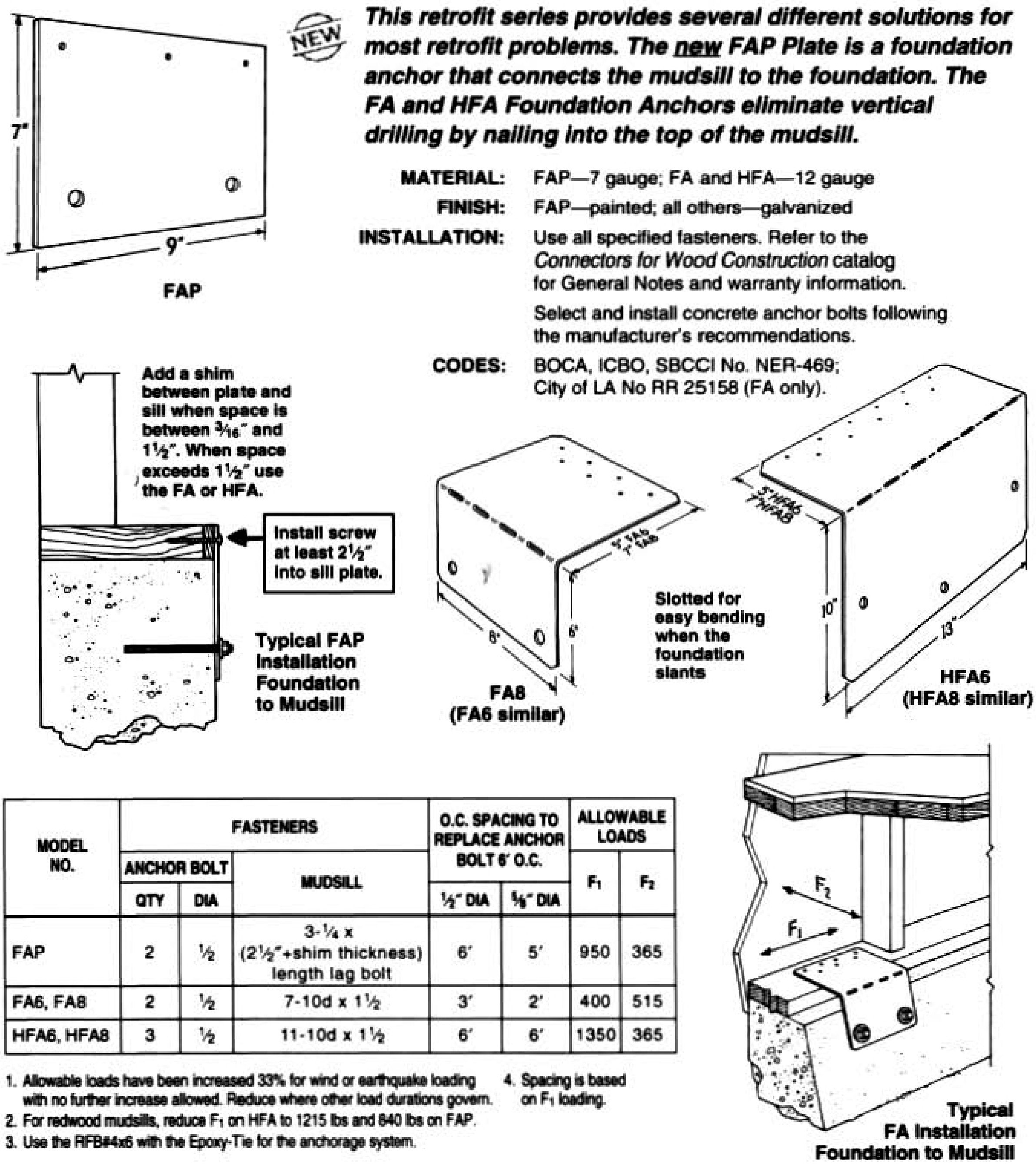


Figure 90
Isometric View of a Typical Retrofit, showing foundation anchor bolts, pony wall bracing, and framing clips, from inside the basement or crawlspace
Source: http://www.soundseismic.com/live/page/project-impact

Task one, drawing the foundation line, involves the measuring of each segment of exterior foundation wall, marking on openings and the direction of floor and joist beams.
Task two involves the selection of the concrete foundation replacement method and reviewing installation information.

Task three involves identifying how to anchor the sill plate to the foundation. Several types of manufactured side plates are designed for specific foundation and sill plate conditions (see Figure 91). The anchors used must also be selected, commonly an expansion bolt or a chemical anchor.



This retrofit series provides several different solutions for most retrofit problems. The new FAP Plate is a foundation anchor that connects the mudsill to the foundation. The FA and HFA Foundation Anchors eliminate vertical drilling by nailing into the top of the mudsill.

MATERIAL: FAP—7 gauge; FA and HFA—12 gauge

FINISH: FAP—painted; all others—galvanized

INSTALLATION: Use all specified fasteners. Refer to the *Connectors for Wood Construction* catalog for General Notes and warranty information.

Select and install concrete anchor bolts following the manufacturer's recommendations.

CODES: BOCA, ICBO, SBCCI No. NER-469; City of LA No RR 25158 (FA only).

MODEL NO.	FASTENERS: ANCHOR BOLT QTY	FASTENERS: ANCHOR BOLT DIA	FASTENERS: MUDSILL	O.C. SPACING TO REPLACE ANCHOR BOLT 6' O.C.: ½" DIA	O.C. SPACING TO REPLACE ANCHOR BOLT 6' O.C.: ⅝" DIA	ALLOWABLE LOADS: F_1	ALLOWABLE LOADS: F_2
FAP	2	½	3-¼ x (2½"+shim thickness) length lag bolt	6'	5'	950	365
FA6, FA8	2	½	7-10d x 1½	3'	2'	400	515
HFA6, HFA8	3	½	11-10d x 1½	6'	6'	1350	365

1. Allowable loads have been increased 33% for wind or earthquake loading with no further increase allowed. Reduce where other load durations govern.
2. For redwood mudsills, reduce F_1 on HFA to 1215 lbs and 840 lbs on FAP.
3. Use the RFB#4x6 with the Epoxy-Tie for the anchorage system.
4. Spacing is based on F_1 loading.

Figure 91
Sample Manufacturer's Sheet for Anchor Side Plates
Source: http://www.soundseismic.com/live/page/project-impact

Task four involves strengthening of the pony walls (also known as cripple walls or jack-studs). Structural panels will be installed on the exterior face of the pony wall studs. These panels must be reviewed in terms of their wood species, durability, intended us, span rating, and the number of plys, or wood layers, in the plywood. The amount and location of panels for installation must also be decided.

Task five involves the method selection to connect the floor framing to the pony wall. The repair condition will often have lack of blocking above the pony wall and no framing elements on which to install framing clips (see Figure 92). Framing modifications are thus necessary to provide the required nailing surfaces for the framing clips and to ensure connections that complete the load path between the pony wall and the floor system. Two methods can be used, method one when the joist is perpendicular to the foundation wall, method two when the joist is parallel to the foundation wall (see Figure 93, 94 and 95).

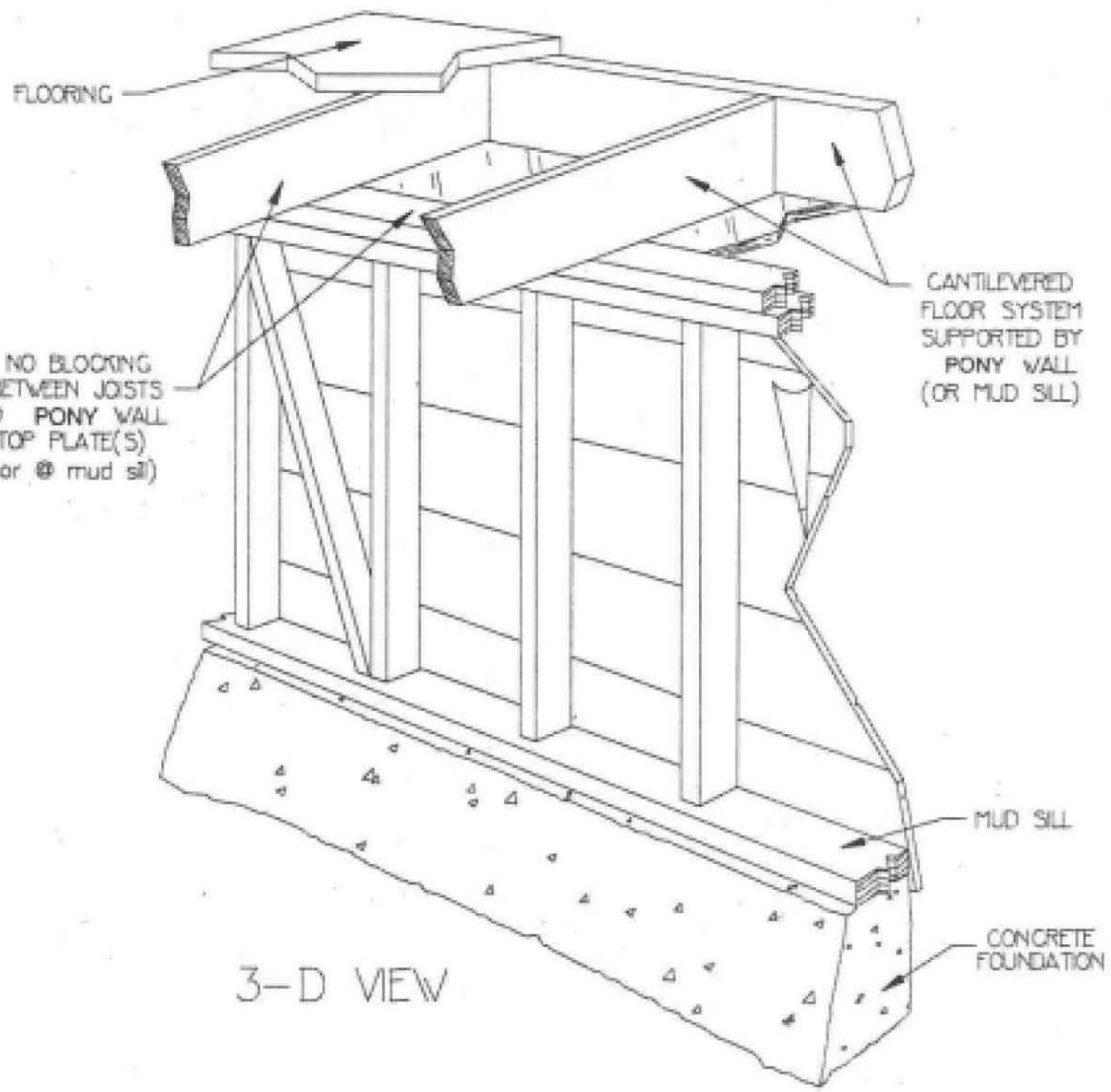


Figure 92
Repair Condition of Pony Wall
Source: http://www.soundseismic.com/live/page/project-impact

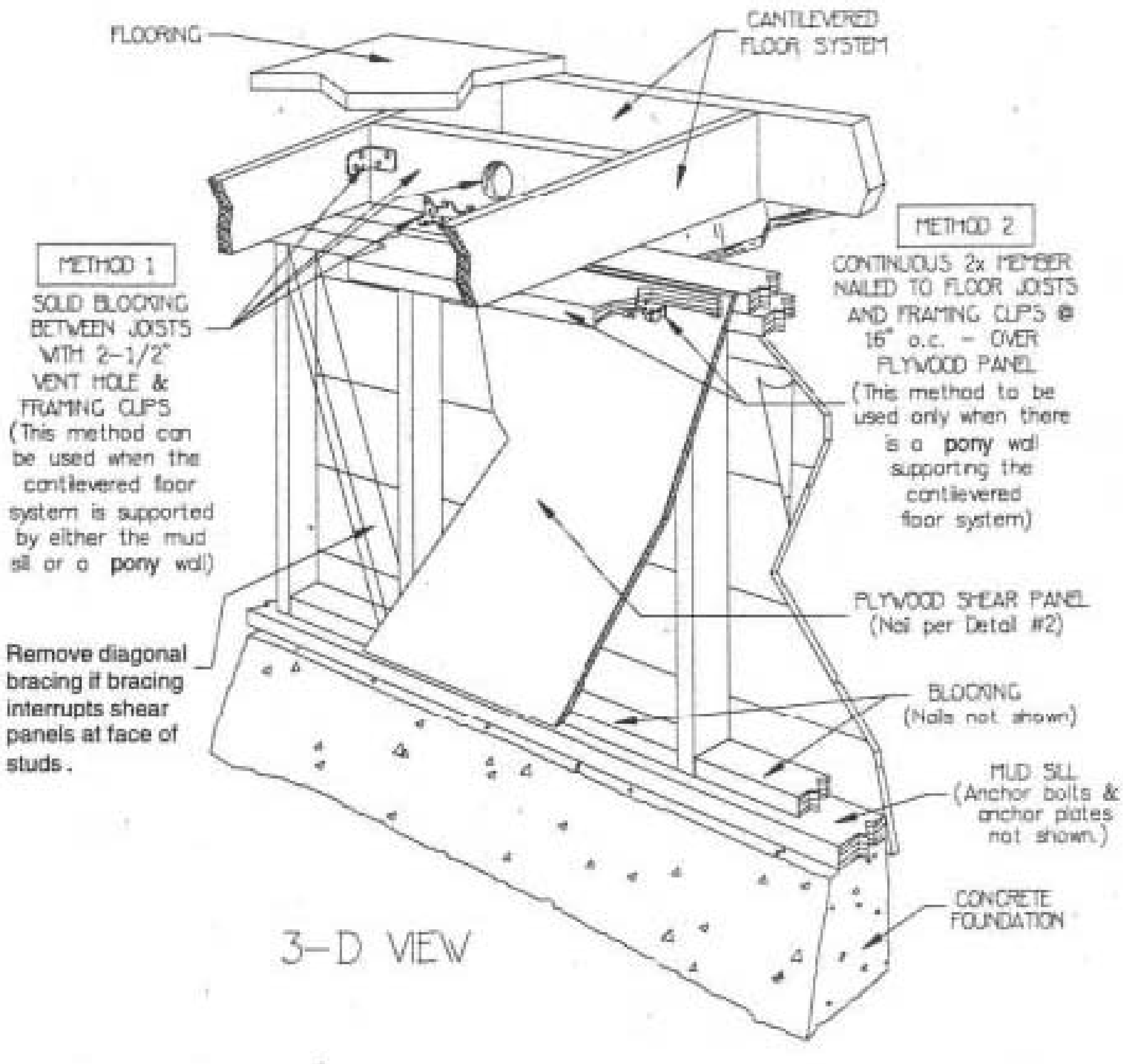


Figure 93
Detail Showing Two Methods for Installing Framing Clips for a Cantilevered Floor with No Blocking above the Pony Wall
Source: http://www.soundseismic.com/live/page/project-impact

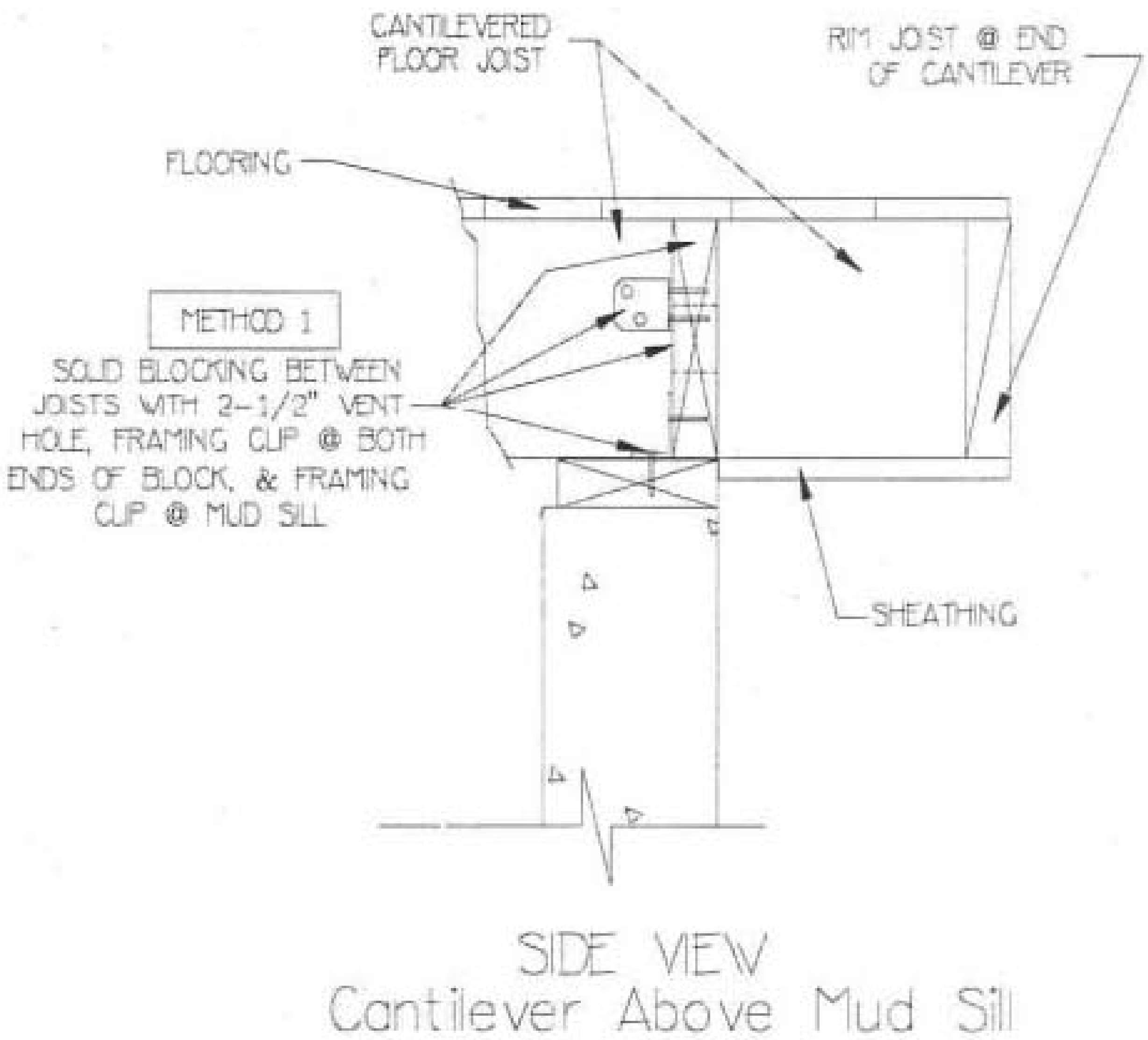


Figure 94
Repair Detail for a Cantilevered Floor with No Blocking above the Sill Plate
Source: http://www.soundseismic.com/live/page/project-impact

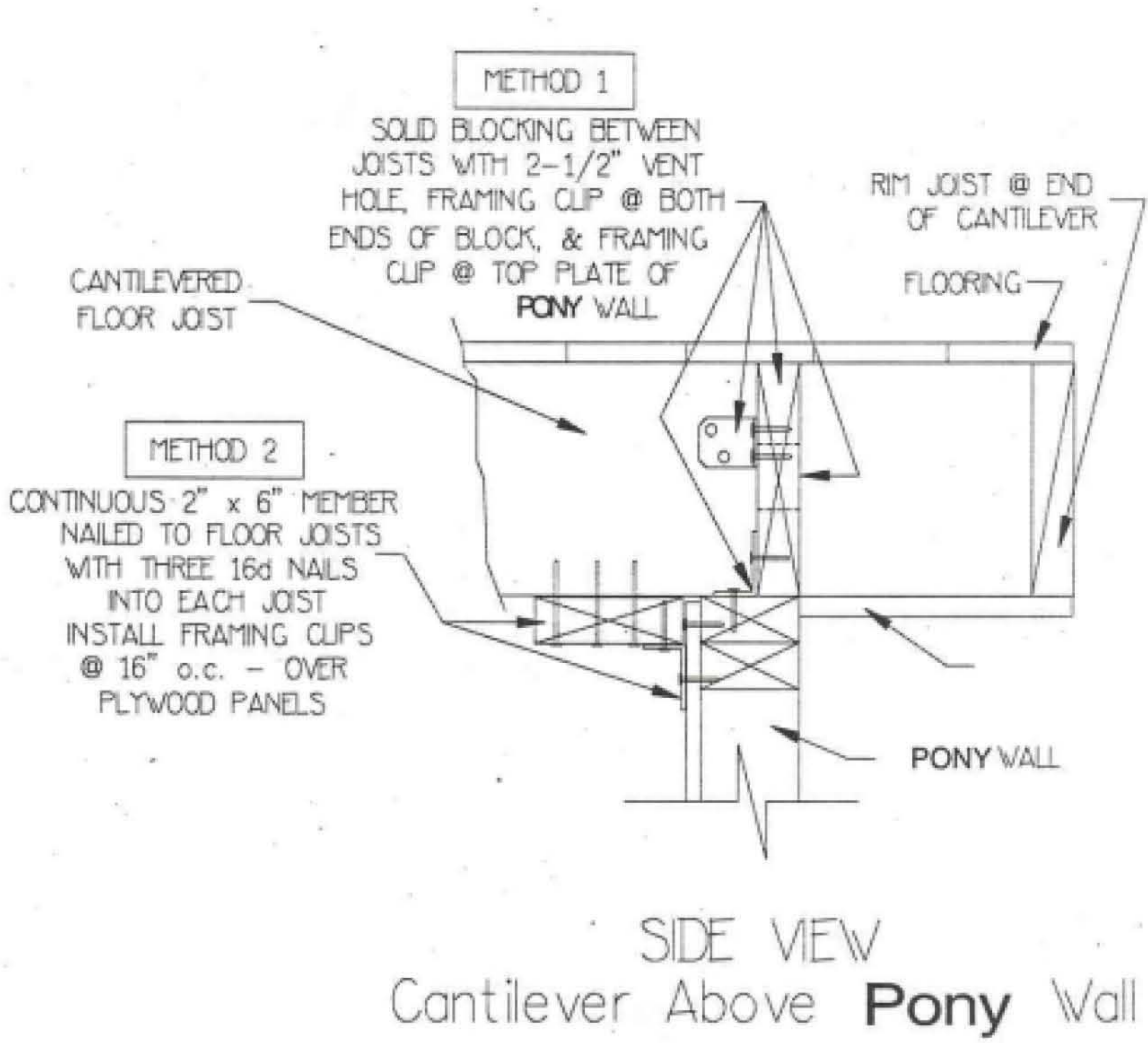


Figure 95
Repair Detail for a Cantilevered Floor with No Blocking above the Pony Wall
Source: http://www.soundseismic.com/live/page/project-impact

When there is no pony wall top plate (see Figure 96) and the rim joist rests on top of the pony wall studs, framing modifications are necessary to provide the required nailing surfaces for the ply shear panels. Framing clips and blocking can be used (see Figures 97 and 98).

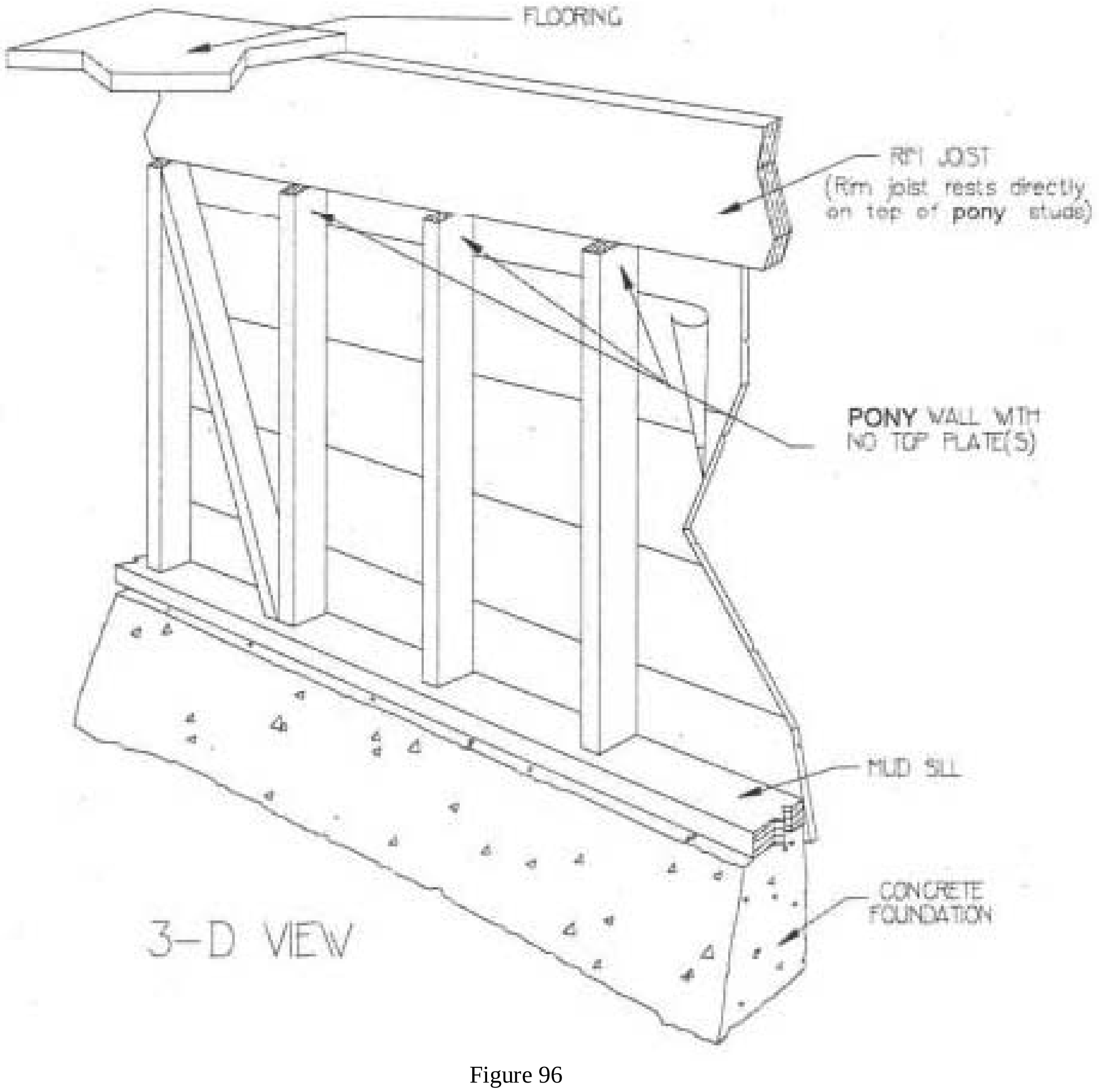


Figure 96
Repair Condition No Pony Wall Top Plates
Source: http://www.soundseismic.com/live/page/project-impact

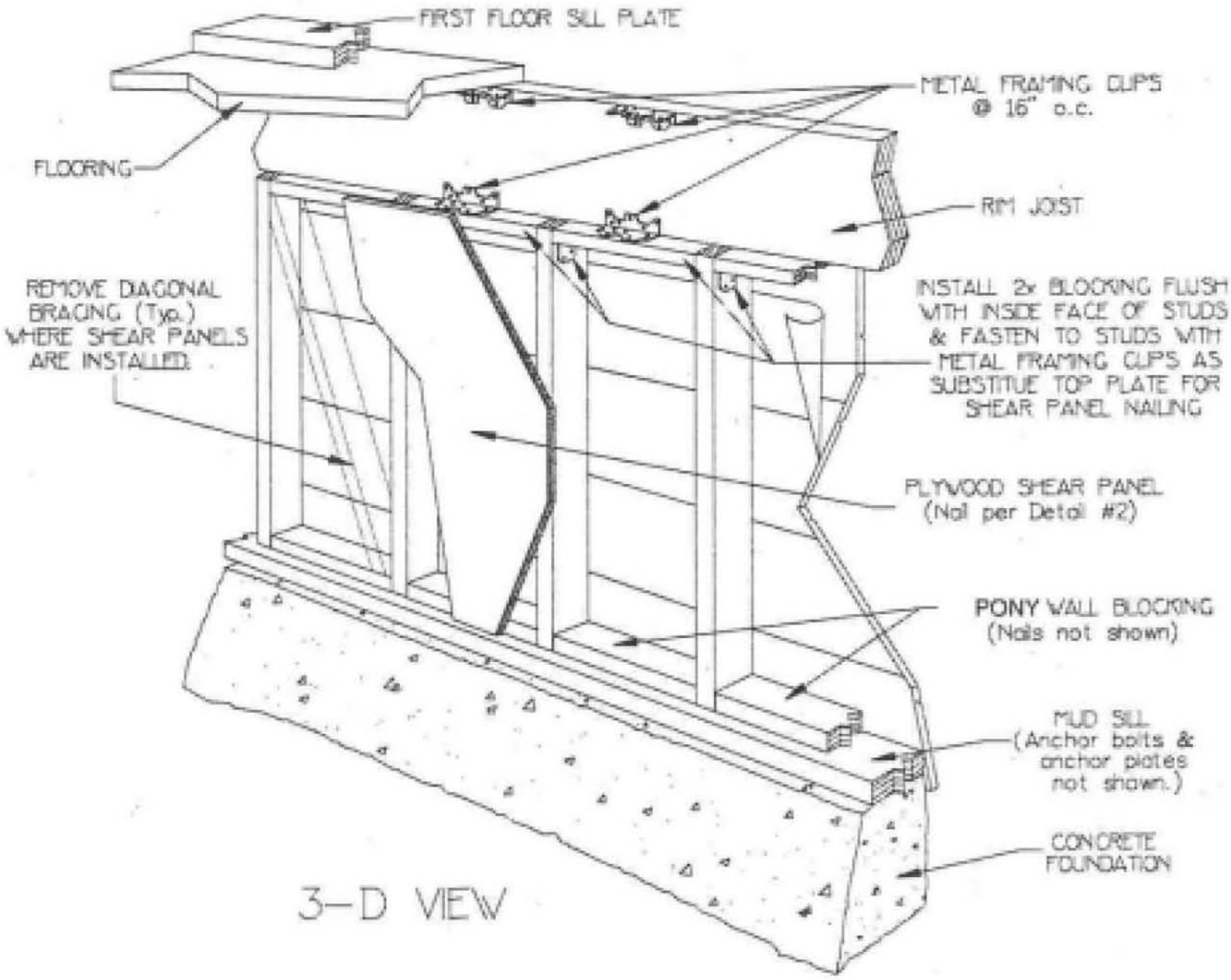


Figure 97
Repair Detail for Pony Wall with No Top Plate
Source: http://www.soundseismic.com/live/page/project-impact

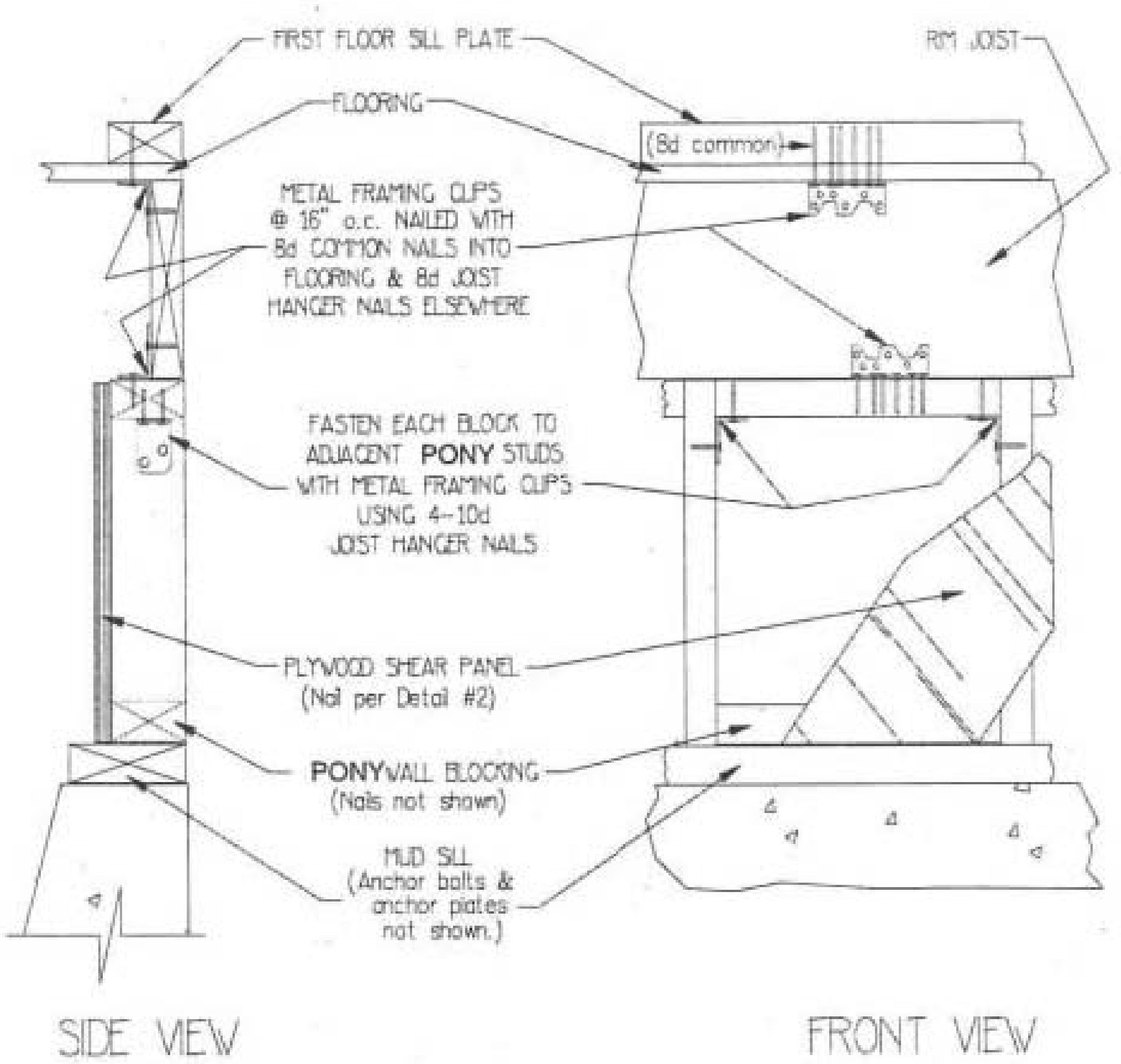


Figure 98
Repair Detail for Pony Wall with No Top Plate
Source: http://www.soundseismic.com/live/page/project-impact

If the parallel floor joists are too close to the sill plate or pony wall to allow access for the installation of framing clips, framing modifications are necessary to allow access to the rim joist and the mud sill to permit the installation of the required framing clips and/or mud sill anchors. This resource is very relevant in providing clear details which may be beneficial for the retrofit of jack-stud foundations which occur in New Zealand dwellings.

Full Foundation Wall/Internal Piles:

This system commonly involves a brick or block veneer from ground to soffit level. The sub-floor wall is frequently "reinforced block and has integrally cast half-piles, on which the bearers sit."[u]

Many of the details which apply to full foundation wall/internal piles foundation types also apply to full foundation wall foundation types. Please see the section on full foundation wall foundations for relevant details.

[u] Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 55.

Slab on Ground:
This consists of a concrete slab floated on the soil; loads from the superstructure above are transferred into the slab through thickened areas in the concrete. Connections, reinforcing at internal corners and reinforcing mesh across the slab are very important to the functioning and performance of this foundation type.[v]

Slab on grade foundations which are prone to slipping sideways have suggested retrofit measures to improve earthquake performance. Firstly the floor is checked for the presence of reinforcing steel; if found then a small excavation into the foundation is necessary to ensure that the steel passes between the two concrete sections. If the steel is not present, the remedy is to drill 12mm diameter holes 200mm deep into the floor in the interior adjacent to exterior walls and glue D12 reinforcing bars into the holes at a maximum of 1m centres.[w]

Research has been conducted into the repair unreinforced and reinforced concrete slabs with fibre reinforced polymer composite strips. This involves slabs fitted with carbon epoxy and E-glass/epoxy composites[x] (see Figure 99). Details of the slab are given (see Figure 100).

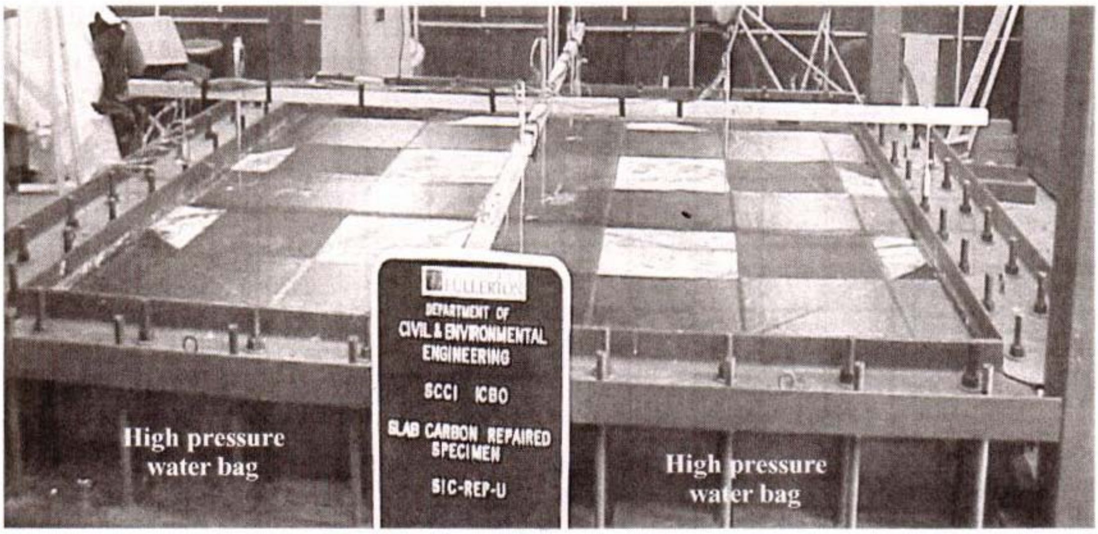


Figure 99
Details of Experimental Setup
Source: Mosallam, Ayman S and Mosalam, Khalid M. *Strengthening of Two-Way Concrete Slabs with FRP Composite Laminates.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2003, vol 17, p 45.

[v] Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 57.
[w] Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 17.

[x] Mosallam, Ayman S and Mosalam, Khalid M. *Strengthening of Two-Way Concrete Slabs with FRP Composite Laminates.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2003, vol 17, p 44.

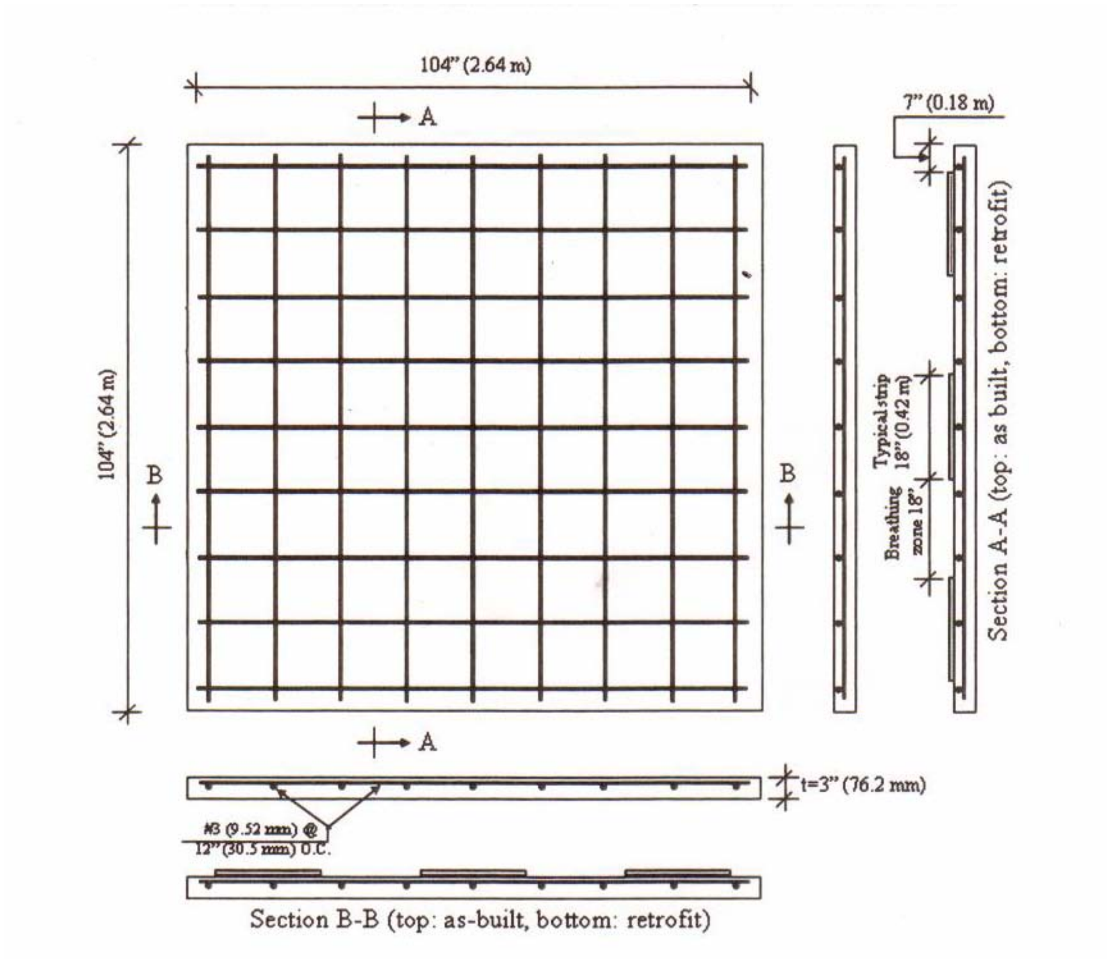


Figure 100
Details of Two-Way Reinforced Concrete Slabs (also same geometry for unreinforced)
Source: Mosallam, Ayman S and Mosalam, Khalid M. *Strengthening of Two-Way Concrete Slabs with FRP Composite Laminates.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2003, vol 17, p 46.

This research concluded that the fibre reinforced polymer systems succeed in "upgrading the structural capacity of both two-way unreinforced and reinforced concrete slabs."[y] This retrofit repair restores the original capacity of the damaged slabs, and further, increases the strength of the slabs "to an average increase of more then 540% the original capacity of the as-built slabs."[z] It is also noted that when failure did occur, it was preceded by large deflections which gives prior warning before imminent failure. This may prove relevant and useful in the seismic retrofitting of slab on grade foundations, a foundation type which is acknowledges as one difficult to repair.

Slab on grade foundations which are prone to slipping sideways have suggested retrofit measures to improve earthquake performance. Firstly the floor is checked for the presence of reinforcing steel; if found then a small excavation into the foundation is necessary to ensure that the steel passes

[y] Mosallam, Ayman S and Mosalam, Khalid M. *Strengthening of Two-Way Concrete Slabs with FRP Composite Laminates.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2003, vol 17, p 53.

[z] Mosallam, Ayman S and Mosalam, Khalid M. *Strengthening of Two-Way Concrete Slabs with FRP Composite Laminates.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2003, vol 17, p 53.

between the two concrete sections. If the steel is not present, the remedy is to drill 12mm diameter holes 200mm deep into the floor in the interior adjacent to exterior walls and glue D12 reinforcing bars into the holes at a maximum of 1m centres.[aa]

Concrete floors and foundations may be re-levelled post earthquake by a process involving injecting proprietary products underneath. "This process performs two functions: the first is to fill voids that may be present in the soil beneath the building (effectively compacting the soil); and the second serves to add extra bearing material between the compacted layers and the foundation or slab (thereby lifting them to the desired levels)."[bb] Disruption to the property is minimal. Three dwellings were tested with this technique, which show that this injection system is successful and efficient, although "may not always be successful if the area to be consolidated and lifted is difficult to confine."[cc] Although this is not a retrofit technique it may prove useful in ensuring that dwellings in New Zealand remain safe and habitable post earthquake.

[aa] Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 17.
[bb] Beattie, GJ. *Repair and Reinstatement of Earthquake Damaged Houses – Phase III.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2006, no 158, p 25.
[cc] Beattie, GJ. *Repair and Reinstatement of Earthquake Damaged Houses – Phase III.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2006, no 158, p 229.

Annotated Bibliography:
Written Texts:

American Society of Civil Engineers. *Seismic Evaluation of Existing Buildings*. American Society of Civil Engineers, United States of America, 2003.

This book outlines a three tiered process for the seismic evaluation of existing buildings and is designed to operate as a tool for design professionals, code officials and building owners. These tiers include the screening phase, the evaluation phase and the detailed evaluation phase, which is then divided into seven sections each looking at a different building type. Wood light frames is considered as a building type, and includes a structural checklist examining load path, vertical discontinuities, deterioration of wood and wood structural panel shear wall fasteners. These are rates as compliant, non-compliant or not applicable. Checklists are provided for differing areas of the building and an assessment able to be made based on these results.
Concrete frames with infill masonry shear walls and stiff diaphragms are also considered as a building type. The structural checklist again examines load path, soft storey, vertical discontinuities, torsion, deterioration of concrete, masonry joints and cracks in infill walls. This resource provides the tools for a thorough building analysis, however, it does not provide any seismic retrofit details.

Applied Technology Council and the Structural Engineers Association of California. *Built to Resist Earthquakes*. ATC/SEAOC Joint Venture, California, 1999.

This resource acts as a training curriculum, divided into three main sections; wood frame construction; concrete and masonry construction; and non-structural building components. Each section details the seismic response of the construction type, load paths, improving earthquake performance, seismic retrofit and inspection checklists. Seismic retrofitting of wood frame construction is outlined, covering issues such as weak storeys, deformation compatibility problems, unregulated penetrations of shear walls and connectors and their stiffness. However, no relevant retrofit details are given. Seismic rehabilitation of concrete and masonry structures is outlines, examining issues such as anchorages and fibre-reinforced composite systems. This resource is very relevant to this report in that it does discuss seismic retrofit measures and issues that may arise, however, no retrofit details are given.

Beattie, Graeme. *Houses in Earthquakes*. Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009.

This article first examines the process of an earthquake, how it affects houses and what areas of New Zealand are susceptible. It then explores dwelling foundations with a close examination across different elements comprising the foundation and subfloor. Firstly pile connections are considered, and adequate connections noted as critical to ensure the house does not fall of the piles in an earthquake. "The connection between the piles and the bearers…should be either a piece of 4mm diameter wire fixed to the piles and the bearer with staples or 'Z' nails…and skewed nails"[dd] (see Figure 101).

[dd] Beattie, Graeme. *Houses in Earthquakes*. Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 5.

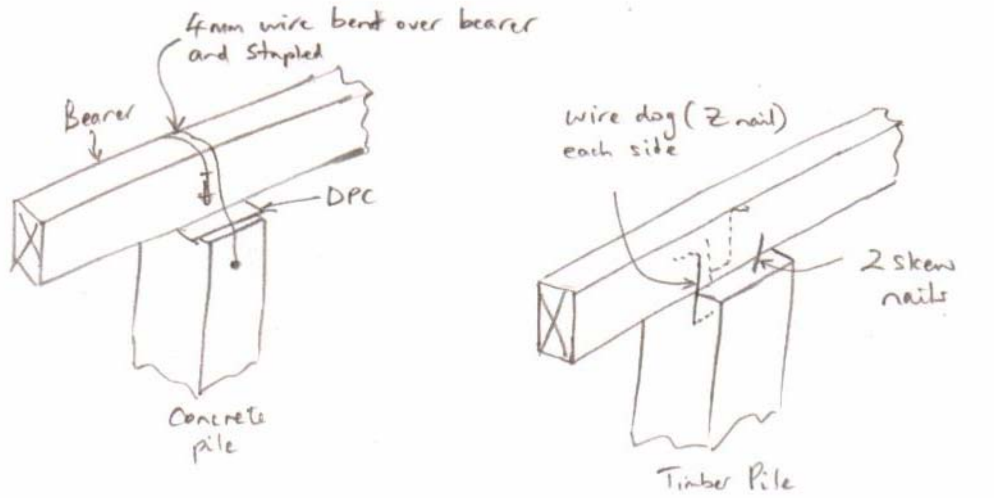


Figure 101
Typical Modern Pile to Bearer Connections
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 5.

Subfloor bracing is considered second, examining corner sections of reinforced concrete foundation wall and the connection to the floor joist, which is often poor. A diagonal brace bolted to the joist and the concrete wall is suggested (see Figure 102).

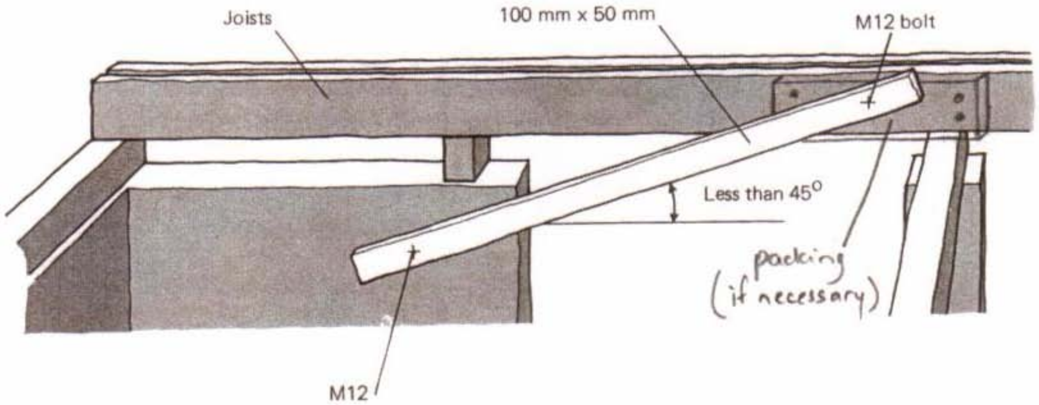


Figure 102
Corner Wall to Joist Remedial Connection Details
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 7.

Bracing with sheet material follows with details suggested for this retrofit (see Figures 103 and 104). Rules are outlined for bracing with diagonal braces in a timber piled foundation situation. These include: “At least two braces should be installed on the outside row and every second row of piles in between and in both directions, the bolt connecting the brace to the bottom of the pile should be a minimum of 300mm above the ground, the bolts should be at least hot-dipped galvanised, the height of the top bolt should be no less than four times the height of the bottom bolt above the ground, the slope angle of the brace should be no steeper than 45 degrees."[ee] Retrofit details are again suggested (see Figures 105 and 106).

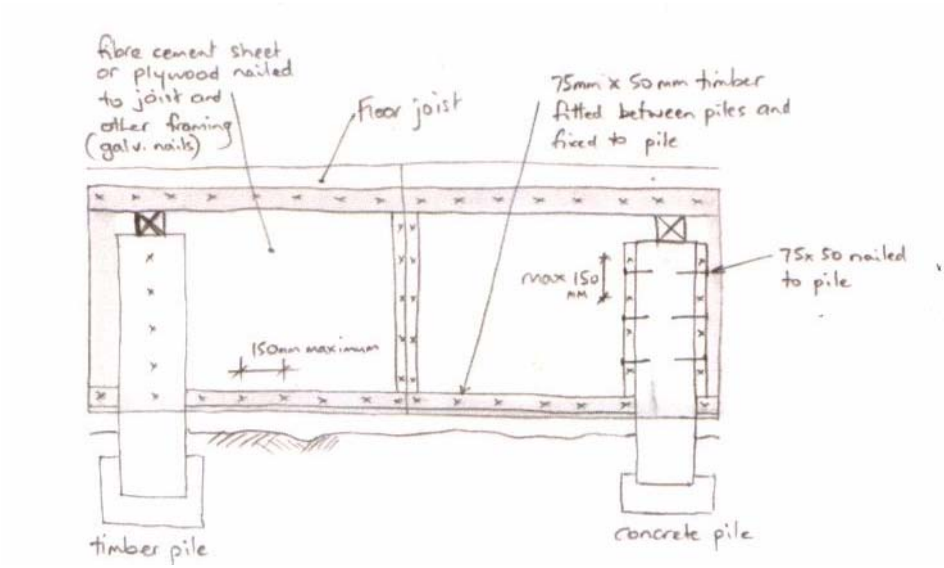


Figure 103
Bracing in a Piled House with Sheet Material: At bearer ends
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 9.

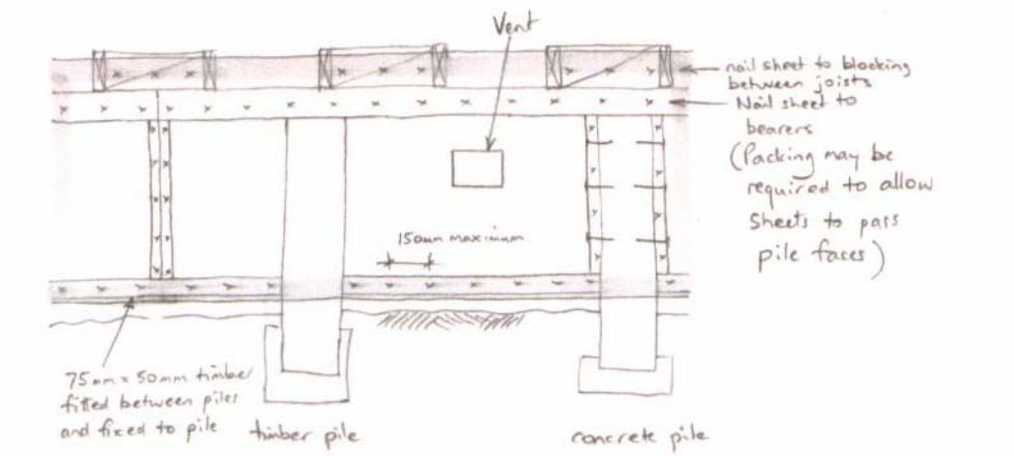


Figure 104
Bracing in a Piled House with Sheet Material: At joist ends
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 9.

[ee] Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2007, p 11.

9, p 7.

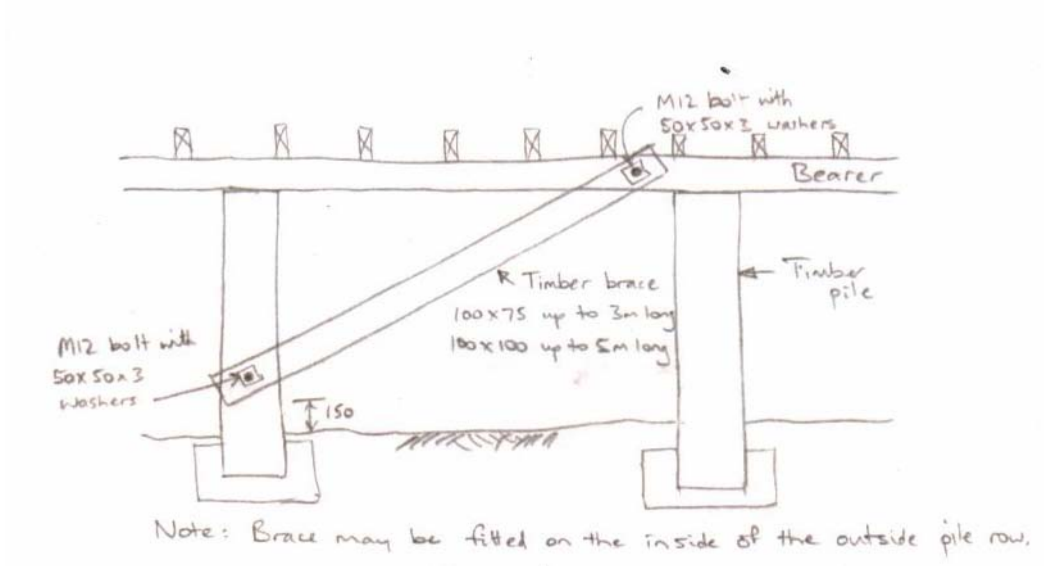


Figure 105
Added Timber Braces to Timber Piles: Fixed to a bearer
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 11.

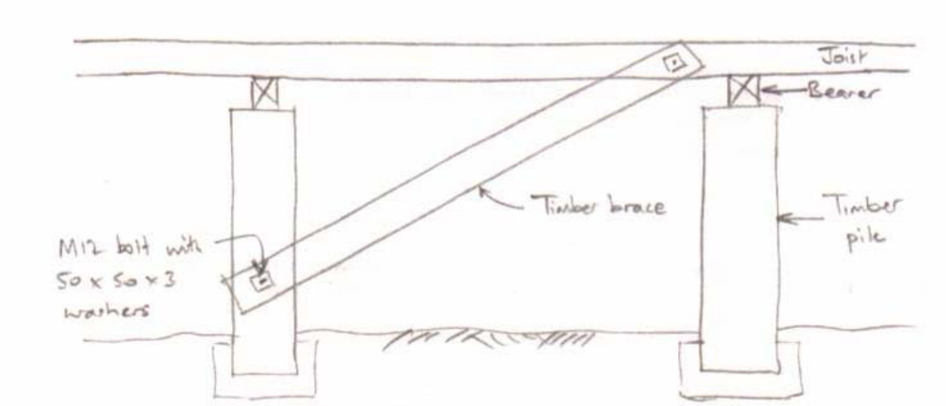


Figure 106
Added Timber Braces to Timber Piles: Fixed to a joist
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 11.

Connections and bracing is very important, too, in timber jack stud subfloor framing (see Figure 107). A retrofit system for strengthening jack stud walls is outlined (see Figure 108) as well as notes on such measures for this foundation type. These include: "remove [the brittle existing sheet cladding] and replace it with modern fibre cement sheet not less than 7.5mm thick and nailed at 150mm centres to the timber plates and studs around the perimeter of all sheets… with 40x2.5 galvanised flat head nails. The sheet should be nailed to the intermediate studs with nails at 300mm centres. Add either fibre cement sheet material to the inside face nailed [as above] or add minimum 7mm thick D-D grade plywood nailed [as above]."[ff]

[ff] Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 12.

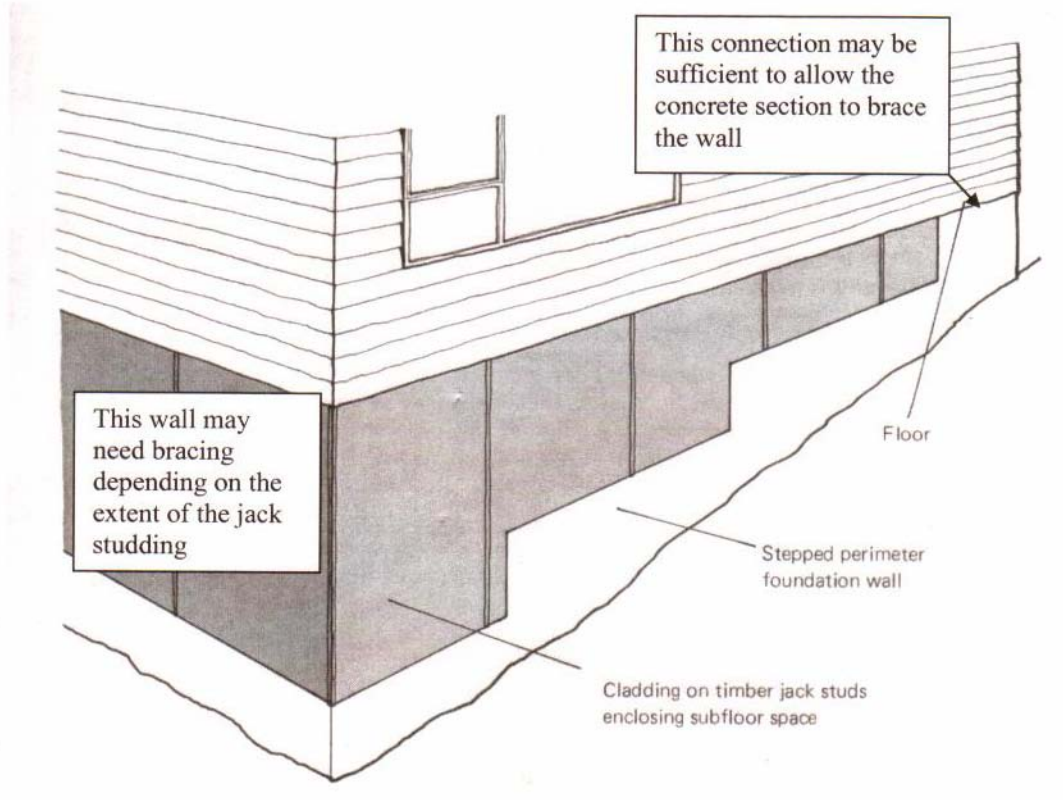


Figure 107
Jack Studs on Perimeter Foundation Wall
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 12.

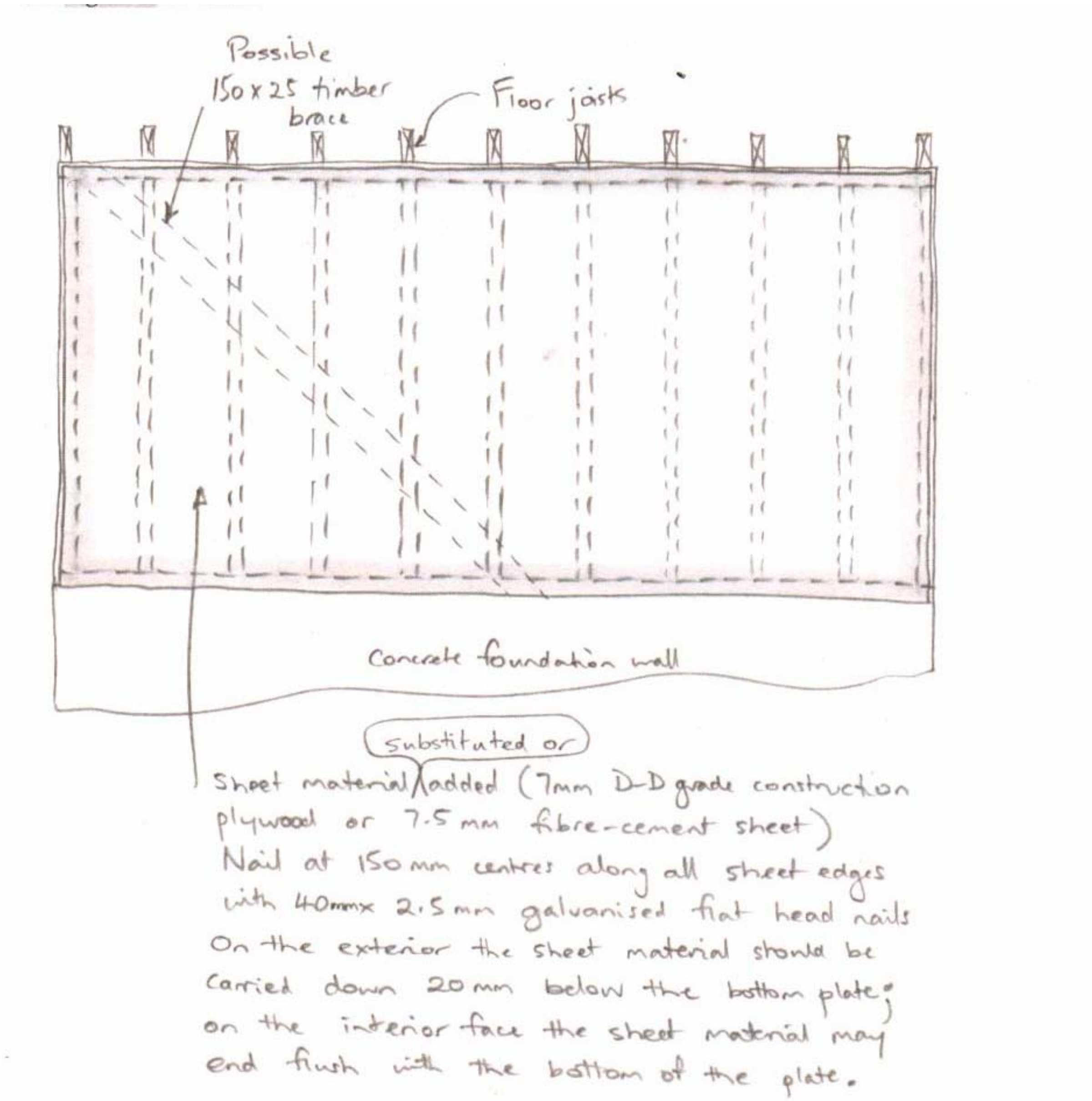


Figure 108
System for Strengthening Jack Stud Walls against Earthquakes
Source: Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 13.

Slab on grade foundations which are prone to slipping sideways have suggested retrofit measures to improve earthquake performance. Firstly the floor is checked for the presence of reinforcing steel; if found then a small excavation into the foundation is necessary to ensure that the steel passes between the two concrete sections. If the steel is not present, the remedy is to drill 12mm diameter holes 200mm deep into the floor in the interior adjacent to exterior walls and glue D12 reinforcing bars into the holes at a maximum of 1m centres.[gg]

Clay and tile roof remedial measures are covered in the following section of this article, then protective measures for chimneys, header tanks, hot water cylinders and house contents are outlined.

[gg] Beattie, Graeme. *Houses in Earthquakes.* Unpublished amendment of Study Report SR0926, Building Research Association of New Zealand, Judgeford, 2009, p 17.

Beattie, G J. *Repair and Reinstatement of Earthquake Damaged Houses – Derivation of Repair Techniques.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2001, no. 100.

This report examines repair for domestic housing structural elements including exterior wall clad with sheet sheathing, a braced pile foundation system, a brick veneer corner and gypsum plasterboard lined interior walls. These systems were indentified through research as the most in need of consideration by the construction industry. Most relevant to this report is the section on braced pile systems, were a test was set up examining four piles and three diagonal braces to determine necessary repairs for such a system for varying levels of damage that could occur in an earthquake (see Figure 109).

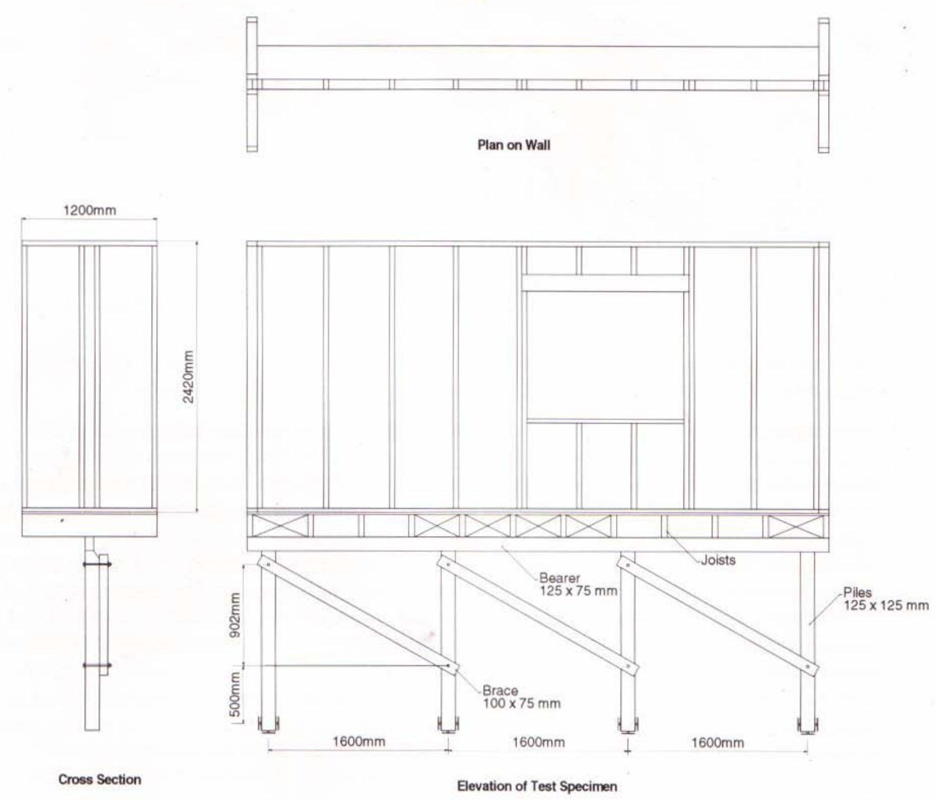


Figure 109
Details of the Braced Pile Specimen
Source: Beattie, G J. *Repair and Reinstatement of Earthquake Damaged Houses – Derivation of Repair Techniques.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2001, no. 100, p 22.

The test followed requirements of NZS3604:1999, "all bolted connections were M12 galvanised bolts through close fitting holes in the timber. A 50mm x 50mm x 3mm flat washer was installed beneath each bolt head and under each nut. The bolts were tightened firmly with an adjustable spanner, as would be expected to occur in practice."[hh] This test revealed that although movement

[hh] Beattie, G J. *Repair and Reinstatement of Earthquake Damaged Houses – Derivation of Repair Techniques.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2001, no. 100, p 21.

occurs (see Figure 110) it is difficult to tell what damage has occurred without removing a brace post earthquake, so this is recommended; a thorough checking of "the state of the bolt and the timber around it"[ii] (see Figure 111).

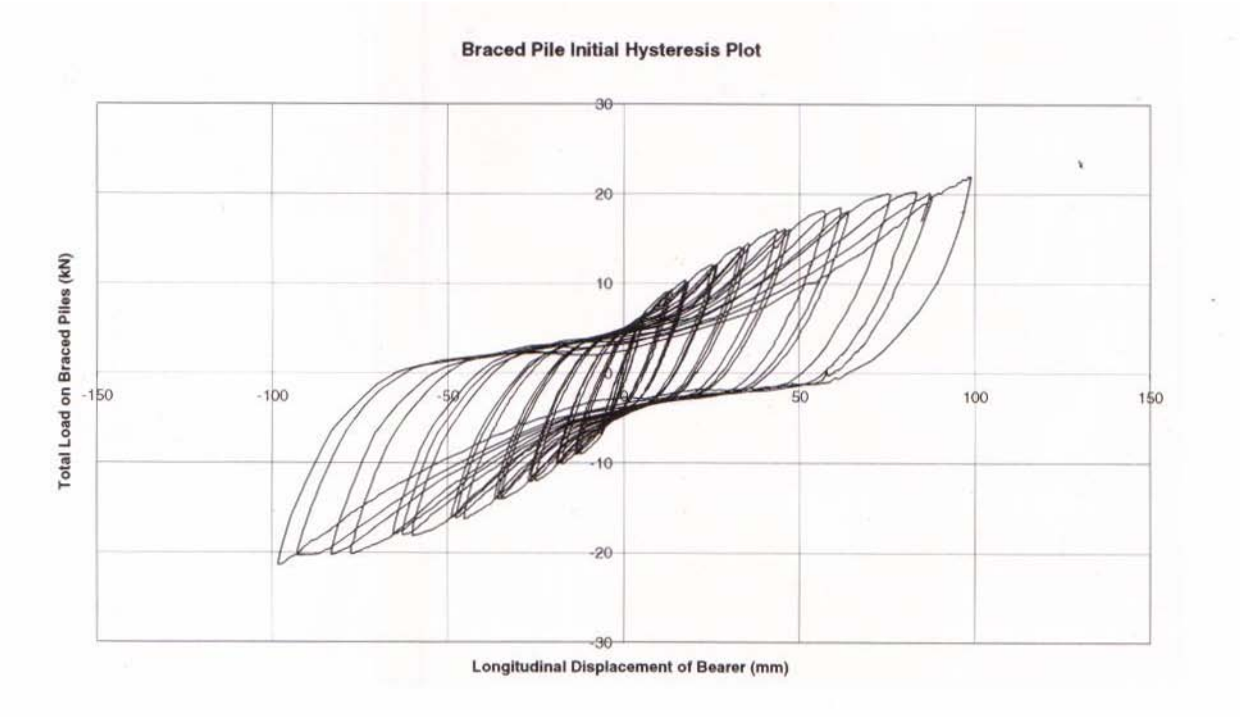


Figure 110
Longitudinal Displacement of Bearer Against Load
Source: Beattie, G J. *Repair and Reinstatement of Earthquake Damaged Houses – Derivation of Repair Techniques.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2001, no. 100, p 23.

[ii] Beattie, G J. *Repair and Reinstatement of Earthquake Damaged Houses – Derivation of Repair Techniques.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2001, no. 100, p 23.

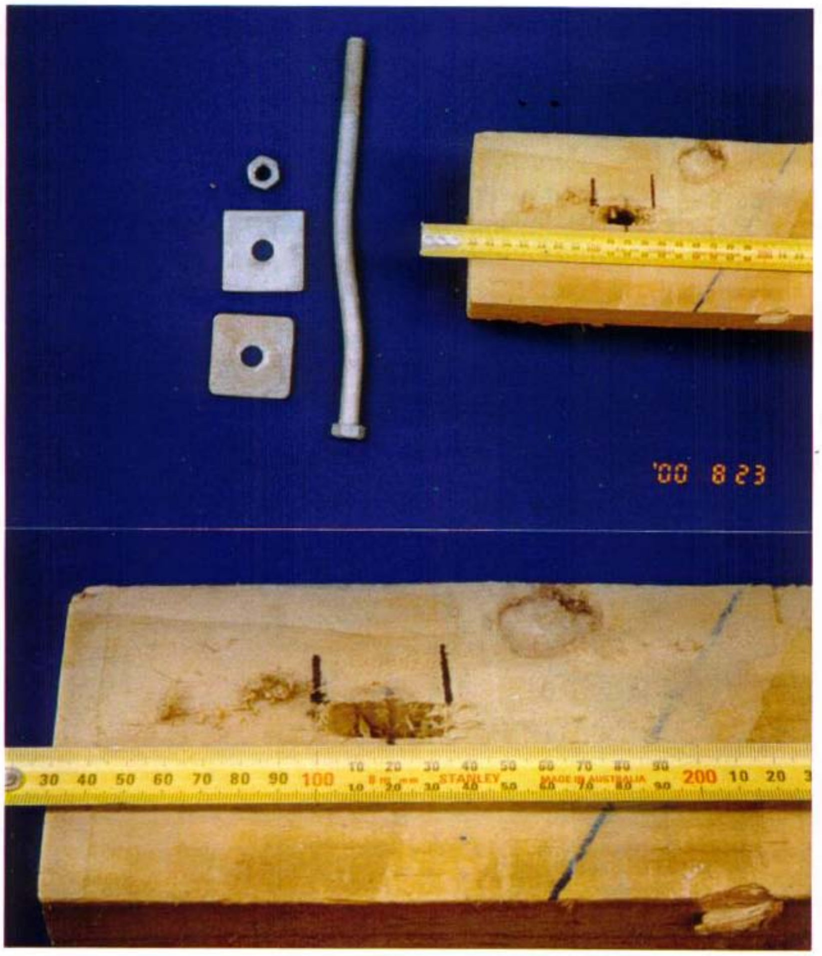


Figure 111
Pile Brace after removal showing bent bolt and slot in brace
Source: Beattie, G J. *Repair and Reinstatement of Earthquake Damaged Houses – Derivation of Repair Techniques.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2001, no. 100, p 24.

Two repair methods were tested; filling the holes with builders' fill and redrilling once fill has hardened, and removing of bolts and enlarging of bolt holes for M16 bolts (See Figures 112 and 113).

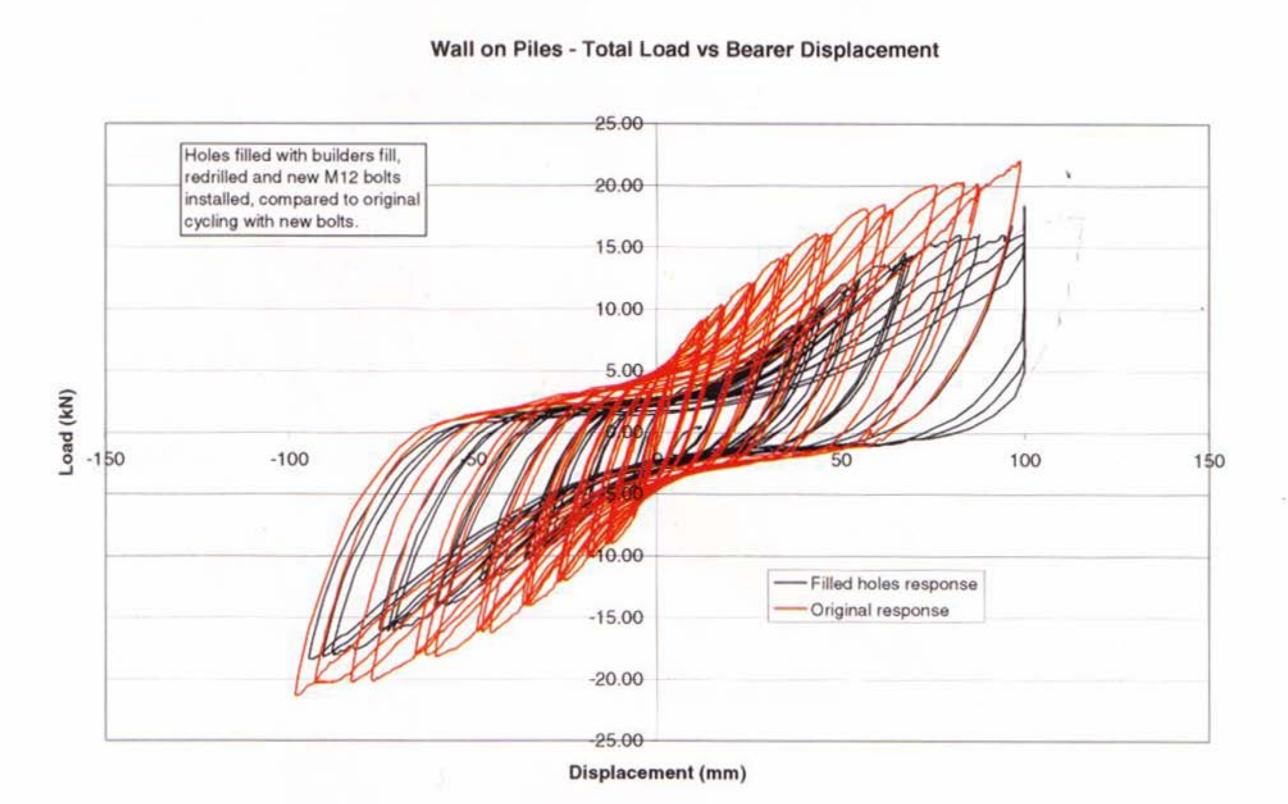


Figure 112
Comparison of Performance Before and After Holes Repaired with Builders' Fill
Source: Beattie, G J. *Repair and Reinstatement of Earthquake Damaged Houses – Derivation of Repair Techniques.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2001, no. 100, p 25.

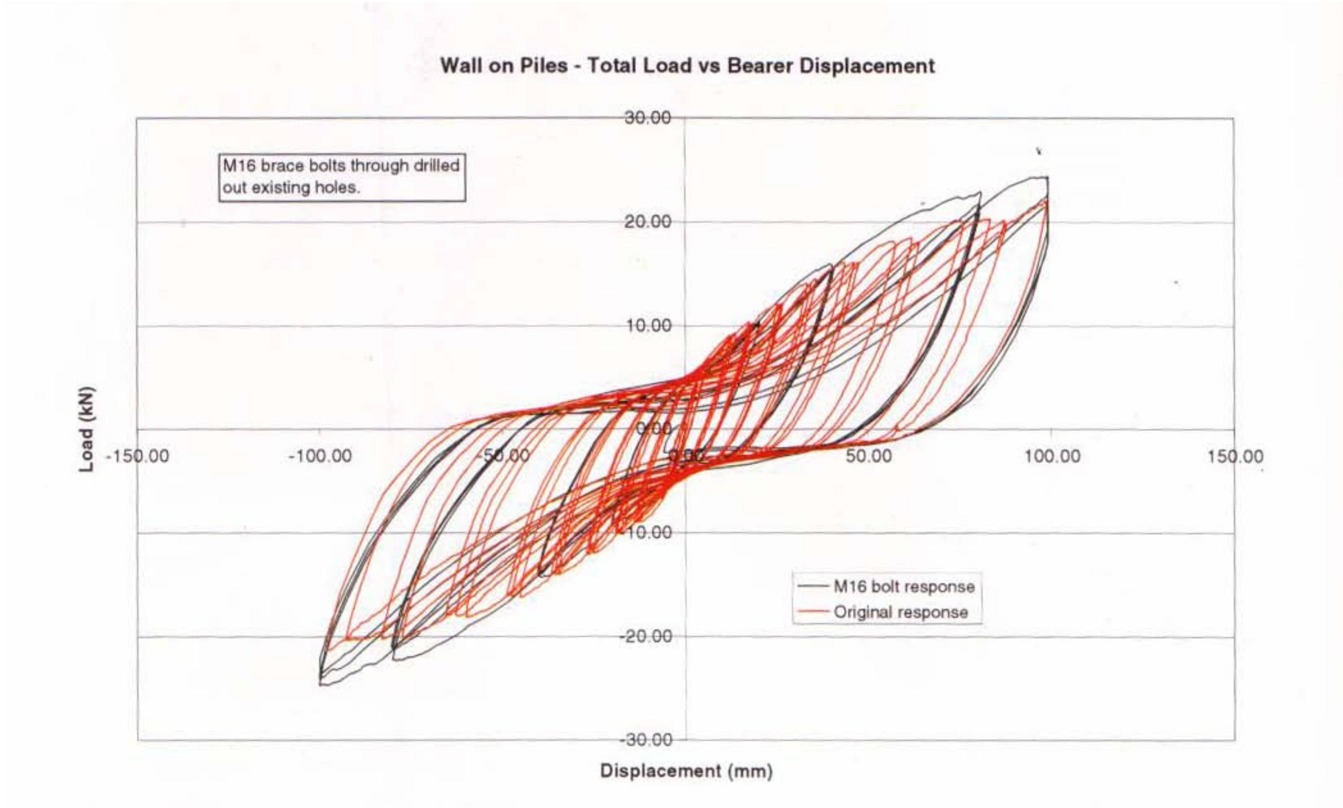


Figure 113
Comparison of Performance Before and After Holes Drilled out and M16 Bolts Installed
Source: Beattie, G J. *Repair and Reinstatement of Earthquake Damaged Houses – Derivation of Repair Techniques.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2001, no. 100, p 26.

Ultimately this decision of repair is to be made once a brace is removed after the earthquake and assessed for internal damage. This study report emphasises that "performance will be influenced by the strength of the subsequent event, the correct identification of the damage sustained and by the quality of the repair carried out,"[jj] suggesting through survey of building elements their maintenance and repair is of paramount importance. Connections and their quality is also emphasised, placing further direction in the focus of this report, where retrofitting of details and their connections is considered.

Beattie, G J. *Repair and Reinstatement of Earthquake Damaged Houses – Derivation of Repair Techniques – Phase II*. BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2003, no 123.

This study report is the second in a series which aims to establish the likely damage of dwelling elements when subjected to earthquakes, and possible retrofit techniques. This report examines brick veneer cladding; exterior walls with only interior linings providing bracing resistance;

[jj] Beattie, G J. *Repair and Reinstatement of Earthquake Damaged Houses – Derivation of Repair Techniques.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2001, no. 100, p 50.

vertically realigning a house that has been left out-of-plumb by an earthquake; and an investigation of the performance of walls with installed windows and various claddings. The vertical realignment of a house relates most closely to this report; this examines a house on a pile foundation and its construction in outlined (see Figure 114).

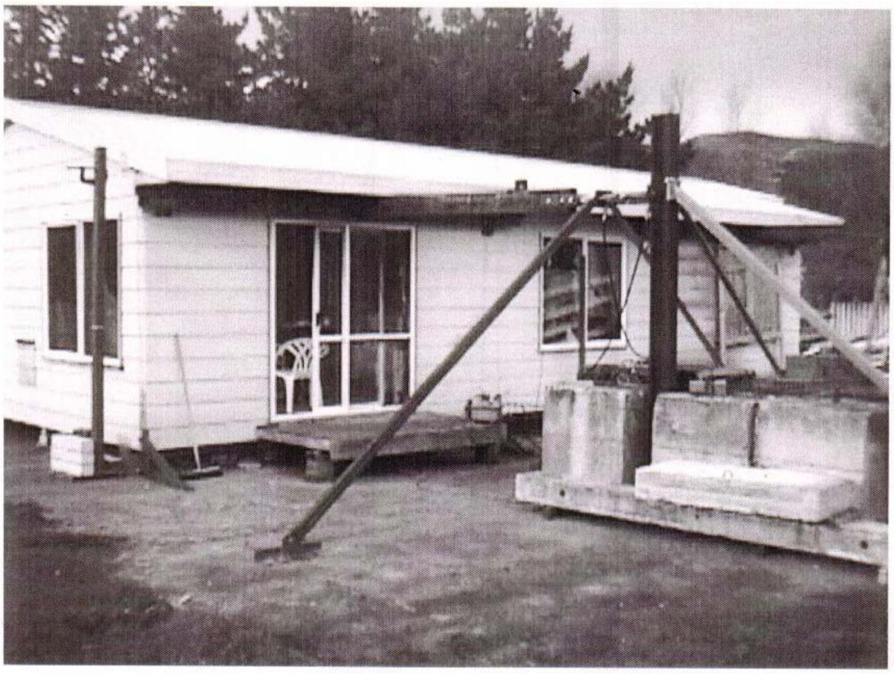


Figure 114
House to be Aligned Vertically
Source: Beattie, G J. *Repair and Reinstatement of Earthquake Damaged Houses – Derivation of Repair Techniques – Phase II.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2003, no 123, p 11.

The repair techniques tested included using a light wire rope and ratchet winch to realign a wall, an using a two tonne capacity car bottle jack to realign a wall. Final recommendations for repair procedures are outlined (see Figures 115 and 116).

System	Damage sustained	Repair procedure	Other considerations
Whole house	House is distorted due to lateral racking so that vertical lines (e.g. edge of door frames) are now sloping at greater than 1 in 480 (5 mm over 2.4 m wall height), but less than 1 in 150 (15 mm over 2.4 m wall height). Doors and windows are jammed	Remove skirting boards and scotias. Attach brackets to the bottom plate and diagonally opposite top plate and fix a minimum capacity 3 tonne rigger's hoist between the two. Tension the hoist until the wall has passed the 'plumb' position and release the hoist. Check that the wall has returned to the 'plumb' position and re-nail the sheet linings. Re-install the skirting and scotia boards and redecorate	The elastic stiffness of modern plasterboard ceiling diaphragms may prevent a single wall from being re-plumbed in isolation. In this instance, more than one wall may need to be re-plumbed at the same time. Check damage to exterior cladding
Whole house	House is distorted due to lateral racking so that vertical lines (e.g. edge of door frames) are now sloping at greater than 1 in 150 (15 mm over 2.4 m wall height). Doors and windows are jammed	Remove skirting boards and scotias. Remove wall linings on affected walls. Attach brackets to the bottom plate and diagonally opposite top plate and fix a minimum capacity 3 tonne rigger's hoist between the two. Tension the hoist until the wall has passed the 'plumb' position by 10 mm. Fit diagonal light gauge metal braces parallel to the hoist and release the hoist. Fit new interior linings and redecorate	The elastic stiffness of modern plasterboard ceiling diaphragms may prevent a single wall from being re-plumbed in isolation. In this instance, more than one wall may need to be re-plumbed at the same time. **During the time that the linings are removed the stability of the structure may be in jeopardy, especially if it is the bottom storey of a two storey structure.** Ensure that temporary braces are installed. **The services of a structural engineer are required**. Also, check damage to exterior cladding

Figure 115
Repair Techniques
Source: Beattie, G J. *Repair and Reinstatement of Earthquake Damaged Houses – Derivation of Repair Techniques – Phase II.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2003, no 123, p 32.

Whole house	House is distorted due to lateral racking so that vertical lines (e.g. edge of door frames) are now sloping at 1 in 480 (5 mm over 2.4 m wall height)	Check operation of doors and windows. If these are stuck, ease and re-paint fresh wood surface to match surrounding paintwork. If not stuck, no reinstatement is expected	Distortion of wall linings may be present at corners and openings

Figure 116
Repair Techniques
Source: Beattie, G J. *Repair and Reinstatement of Earthquake Damaged Houses – Derivation of Repair Techniques – Phase II.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2003, no 123, p 31.

This emphasises assessment of the individual situation and although these methods are not retrofit techniques, they do aim to make the dwelling safe and habitable post earthquake.

Beattie, GJ. *Repair and Reinstatement of Earthquake Damaged Houses – Phase III.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2006, no 158.

This study report is the third in this series, examining likely damage that will occur in different dwelling elements in the event of an earthquake. Repair procedures are tested for each element also. This study report investigates stucco wall claddings; softboard ceiling linings; hardboard ceiling linings; and lath and plaster walls. A further section is detailed on the soil injection procedures to level house foundations and floor slabs. This settlement may take place during an earthquake if "liquefaction of layers of soil deep beneath the house foundation occurs."[kk] Timber pile foundations can be re-levelled by jacking up and inserting packers between piles and bearers. Concrete floors and foundations may be levelled by a process involving injecting proprietary products underneath. "This process performs two functions: the first is to fill voids that may be present in the soil beneath the building (effectively compacting the soil); and the second serves to add extra bearing material between the compacted layers and the foundation or slab (thereby lifting them to the desired levels)."[ll] Disruption to the property is minimal. Three dwellings were tested with this technique, which show that this injection system is successful and efficient, although "may not always be successful if the area to be consolidated and lifted is difficult to confine."[mm] Although this is not a retrofit technique it may prove useful in ensuring that dwellings in New Zealand remain safe and habitable post earthquake.

Beattie, GJ. *Retrofitting of Houses to Resist Extreme Wind Events*. BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2008, no 187.

This study report explores wind design in New Zealand, where many earlier New Zealand dwellings do not meet current NZ3604 standards for wind loading. This predominantly affects wall and roof claddings and roof connections. This study is divided into ten sections covering areas such as cladding systems; considerations of building standards requirements; and wind effects on houses.

[kk] Beattie, GJ. *Repair and Reinstatement of Earthquake Damaged Houses – Phase III.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2006, no 158, p 25.
[ll] Beattie, GJ. *Repair and Reinstatement of Earthquake Damaged Houses – Phase III.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2006, no 158, p 25.
[mm] Beattie, GJ. *Repair and Reinstatement of Earthquake Damaged Houses – Phase III.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2006, no 158, p 229.

Retrofit solutions are given for roof claddings and varying roof connections and the costing of these proposed solutions is outlined. Although this study report does not directly relate to foundation retrofit, it does emphasise retrofit as a pre-emptive strategy to minimise damage and reinforces the importance of connections, two principles which align closely with the seismic retrofit of dwelling foundations.

Bosher, Lee and Dainty, Andrew and Carrillo, Patricia and Glass, Jacqueline. *Built In Resilience to Disasters: A Pre-Emptive Approach.* In Engineering, Construction and Architectural Management, Emerald Group Publishing Ltd., United Kingdom, 2007, vol 14, no 5, pp 434-446.

This article presents the findings of a UK-wide questionnaire which aims to identify which construction-associated stakeholders should be involved with disaster risk management initiatives. Disaster risk management is summarised into four phases: "hazard identification; mitigative adaptations; preparedness planning; and recovery (short term) and reconstruction (long term) planning."[nn] The design construction operation process is then outlined and the research findings discussed, developed from questionnaires, in-depth interviews and validation exercises (see Figure 117).

	Number of respondents		
Disciplinary background	Questionnaires	In-depth interviews	Validation exercise
Architecture	7	2	2
Engineering (civil and structural)	9	3	2
General contractors	28	2	3
Project management	15	2	3
Utilities and transportation	2	2	2
Insurance and emergency management	23	4	2
Property developer	8	1	1
Trade representation	6	0	0
Urban planning	4	1	1
Total	102	17	16

Figure 117
Respondent Numbers
Source: Bosher, Lee and Dainty, Andrew and Carrillo, Patricia and Glass, Jacqueline. *Built In Resilience to Disasters: A Pre-Emptive Approach.* In Engineering, Construction and Architectural Management, Emerald Group Publishing Ltd., United Kingdom, 2007, vol 14, no 5, p 438.

The results can be understood via tables showing where key stakeholders should provide disaster risk management input (see Figures 118 and 119).

[nn] Bosher, Lee and Dainty, Andrew and Carrillo, Patricia and Glass, Jacqueline. *Built In Resilience to Disasters: A Pre-Emptive Approach.* In Engineering, Construction and Architectural Management, Emerald Group Publishing Ltd., United Kingdom, 2007, vol 14, no 5, p 435.

Stakeholder input		Stakeholder input		Stakeholder input		Stakeholder input	
Preliminary phase	Percentage input	Pre-construction phase	Percentage input	Construction phase	Percentage input	Post-completion phase	Percentage input
Urban planners/designers	75[a]	Architects/designers	95[a]	Civil engineers	75[a]	Client	72[b]
Client	75[a]	Civil engineers	75[a]	Architects/designers	67[b]	Insurers	72[b]
Civil engineers	69[b]	Specialist contractors	75[a]	Engineering consultant	66[b]	End user	72[b]
Developers	64[b]	Structural engineers	70[b]	Contractors	63[b]	Utilities companies	69[b]
Emergency/risk managers	59[b]	Engineering consultant	68[b]	Structural engineers	59[b]	Emergency/risk managers	66[b]
Architects/designers	55[b]	Developers	67[b]	Utilities companies	55[b]	Emergency services	64[b]
Utilities companies	45[c]	Contractors	63[b]	Developers	53[b]	Developers	58[b]
Local authorities	41[c]	Client	58[b]	Specialist contractors	53[b]	Structural engineers	53[b]
Engineering consultant	41[c]	Quantity surveyors	58[b]	Client	50[b]	Government agencies	53[b]
Structural engineers	39[c]	Urban planners/designers	52[b]	Emergency/risk managers	47[b]	Contractors	52[b]
End user	34[c]	Emergency/risk managers	50[b]	Emergency services	42[b]	Architects/designers	50[b]
Emergency services	34[c]	Materials supplier	49[c]	Quantity surveyors	39[b]	Civil engineers	47[c]
Specialist contractors	31[c]	Local authorities	47[c]	Materials supplier	38[b]	Local authorities	47[c]
Professional organizations/institutions	28[c]	Utilities companies	46[c]	Urban planners/designers	22[d]	Urban planners/designers	44[c]
Government agencies	28[c]	Emergency services	42[c]	Local authorities	22[d]	Engineering consultant	41[c]
Insurers	19[d]	Government agencies	41[c]	Government agencies	20[d]	Specialist contractors	38[c]
General public	19[d]	Insurers	38[c]	Insurers	19[d]	General public	33[c]
Contractors	17[d]	End user	27[c]	General public	14[d]	Materials supplier	25[c]
Trade organization/representation	16[d]	Professional organizations/institutions	27[c]	Professional organizations/institutions	13[d]	Professional organizations/institutions	25[c]
Materials supplier	11[d]	Trade organization/representation	27[c]	End user	9[d]	Trade organization/representation	19[d]
Quantity surveyors	8[d]	General public	17[d]	Trade organization/representation	9[d]	Quantity surveyors	6[d]

Notes: [a]Formal specified input; [b]formal open/unspecified input; [c]informal input; [d]no input required

Figure 118

The Phases when Key Stakeholders Should Provide Disaster Risk Management-related Inputs

Source: Bosher, Lee and Dainty, Andrew and Carrillo, Patricia and Glass, Jacqueline. *Built In Resilience to Disasters: A Pre-Emptive Approach.* In Engineering, Construction and Architectural Management, Emerald Group Publishing Ltd., United Kingdom, 2007, vol 14, no 5, p 442.

Phase of DCOP	Formal specified input (stage of optimal input indicated in parentheses)	Formal unspecified input (stage of optimal input indicated in parentheses)
Preliminary (four stages, 1-4)	Urban planners/designers (1, 2, 3) Client (1, 2, 3) Developers (3) Civil engineers (4)	Emergency/risk managers (all) Architects/designers (2-4) Utilities companies (3, 4) Structural engineers (4) Local authorities (3, 4) Emergency services (3, 4)
Pre-construction (six stages, 5-10)	Architects/designers (5-9) Engineering consultant (5-8) Structural engineers (5-7) Specialist contractors (5-7) Urban planners/designers (5-7) Civil engineers (5-7) Emergency/risk managers (5-7) Local authorities (5-7) Developers (5-6) Contractors (8-10) Materials supplier (8-9) Client (6) Utilities companies (6) Quantity surveyor (9)	Emergency services (6-8) End user (7) Government agencies (5) Professional organisations/ institutions (5) Insurers (8)
Construction (four stages, 11-14)	Architects/designers (11, 13) Civil engineers (11, 12) Engineering consultant (11, 12) Contractors (11, 12) Utilities companies (12) Specialist contractors (12) Structural engineers (12)	Client (12) Materials supplier (12) Emergency/risk managers (12) Developers (13) Emergency services (14)
Post-completion (four stages, 15-18)	Insurers (15, 17, 18) Utilities companies (16, 17) Client (15, 18) End user (15, 16) Architects/designers (15) Emergency/risk managers (18) Emergency services (18) Developers (18) Urban planners/designers (18)	Contractors (15, 17, 18) Structural engineers (15, 18) Government agencies (17, 18)

Figure 119
Summary of the Key Stakeholders that Should be Involved and Where Inputs Should be Made
Source: Bosher, Lee and Dainty, Andrew and Carrillo, Patricia and Glass, Jacqueline. *Built In Resilience to Disasters: A Pre-Emptive Approach.* In Engineering, Construction and Architectural Management, Emerald Group Publishing Ltd., United Kingdom, 2007, vol 14, no 5, p 443.

This study emphasises that resilience of the built environment should be "systematically built into the planning, design, construction and operation processes."[oo] Thus, the study relates to this report by its focus on pre-planning, understanding of rick and tailored construction solutions, all of which operate closely with seismic retrofit of dwelling foundations in New Zealand.

Building Research Association of New Zealand. *Subfloor Bracing for Single Storey Light Timber Frame Buildings.* Building Research Association of New Zealand, Judgeford, 1984, Technical Recommendation no 5.

[oo] Bosher, Lee and Dainty, Andrew and Carrillo, Patricia and Glass, Jacqueline. *Built In Resilience to Disasters: A Pre-Emptive Approach.* In Engineering, Construction and Architectural Management, Emerald Group Publishing Ltd., United Kingdom, 2007, vol 14, no 5, p 444.

This technical recommendation covers varying aspects of bracing, its requirements and implementation, which is crucial to withstand earthquakes. The document outlines the buildings to which this bracing is applicable and then covers the specification of braces including subfloor bracing construction; required amount of subfloor bracing; location of subfloor braces; and attic room construction. Tables are given to enable proper bracing implementation (see Figure 120) and possible layouts suggested for when floor diaphragms are present and not present (see Figures 121 and 122).

Earthquake zone	Roof type	Average slope of roof$^{(o)}$ (see Figure 2)	Number of subfloor braces in each direction for a ground floor area (m^2) not exceeding:									
			50	60	70	80	90	100	120	140	160	180
A	Light	0-60	3	4	4	5	6	6	7	9	10	11
	Heavy	0-25	3	4	5	5	6	7	8	9	11	12
		26-45	4	5	5	6	7	7	9	11	12	13
		46-60	4	5	6	7	8	9	10	12	14	15
B	Light	0-60	3	3	4	4	5	5	6	7	8	9
	Heavy	0-25	3	3	4	4	5	5	7	8	9	10
		26-45	3	4	4	5	6	6	7	9	10	11
		46-60	4	4	5	6	6	7	9	10	11	13
C	Light	0-60	2	3	3	3	4	4	5	6	7	7
	Heavy	0-25	2	3	3	4	4	4	5	6	7	8
		26-45	3	3	4	4	5	5	6	7	8	9
		46-60	3	4	4	5	5	6	7	8	9	10

Figure 120
Number of Subfloor Braces for Earthquake 1.5kPa Floor Live Load
Source: Building Research Association of New Zealand. *Subfloor Bracing for Single Storey Light Timber Frame Buildings.* Building Research Association of New Zealand, Judgeford, 1984, Technical Recommendation no 5, p 4.

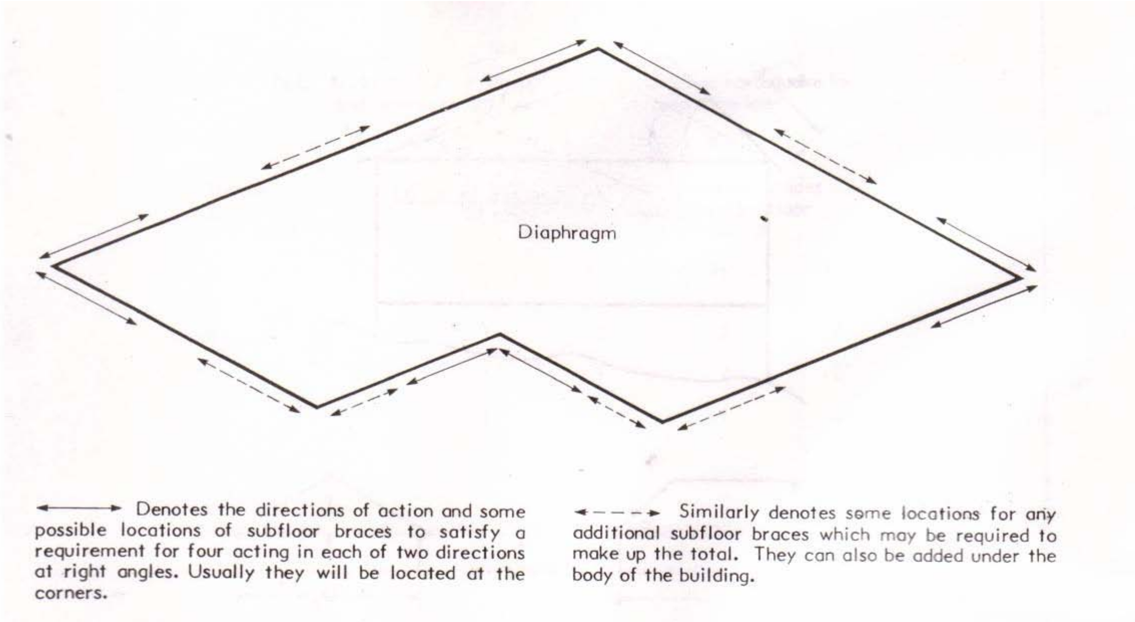


Figure 121
Example of Location of Subfloor Braces when a Floor Diaphragm is Used
Source: Building Research Association of New Zealand. *Subfloor Bracing for Single Storey Light Timber Frame Buildings.* Building Research Association of New Zealand, Judgeford, 1984, Technical Recommendation no 5, p 8.

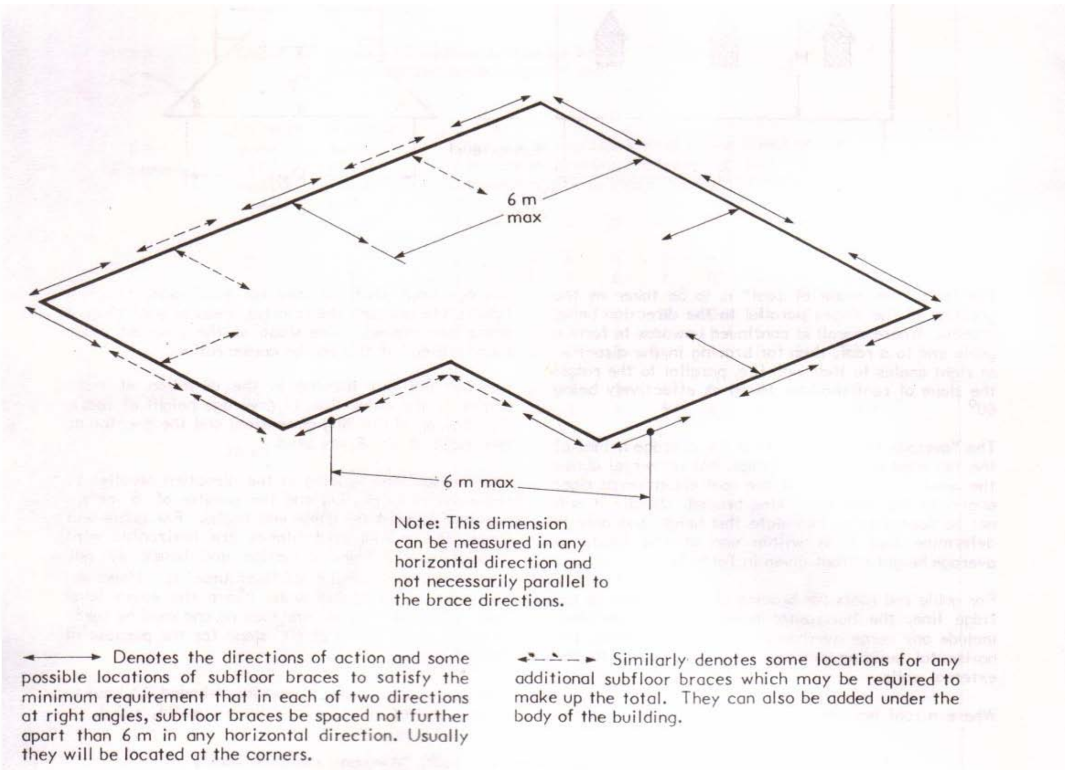
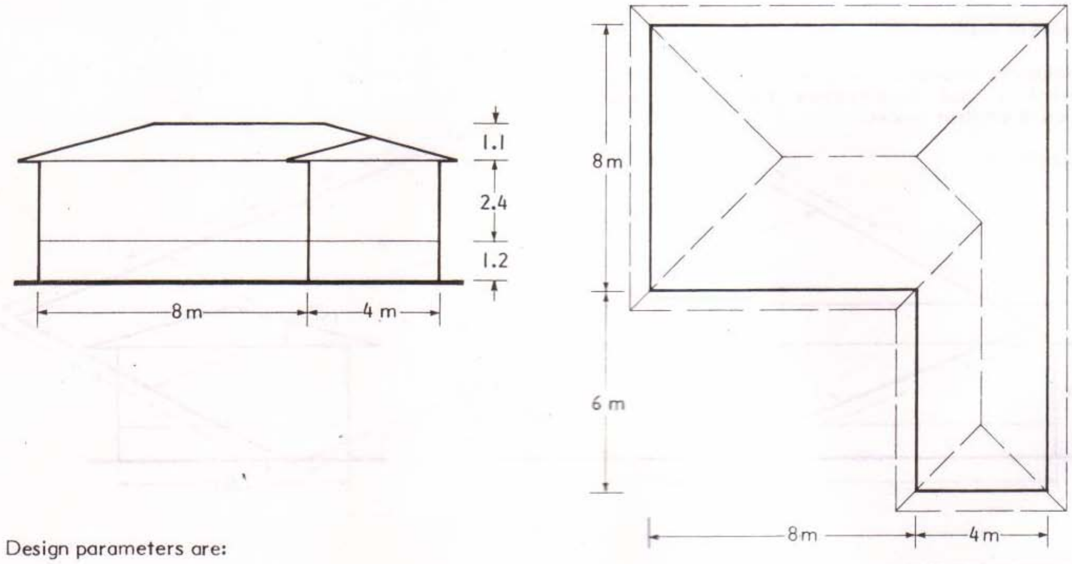


Figure 122
Example of Location of Subfloor Braces when a Floor Diaphragm is Not Used
Source: Building Research Association of New Zealand. *Subfloor Bracing for Single Storey Light Timber Frame Buildings.* Building Research Association of New Zealand, Judgeford, 1984, Technical Recommendation no 5, p 8.

Thorough worked examples follow this, showing how the given tables and resources can be applied to correctly brace a dwelling (see Figure 123).



Design parameters are:

Earthquake zone:	A
Roof type:	heavy
Average slope of roof:	15°
Floor area:	120 m²
Floor design live load:	1.5 kPa
Wind exposure:	high
Maximum slope of roof:	15° (all directions)
Horizontal building dimensions:	12 m and 14 m
Average height of roof:	less than 1.0 m
Floor decking:	either sheet material or tongue and groove boarding

From Table 1 the number of subfloor braces required in each direction for earthquake is 8 (using "A", "Heavy", "0°-25°", and "120").

From Table 5 the number of subfloor braces required is: 5 for bracing at right angles to the 12 m dimension(using "High", "0°-25°", "1", and "12"); and 6 for bracing at right angles to the 14 m dimension (using "High", "0°-25°", "1", and "14").

The requirement is therefore a minimum of 8 in each direction (earthquake governs).

10

Figure 123
Example of Bracing Design
Source: Building Research Association of New Zealand. *Subfloor Bracing for Single Storey Light Timber Frame Buildings.* Building Research Association of New Zealand, Judgeford, 1984, Technical Recommendation no 5, p 10.

This resource is relevant both in a new build and a retrofit as it allows one to assess the need for and placement of bracing. This is clearly communicated and able to be applied by the user. This is relevant to this report in that it enables the assessment of current bracing of a dwelling and whether retrofit measures may be necessary.

Burdon, Nigel and Kueh, Hsueh-Lynn and McMannus, Kevin J. *Design of Foundations to resist Shear during Earthquakes.* University of Canterbury, Christchurch, 2004.

This report seeks to develop a uniform approach to resisting base shear when designing structures. The study conducted investigated the behaviour of three foundation systems: slab on grade; slab on grade with two parallel foundation beams; and a slab and beam foundation interacting with a pile;

under lateral loading and noted the characteristics which began to develop. Following this a general design approach outline is defined. Although most useful in a new build rather than a retrofit construction, the study yields valuable information on the construction of these foundation types, the importance of their connections and the quality of construction, all of which are paramount in the retrofitting of foundation and subfloor details also.

Camli, Unut Serdar and Binici, Baris. *Strength of Carbon Fibre Reinforced Polymers Bonded to Concrete and Masonry.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2007, vol 22, pp 1431-1446.

This article reports on a study where fifty seven double shear push out tests were conducted to determine the strength of carbon fibre reinforced polymers which were bonded to concrete prisms and hollow tiles. Differing types of anchorage methods were tested. The test method is outlined, utilising low and normal strength concrete in blocks and tiles (see Figure 124).

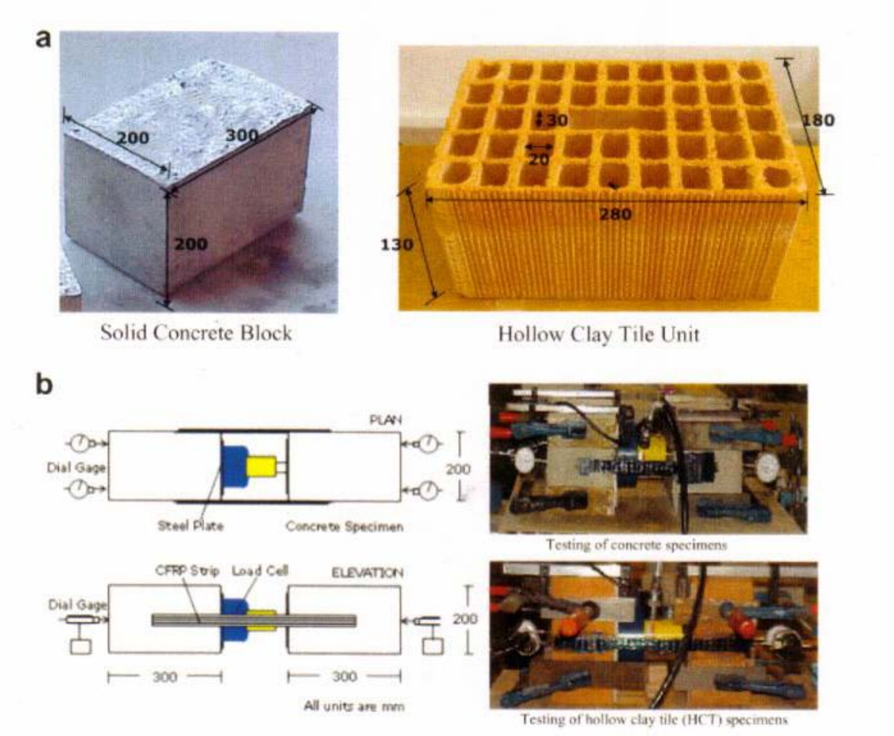


Figure 124
Specimens and Test Setup
Source: Camli, Unut Serdar and Binici, Baris. *Strength of Carbon Fibre Reinforced Polymers Bonded to Concrete and Masonry*. In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2007, vol 22, p 1433.

Te test included strip type anchors, embedded type anchors and fan type anchors. The study concludes that bond strength is sensitive to anchorage length and width over concrete or tile compressive strength[pp] and the presence of a layer of plaster decreased the capacity of these anchors.[qq] Although this study does not directly focus on retrofit details in line with this report, it

[pp] Camli, Unut Serdar and Binici, Baris. *Strength of Carbon Fibre Reinforced Polymers Bonded to Concrete and Masonry*. In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2007, vol 22, p 1444.
[qq] Camli, Unut Serdar and Binici, Baris. *Strength of Carbon Fibre Reinforced Polymers Bonded to Concrete and Masonry*. In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2007, vol 22, p 1444.

does reinforce the importance of connections and the development of retrofit measures as a necessary focus.

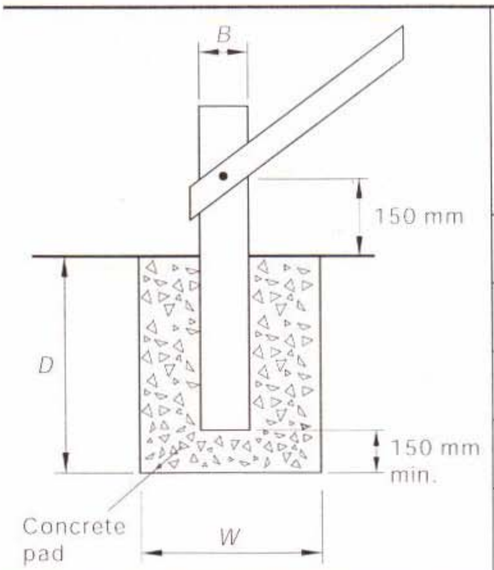
Carpenter, P and Jamieson, N J and Beattie, G J. *Review of Low Cost Passive Damping Systems for Retrofitting Lightweight Buildings and Structures*. Central Laboratories Report 94-29139, Works Consultancy Services Ltd., 1994.

This report examines the use of low cost, passive damping systems which may be used in wind sensitive structures, where additional loads occur as a result of the dynamic interaction of the wind and structure. The dampers are described, including tuned mass dampers, impact dampers, shot dampers and liquid sloshing dampers. A test method is then outlines which aimed to assess the effectiveness of a damper by mounting it on a shaking table. Carpenter, Jamieson and Beattie's report is most useful in the design of larger scale buildings than this report is considering; slender towers, tall chimneys, tall buildings, bridges and lightweight structures such as grandstand roofs are more closely related.

Committee TM-002 Timber Framing. *AS1684.2 Residential Timber-Framed Construction: Part 2 Non-Cyclonic Areas.* Standards Australia, Australia, 2006.

> **Committee TM-002 Timber Framing. *AS1684.3 Residential Timber-Framed Construction: Part 3 Cyclonic Areas.* Standards Australia, Australia, 2006.**
> **Committee TM-002 Timber Framing. *AS1684.4 Residential Timber-Framed Construction: Part 4 Simplified Non-Cyclonic Areas.* Standards Australia, Australia, 2006.**

These three Australia Standards have been analysed together as each is a slightly varied version of the other. Each is divided into nine sections covering building elements such as substructure; floor framing; wall framing; roof framing; and fixing and tie down design. Within the section on substructure, areas such as soil classification; ventilation; and bracing are covered. Braced timber stumps are detailed (see Figures 125 and 126) which are specified further with tables depending on soil classification. Timber braces on masonry or timber columns are also detailed (see Figure 127) which is a situation common in New Zealand dwellings. The bolted fixings are ideal for retrofitting.



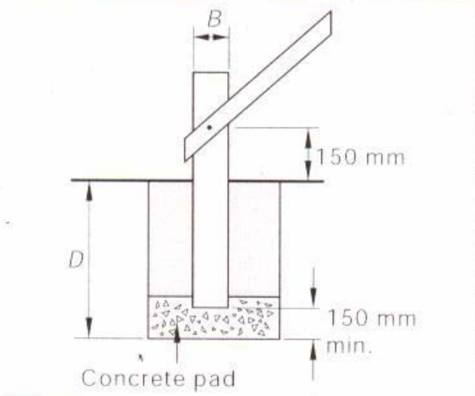
Concrete pier diameter *W* (mm)	Concrete depth *D* (mm) 400	600	800	1000
	Bracing capacity per stump *H* (kN)			
250	6.0	10	15	19
300	7.2	12	18	23
350	8.4	14	21	27
400	9.6	16	23	31
450	11	19	26	35

NOTES:

1 This Table is suitable for wind classification up to N3.

2 Footing size needs also to be assessed for bearing (see Clause 3.6).

Figure 125
Bracing Capacity of Diagonally Braced Stump In Concrete Backfill
Source: Committee TM-002 Timber Framing. *AS1684.2 Residential Timber-Framed Construction: Part 2 Non-Cyclonic Areas.* Standards Australia, Australia, 2006, p 126.



Stump diameter *B* (mm)	Depth of stump into ground *D* (mm) 400	600	800	1000
	Bracing capacity per stump *H* (kN)			
100	3.3	5.4	7.7	9.9
125	4.1	6.8	9.5	12
150	5.0	8.1	11	15
200	6.6	11	15	20

NOTES:

1 This Table is suitable for wind classification up to N3.

2 Footing size needs also to be assessed for bearing (see Clause 3.6).

Figure 126
Bracing Capacity of Diagonally Braced Stump In Soil Backfill
Source: Committee TM-002 Timber Framing. *AS1684.2 Residential Timber-Framed Construction: Part 2 Non-Cyclonic Areas.* Standards Australia, Australia, 2006, p 126.

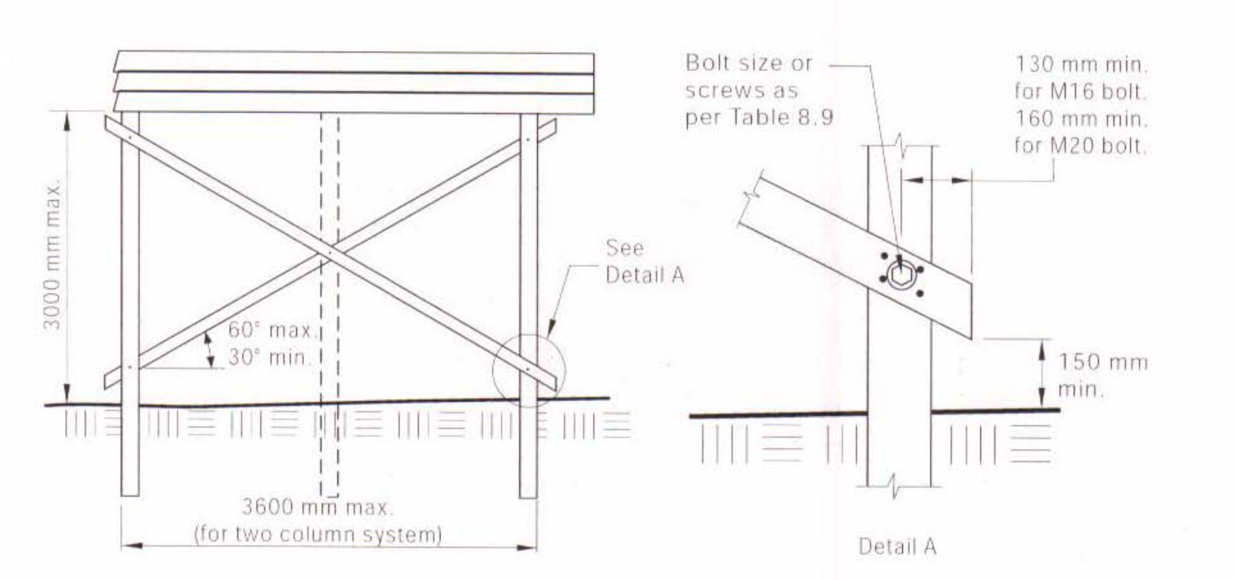


Figure 127
Timber Braces on Masonry or Timber Columns
Source: Committee TM-002 Timber Framing. *AS1684.2 Residential Timber-Framed Construction: Part 2 Non-Cyclonic Areas.* Standards Australia, Australia, 2006, p 127.

Bracing columns are then detailed (see Figure 128) which are used for transferring racking forces to the foundation.

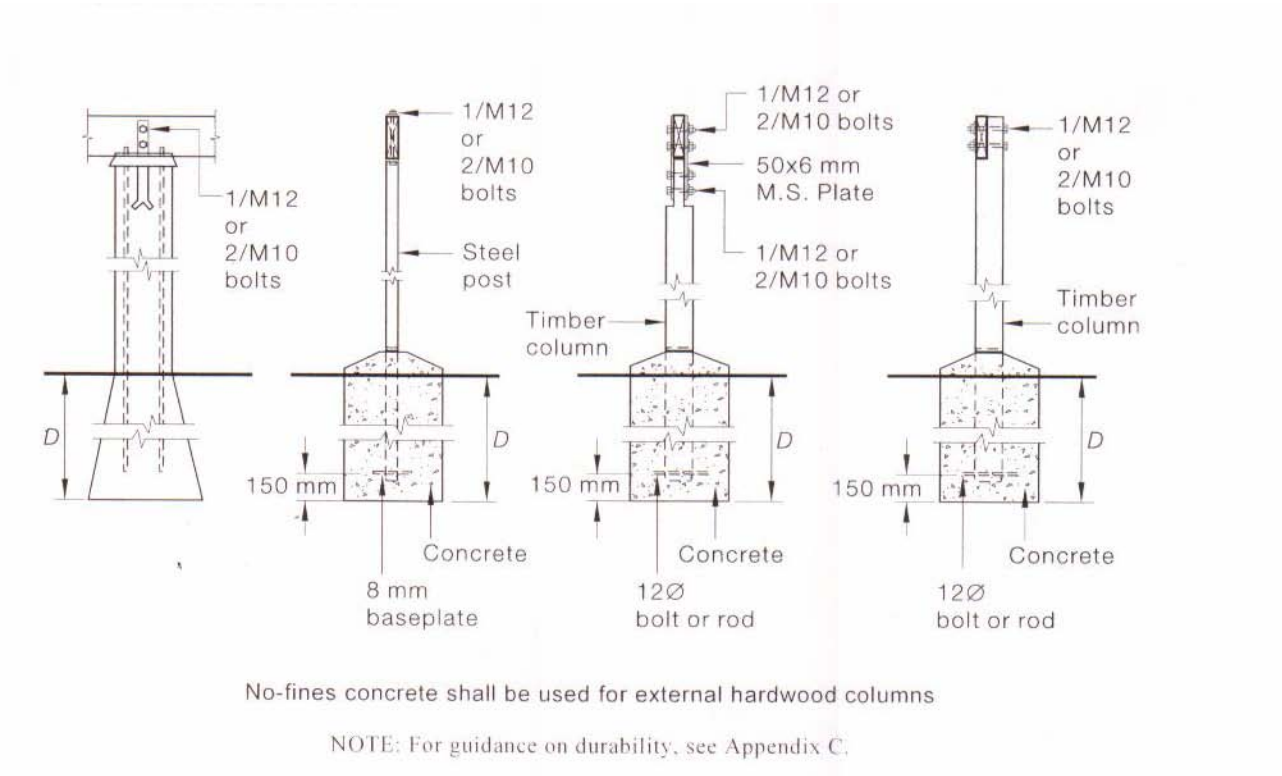
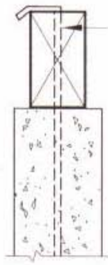
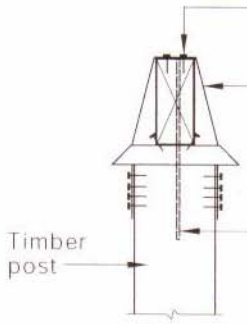
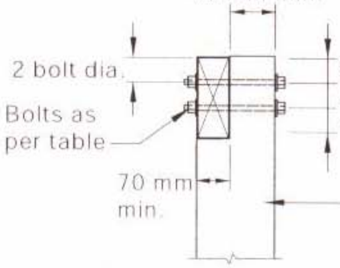
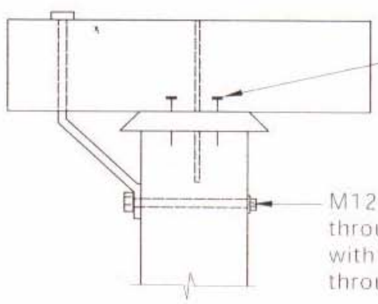


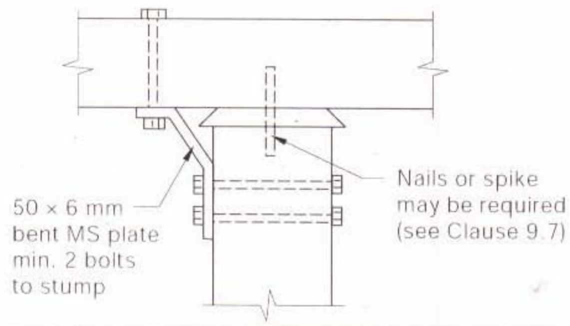
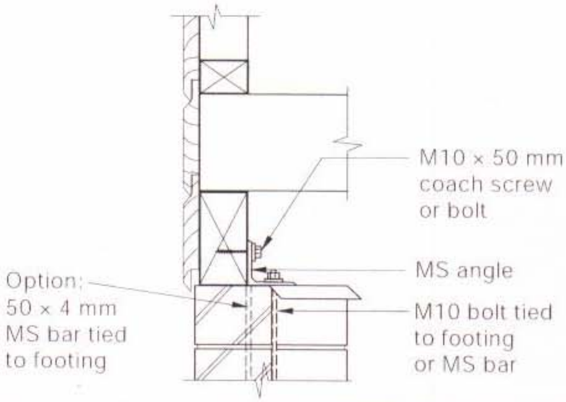
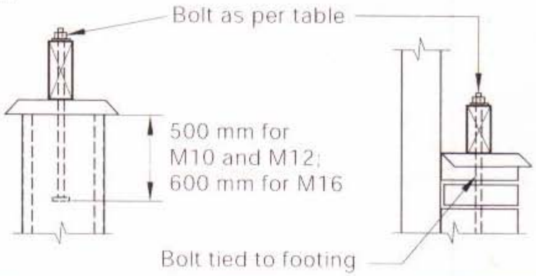
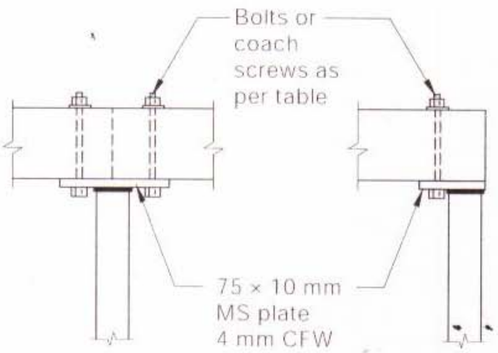
Figure 128
Concrete, Masonry and Steel Bracing Columns
Source: Committee TM-002 Timber Framing. *AS1684.2 Residential Timber-Framed Construction: Part 2 Non-Cyclonic Areas.* Standards Australia, Australia, 2006, p 138.

Bearer tie down connectors are detailed in the section on fixings and tie down design (see Figures 129, 130, 131 and 132), with their uplift capacity noted. This may be relevant to seismic design here in New Zealand dwellings.

Position of tie-down connection	Uplift capacity (kN)					
	Unseasoned timber			Seasoned timber		
Bearers to stumps, posts, piers	**J2**	**J3**	**J4**	**JD4**	**JD5**	**JD6**
(a)  6 mm rod cast into concrete stump and bent over bearer at top	1.0	1.0	1.0	1.0	1.0	1.0
(b)  2/2.8 mm Ø nails; 30 0.8 mm G.I. strap as per table nailed with 2.8 mm Ø nails; Timber post; Nails or spike may be required (see Clause 9.7)	1 strap with 4 nails each end					
	9.9	7.1	5.0	7.1	5.8	4.4
	2 strap with 4 nails each end					
	17	12	8.4	12	9.7	7.4
	1 strap with 6 nails each end					
	13	9.3	6.6	9.3	7.6	5.8
	2 strap with 6 nails each end					
	23	17	12	17	14	10
(c)  70 mm min.; 2 bolt dia.; Bolts as per table; 6 bolt dia.; 5 bolt dia.; 4 bolt dia.; 70 mm min.; Timber post — No. of bolts						
1/M10	5.7	5.2	3.6	5.2	4.5	3.9
1/M12	8.1	6.8	4.7	7.4	6.4	5
2/M10	13	10	7.3	12	11	8.3
2/M12	17	14	9.4	17	14	10
2/M16	26	20	14	27	20	13
(d)  Nails or spikes may be required (see Clause 9.7); M12 cranked bolt through bearer with M12 bolt through stump	2	2	2	2	2	2

(continued)

Figure 129
Uplift Capacity of Bearer Tie Down Connections
Source: Committee TM-002 Timber Framing. *AS1684.2 Residential Timber-Framed Construction: Part 2 Non-Cyclonic Areas.* Standards Australia, Australia, 2006, p 182.

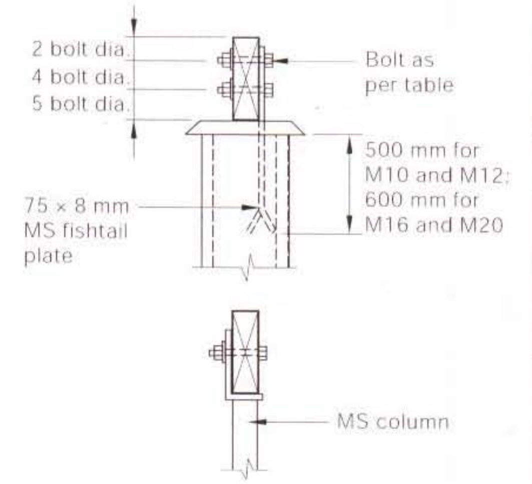
<table>
<tr><th rowspan="2" colspan="2">Position of tie-down connection</th><th colspan="6">Uplift capacity (kN)</th></tr>
<tr><th colspan="3">Unseasoned timber</th><th colspan="3">Seasoned timber</th></tr>
<tr><th colspan="2">Bearers to stumps, posts, piers</th><th>J2</th><th>J3</th><th>J4</th><th>JD4</th><th>JD5</th><th>JD6</th></tr>
<tr><td colspan="2">(e)

</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td></tr>
<tr><td colspan="2">(f)

</td><td>5.5</td><td>3.1</td><td>1.6</td><td>3.2</td><td>1.8</td><td>1</td></tr>
<tr><td rowspan="4">(g)

</td><td colspan="7">Bolts</td></tr>
<tr><td>M10</td><td>18</td><td>18</td><td>18</td><td>15</td><td>12</td><td>9</td></tr>
<tr><td>M12</td><td>27</td><td>27</td><td>26</td><td>20</td><td>16</td><td>12</td></tr>
<tr><td>M16</td><td>50</td><td>50</td><td>46</td><td>35</td><td>28</td><td>21</td></tr>
<tr><td rowspan="10">(h)

</td><td colspan="7">No. of bolts</td></tr>
<tr><td>1/M10</td><td>18</td><td>18</td><td>18</td><td>15</td><td>12</td><td>9</td></tr>
<tr><td>1/M12</td><td>27</td><td>27</td><td>26</td><td>20</td><td>16</td><td>12</td></tr>
<tr><td>2/M10</td><td>36</td><td>36</td><td>36</td><td>30</td><td>24</td><td>18</td></tr>
<tr><td>2/M12</td><td>54</td><td>54</td><td>52</td><td>40</td><td>32</td><td>24</td></tr>
<tr><td colspan="7">No. of coach screw (75 mm min.)</td></tr>
<tr><td>1/M10</td><td>7.5</td><td>5.5</td><td>3.7</td><td>4.7</td><td>3.6</td><td>2.6</td></tr>
<tr><td>1/M12</td><td>8.2</td><td>6.0</td><td>4.0</td><td>5.0</td><td>4.2</td><td>3.0</td></tr>
<tr><td>2/M10</td><td>15</td><td>11</td><td>7.4</td><td>9.4</td><td>7.2</td><td>5.2</td></tr>
<tr><td>2/M12</td><td>16</td><td>12</td><td>8.0</td><td>10</td><td>8.4</td><td>6.0</td></tr>
</table>

(continued)

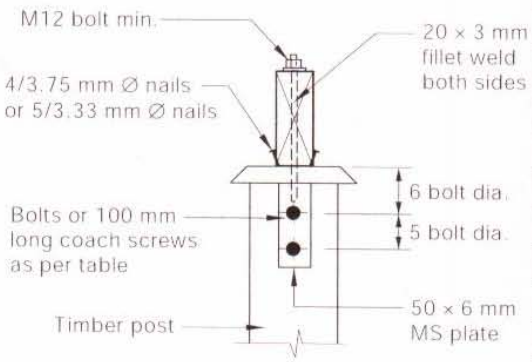
Figure 130
Uplift Capacity of Bearer Tie Down Connections
Source: Committee TM-002 Timber Framing. *AS1684.2 Residential Timber-Framed Construction: Part 2 Non-Cyclonic Areas.* Standards Australia, Australia, 2006, p 183.

Position of tie-down connection		Uplift capacity (kN)					
		Unseasoned timber			Seasoned timber		
Bearers to stumps, posts, piers		J2	J3	J4	JD4	JD5	JD6
(i)	Bolts						
	1/M10	7.7	6.2	4.4	7.9	6.3	5.0
	1/M12	10	8.2	5.7	10	8.3	6.0
	1/M16	16	12	8.6	16	12	8.0
	2/M10	15	12	8.8	16	13	9.9
	2/M12	21	16	11	21	17	12
	2/M16	32	24	17	32	24	16
(j)	No. of bolts						
	1/M10	9.1	8.3	6.6	8.3	7.3	6.2
	1/M12	13	12	9.5	12	10	9.1
	2/M10	18	17	13	17	15	12
	2/M12	26	24	19	20	16	12
	2/M16	27	27	26	20	16	12
	No. of coach screws						
	1/M10	9.1	8.3	6.6	8.3	7.3	5.1
	1/M12	13	12	7.9	12	8.5	6.3
	2/M10	18	17	13	17	15	10
	2/M12	26	24	16	20	16	12
	2/M16	27	27	21	20	16	12
(k)	No. of bolts						
	1/M10	9.1	8.3	6.6	8.3	7.3	6.2
	1/M12	13	12	9.5	12	10	9.1
	2/M10	18	17	13	17	15	12
	2/M12	26	24	19	20	16	12
	2/M16	27	27	26	20	16	12
	No. of coach screws						
	1/M10	9.1	8.3	6.6	8.3	7.3	5.1
	1/M12	13	12	7.9	12	8.5	6.3
	2/M10	18	17	13	17	15	10
	2/M12	26	24	16	20	16	12
	2/M16	27	27	21	20	16	12

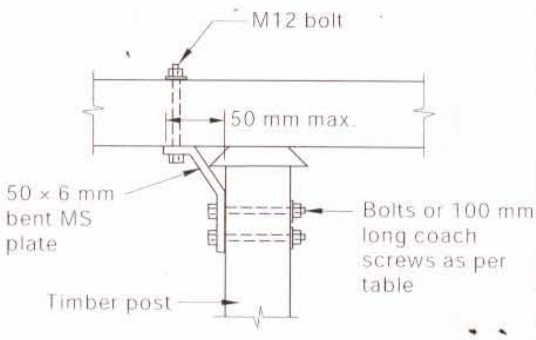
(i)



(j)



(k)



(*continued*)

Figure 131
Uplift Capacity of Bearer Tie Down Connections
Source: Committee TM-002 Timber Framing. *AS1684.2 Residential Timber-Framed Construction: Part 2 Non-Cyclonic Areas.* Standards Australia, Australia, 2006, p 184.

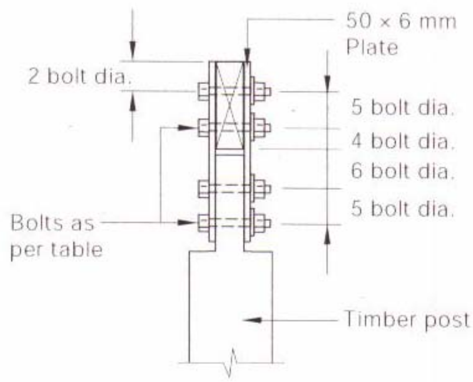
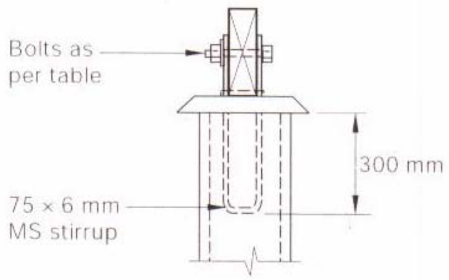
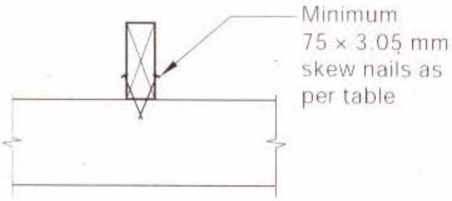
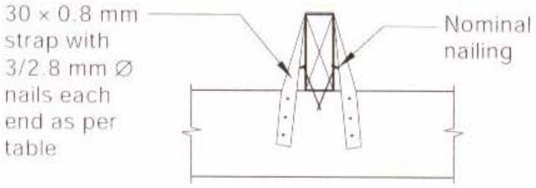
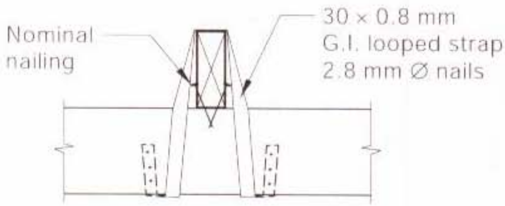
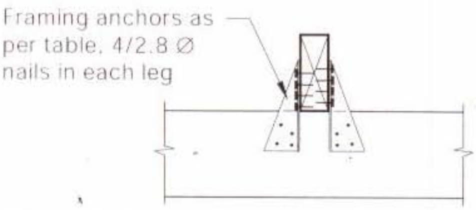
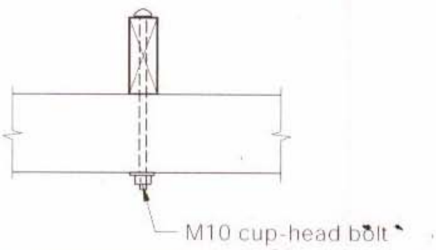
Position of tie-down connection		Uplift capacity (kN)					
		Unseasoned timber			Seasoned timber		
Bearers to stumps, posts, piers		J2	J3	J4	JD4	JD5	JD6
(l) 	No. of bolts						
	2/M10	31	20	13	20	14	9.8
	2/M12	36	23	15	24	17	12
	2/M16	49	31	20	33	23	16
(m) 	No. of bolts						
	M10	14	9.8	6.3	10	7.3	4.9
	M12	18	12	7.5	12	8.7	6.1
	M16	24	16	9.8	17	12	8

Figure 132
Uplift Capacity of Bearer Tie Down Connections
Source: Committee TM-002 Timber Framing. *AS1684.2 Residential Timber-Framed Construction: Part 2 Non-Cyclonic Areas.* Standards Australia, Australia, 2006, p 185.

The joist tie down connections are detailed following this (see Figures 133 and 134).

Position of tie-down connection		Uplift capacity (kN)					
		Unseasoned timber			Seasoned timber		
Floor joists to bearers or top plates		**J2***	**J3**	**J4**	**JD4**	**JD5**	**JD6**
(a) 	No. of nails	Glue-coated or deformed shank machine-driven nails shall be used.					
	2	1.5	1.2	1.1	0.77	0.50	0.36
	3	2.2	1.8	1.6	1.1	0.75	0.55
	4	3.0	2.4	2.2	1.5	1.0	0.72
(b) 	No. of straps						
	1	6.5	4.7	3.3	4.7	3.8	2.9
	2	12	8.4	5.9	8.4	6.9	5.2
(c)  Nails required for each end of looped strap: 3/2.8 mm Ø for J2 4/2.8 mm Ø for J3 and JD4 5/2.8 mm Ø for J4, JD5 and JD6		13	13	13	13	13	13
(d) 	No. of framing anchors						
	1	4.9	3.5	2.5	3.5	2.9	2.2
	2	8.3	5.9	4.2	5.9	4.9	3.7
	3	12	8.4	5.9	8.4	6.9	5.2
	4	15	11	7.7	11	8.9	6.8
(e) 		16	14	10	10	7.0	5.0

(continued)

Figure 133
Uplift Capacity of Floor Joist Tie Down Connections
Source: Committee TM-002 Timber Framing. *AS1684.2 Residential Timber-Framed Construction: Part 2 Non-Cyclonic Areas.* Standards Australia, Australia, 2006, p 186.

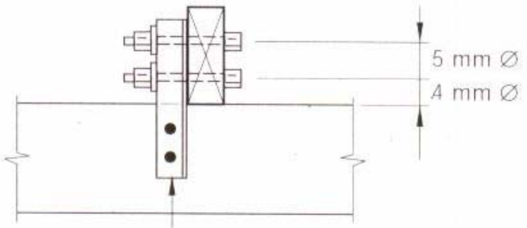
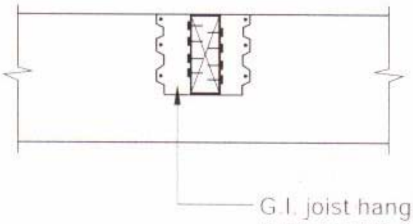
Position of tie-down connection		Uplift capacity (kN)					
		Unseasoned timber			Seasoned timber		
Floor joists to bearers or top plates		J2	J3	J4	JD4	JD5	JD6
(f) 	No. of bolts						
	2/M10	14	9.2	5.9	10	7.3	4.9
	2/M12	18	11	7.0	12	8.7	6.1
	Coach screws						
	2/M10	7	4.6	3.0	5	3.6	2.5
(g) 	No of nails per wing						
	3	6.5	4.7	3.3	4.7	3.8	2.9
	4	8.3	5.9	4.2	5.9	4.9	3.7
	5	9.9	7.1	5	7.1	5.8	4.4
	6	12	8.4	5.9	8.4	6.9	5.2

Figure 134
Uplift Capacity of Floor Joist Tie Down Connections
Source: Committee TM-002 Timber Framing. *AS1684.2 Residential Timber-Framed Construction: Part 2 Non-Cyclonic Areas.* Standards Australia, Australia, 2006, p 187.

This resource gives a comprehensive selection of tables, details and information relevant to residential timber-framed construction in Australia. These details may prove useful to be applied in New Zealand, or altered to best fir New Zealand's unique conditions.

Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures*. BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37.

This technical report explores remedial measures to strengthen dwellings for earthquakes, across four main sections: chimneys, concrete or clay tile roofs, walls, foundations and subfloor framing; and three lesser sections: header tank, hot water cylinder and house contents. Each section is briefly introduced then a series of practical and cost effective remedial measures laid out. The section on foundations and subfloor framing relates most closely to this report. Perimeter foundation walls are first considered, and praised for their qualities of a sound method of construction if "properly connected to the foundation wall."[rr] Should only 4mm wires and staples have been used to connect, as was common practice, remedial measures are recommended (see Figure 135).

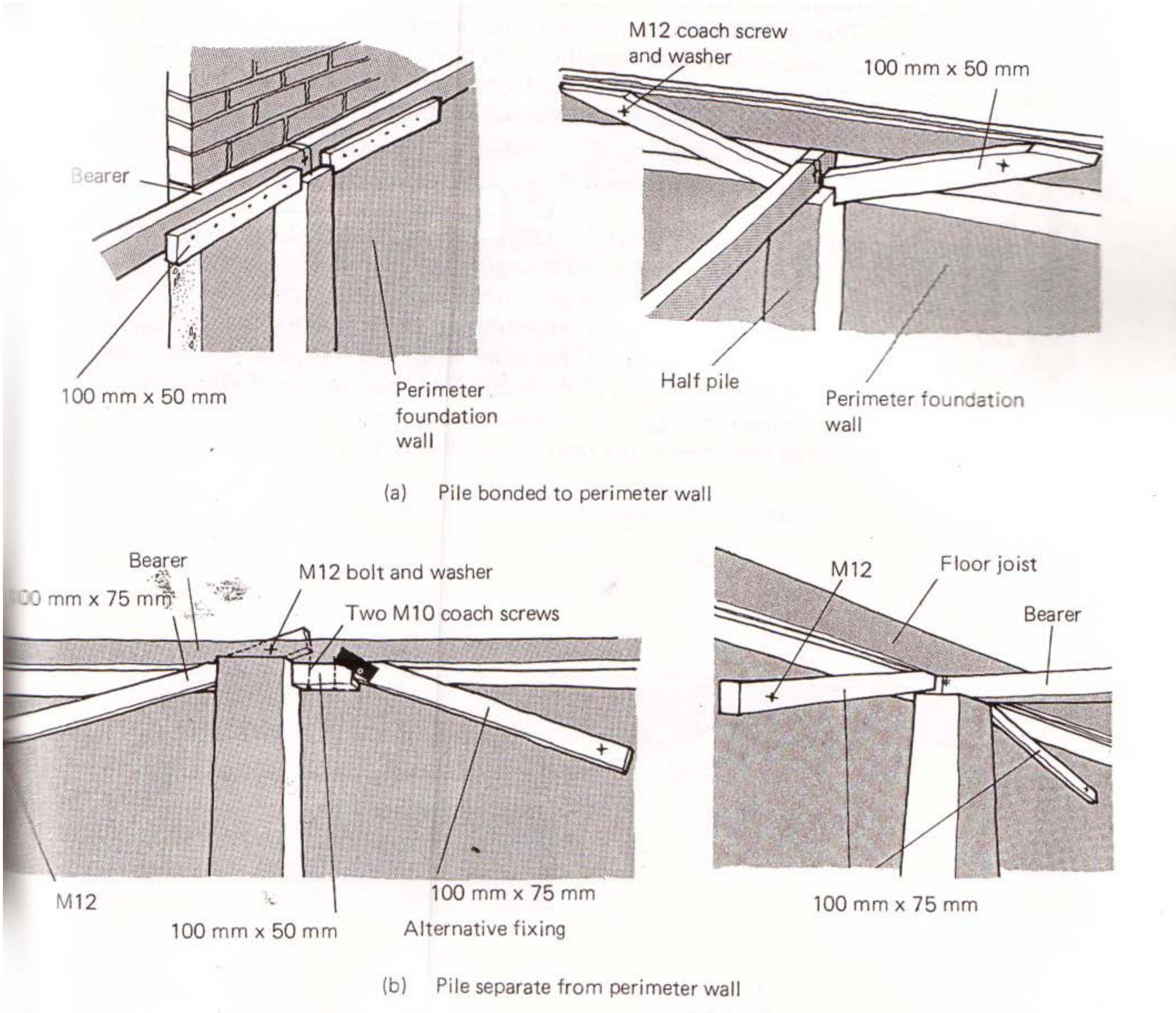


Figure 135
Masonry Veneer Detail; half-pile detail
Source: Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures*. BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37, p 33.

[rr] Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures.* BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37, p 32.

Corner walls and piles are considered second, and again proper connection is essential for its performance. If the leg of the corner foundation running parallel to the floor joist is not connected to the subfloor framing, remedial connections should be considered (see Figure 136 and 137).

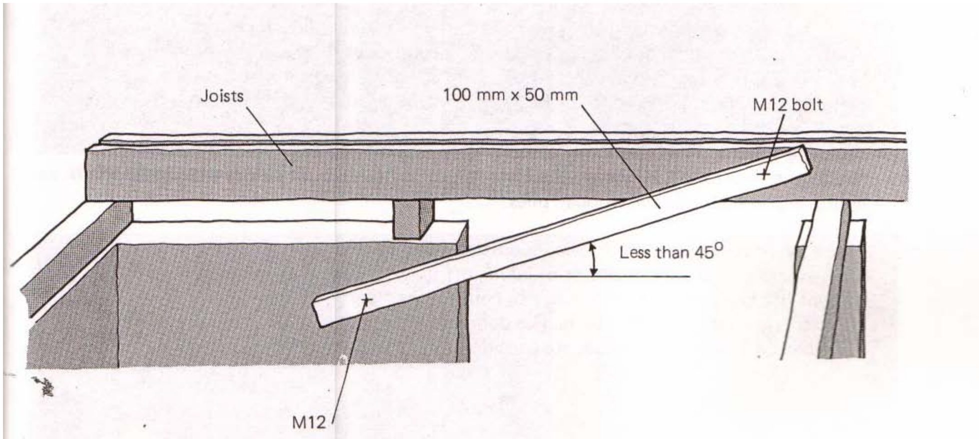


Figure 136
Corner Wall Foundation Remedial Detail
Source: Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures*. BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37, p 35.

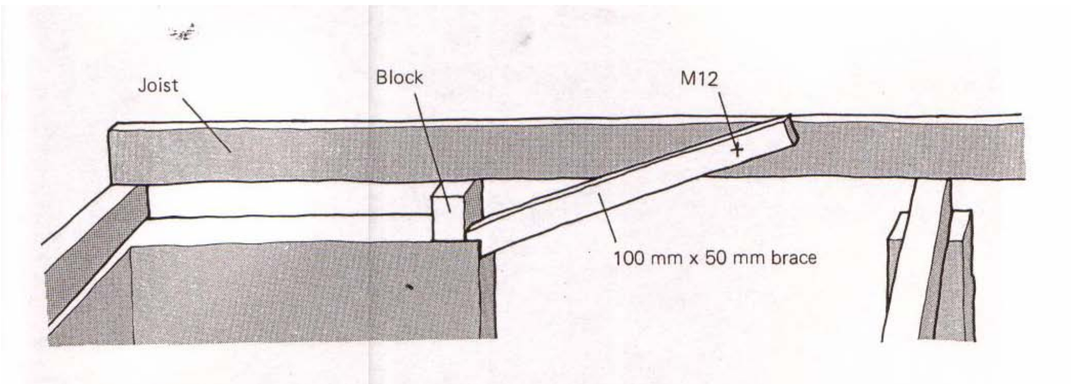


Figure 137
Corner Wall Foundation Remedial Details – To be duplicated at opposing corner wall
Source: Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures*. BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37, p 35.

Piled foundations are considered third; houses on these types of foundations are at risk in a large earthquake of significant sideways movement "or of falling off their foundations altogether."[ss] Remedial measures outlines fall into three subcategories: infill walls, bracing with sheet material and timber jack stud subfloor framing. Infill walls operate in a similar manner to a corner foundation wall and recommendations are given for configuration and placement of infill walls

[ss] Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures.* BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37, p 36.

depending on dwelling design and dimensions. Connections are of paramount consideration and must be executed properly for the ideal functioning of the infill wall (see Figures 138 and 139).

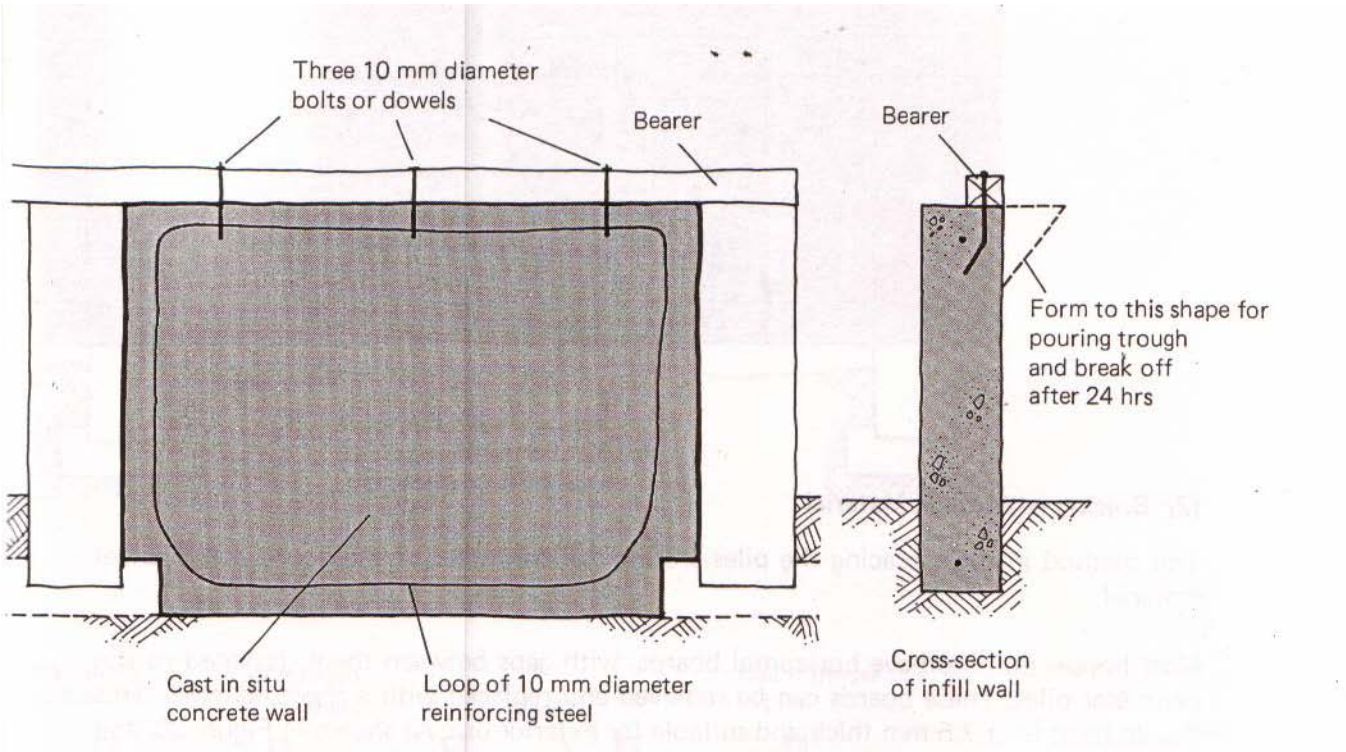


Figure 138
Infill Walls and Connections
Source: Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures*. BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37, p 39.

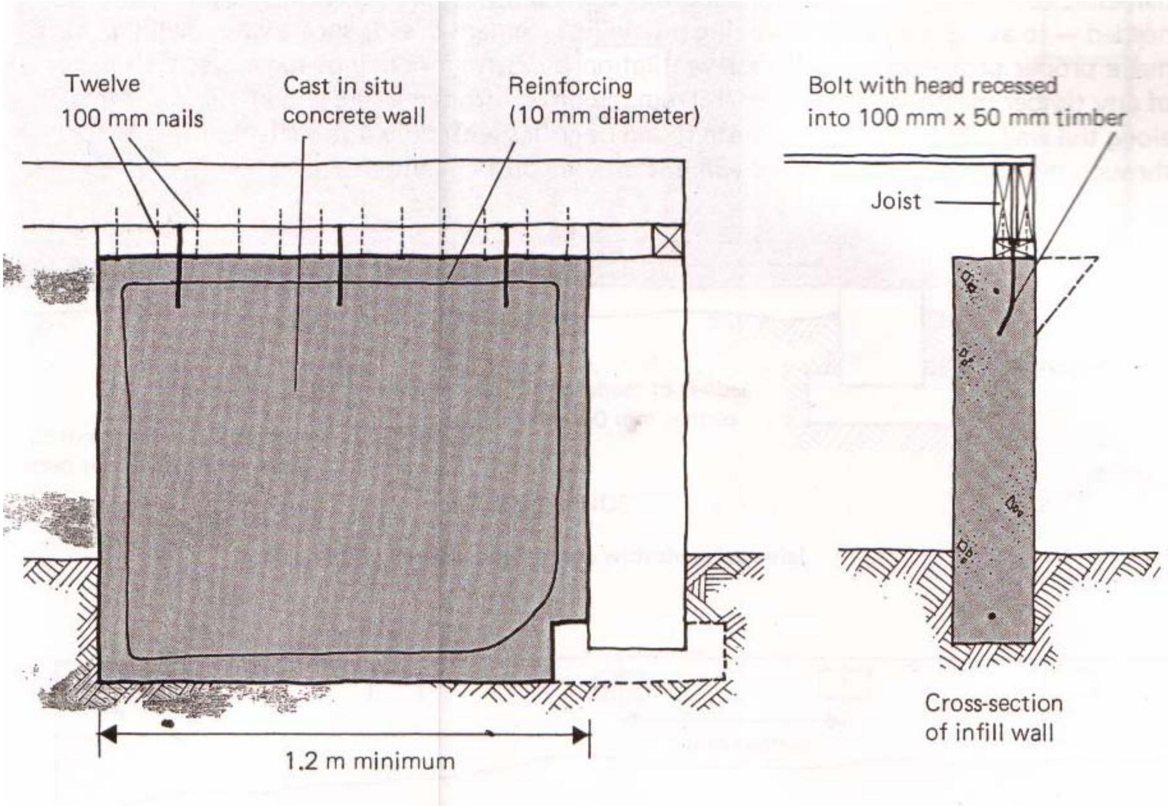


Figure 139
Infill Walls and Connections
Source: Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures*. BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37, p 39.

Bracing with sheet materials occurs between the piles on the perimeter of the house; this is a simple remedial measure to execute but care must be taken to ensure the boards are flush and ventilation may occur to the subfloor (see Figures 140 and 141).

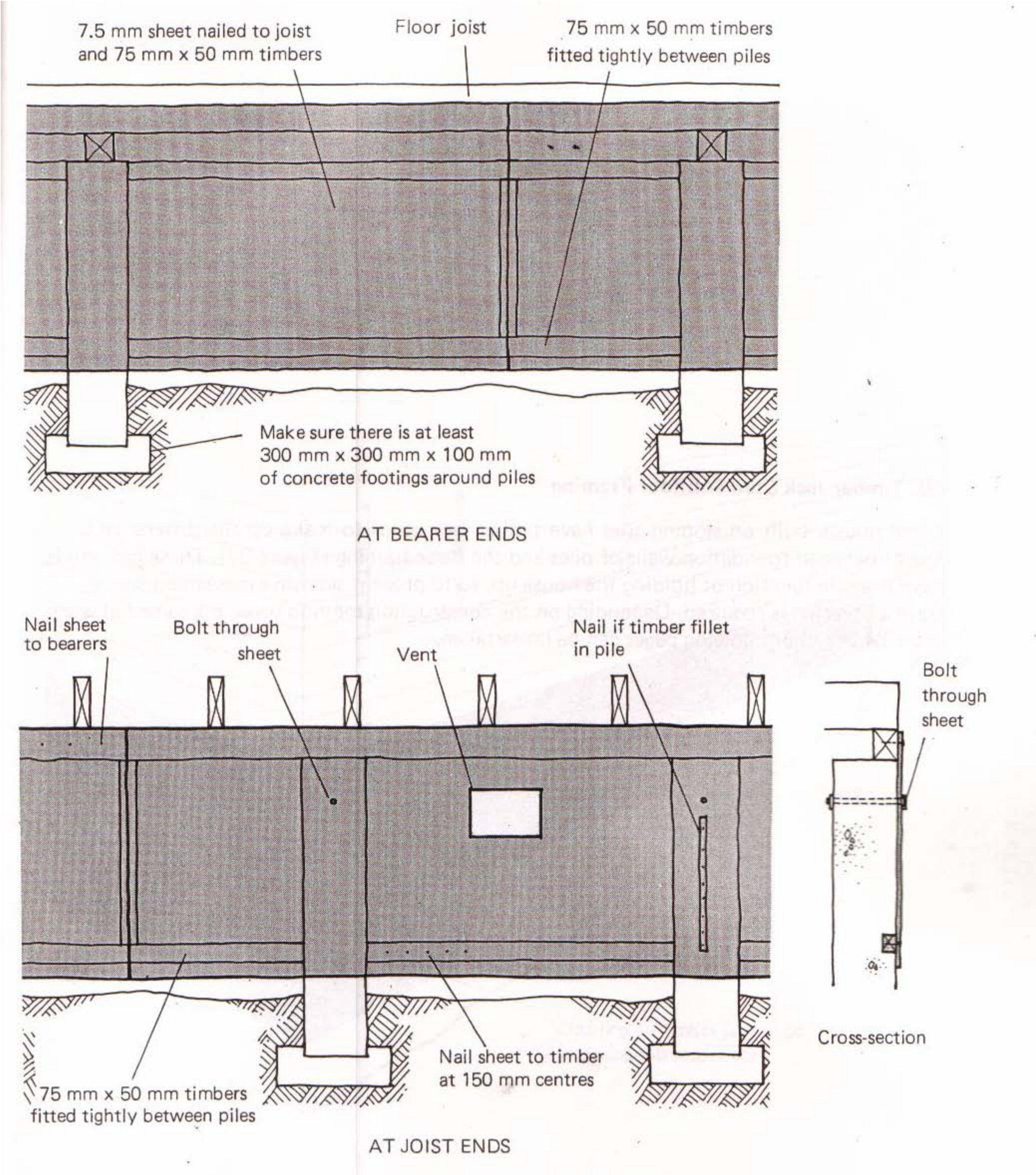


Figure 140
Bracing Piled House with Sheet Material
Source: Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures*. BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37, p 41.

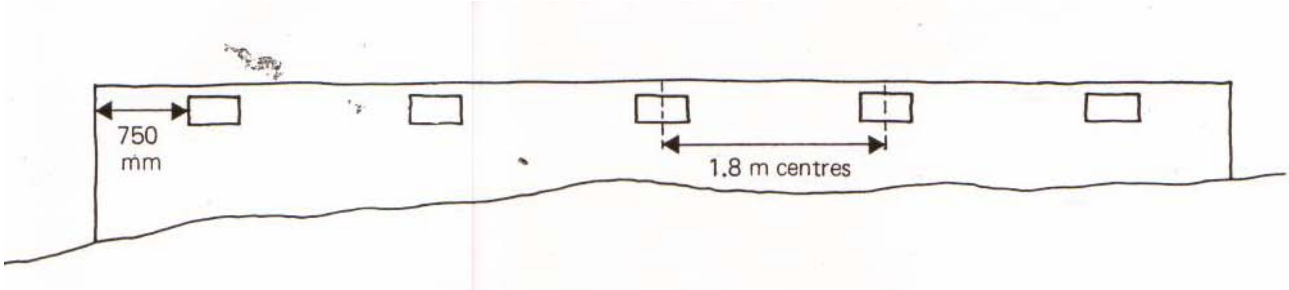


Figure 141
Subfloor Ventilation Detail
Source: Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures*. BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37, p 41.

Timber jack stud subfloor framing is used on sloping sites to mediate height difference "between foundation walls or piles and the floor framing."[tt] Bracing is required against horizontal movement and can consist of a timber brace, sheet material, or an infill wall (see Figures 142, 143 and 144).

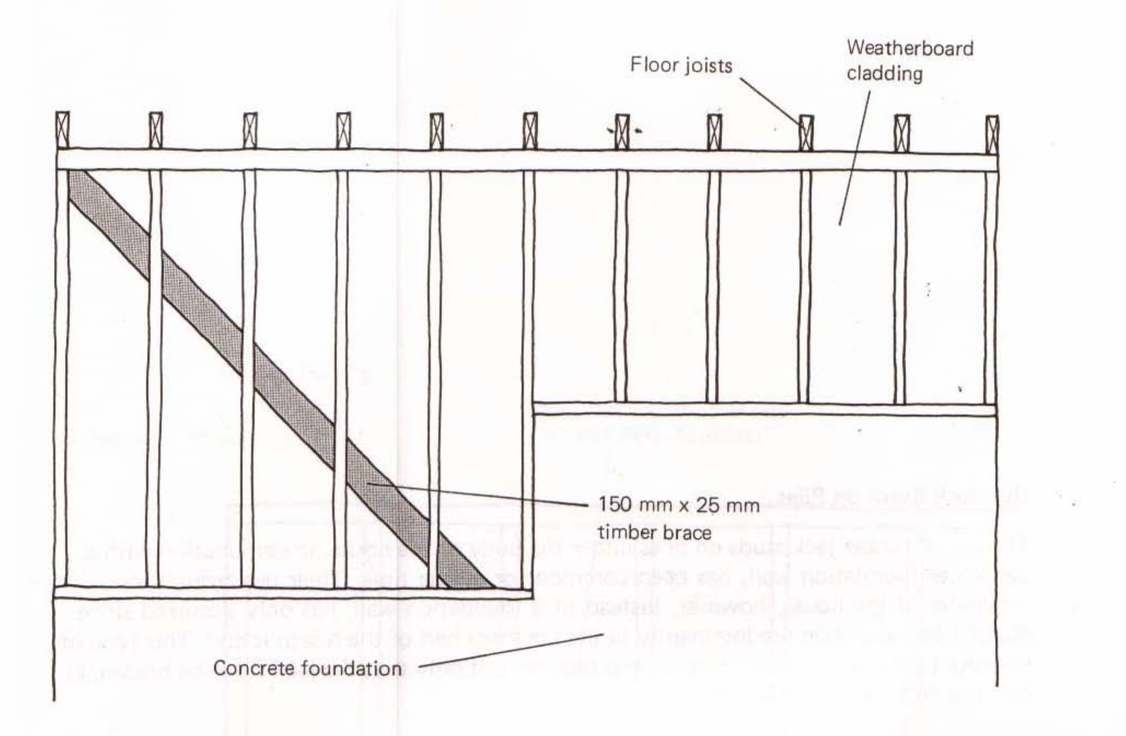


Figure 142
Perimeter Jack-Studding
Source: Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures*. BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37, p 45.

[tt]Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures*. BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37, p 42.

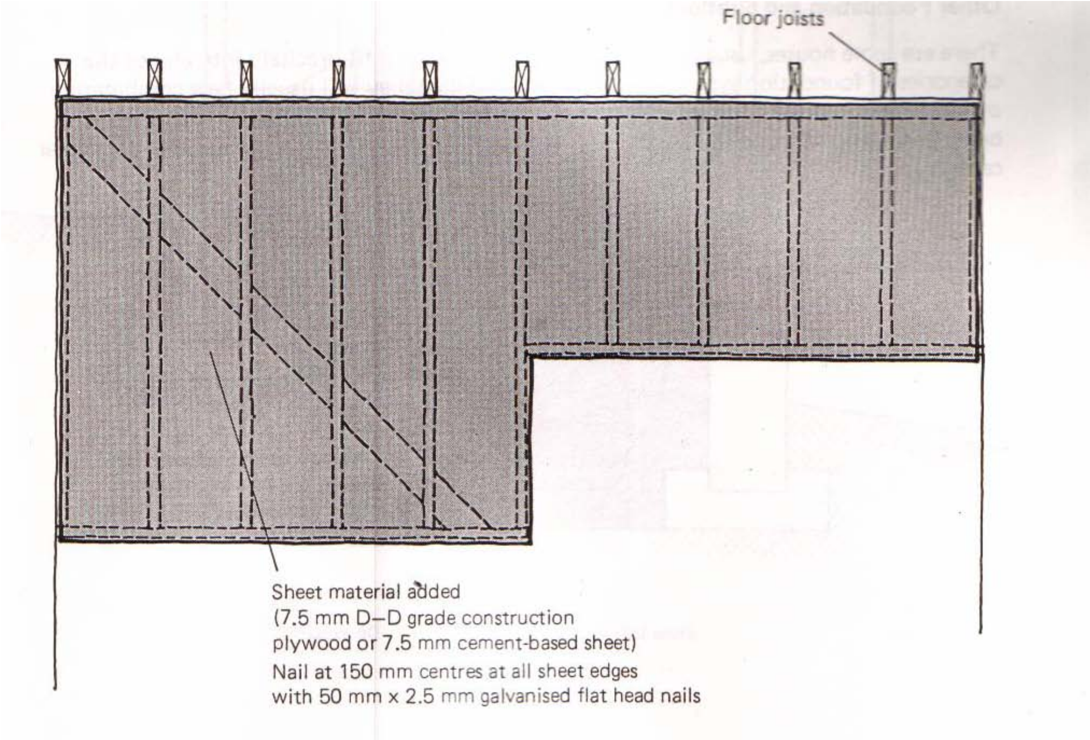


Figure 143
Jack-Studding Remedial Work
Source: Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures*. BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37, p 45.

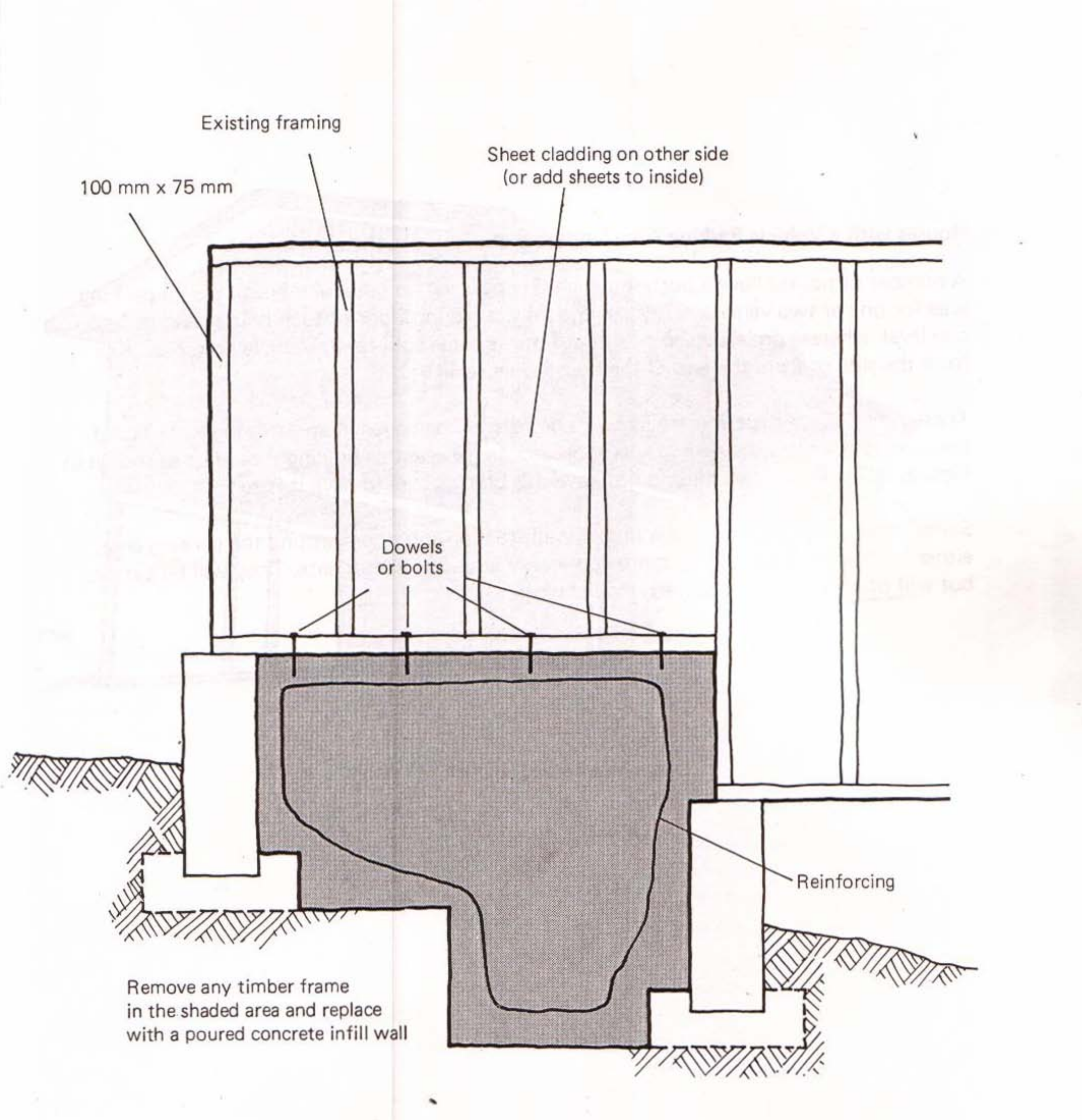


Figure 144
Jack-Studs on Piles Remedial Work
Source: Cooney, Russel. *Strengthening Houses Against Earthquakes: A Handbook of Remedial Measures*. BRANZ Technical Paper, Building Research Association of New Zealand, Judgeford, 1982, no. P37, p 47.

Further explanation on bracing and its placement in the dwelling's design concludes this section on foundation and subfloor framing. Ultimately emphasis is placed on connections for minimisation of post earthquake damage, and of simple and cost effective remedial solutions which increase safety and performance across a variety of foundations and subfloor types. This practical approach is ideal and has served to refine the details shown in this report through the emphasis on functional and feasible solutions.

Corradi, M and Tedeschi, C and Binda, L and Borri, A. *Experimental Evaluation of Shear and Compression Strength of Masonry Wall Before and After Reinforcement: Deep Repointing.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, pp 463-472.

This article documents a study conducted into a new technique to retrofit masonry walls, which increases its shear strength and stiffness. Firstly and introduction into masonry wall construction and seismic damage is outlined, with the basic reinforcement techniques including injection of gout, injections and jacketing with reinforced cement and partial reconstruction of walls.[uu] The new technique to be tested is then outlined, involving deep repointing to replace mortar to a depth of 70-80mm, then confining the wall externally.[vv] The study concludes that this method produces a "significant increase of the shear strength and especially of the shear stiffness…compared to the virgin masonry."[ww] Shear stiffness was noted to increase by up to 300%, thus this technique has strong potential for use in seismic retrofit of dwelling foundations, where masonry walls need to be strengthened to withstand a seismic event.

Deam, B and King, A. *The Seismic Behaviour of Timber Structures: State of the Art.* In Pacific Timber Engineering Conference, Timber Research and Development Advisory Council, Australia, 1994, vol 1, pp 215-221.

This conference paper reviews timber framed structures, why they survive earthquakes so well and how this can be harnessed for design. Timber is ideal due to its lighter mass which reduces lateral forces, and due to its ability to deform during an earthquake. Timber is tested in terms of its yield and ductile capacity, and the results indicate that slackness, which is often present in timber elements, "reduces seismic forces by increasing the natural period of the structure."[xx] A computer program has been developed which can be used to determine the seismic mass able to be restrained by the test specimen."[yy] Although this conference paper does not cover seismic retrofit, it does advocate use of timber construction in seismic design, which could influence the choice and method of seismic detailing for dwelling subfloor and foundations.

Dutta, Anindya and Mander, John B and Kokorina, Tatiana. *Retrofit for Control and Repairability of Damage.* In *Earthquake Spectra*, Earthquake Engineering Research, United States of America, 1999, vol 15, no 4, pp 657-679.

This article addresses the issue that collapse or severe damage to bridges has ensued in California and Japan after recent earthquakes. Retrofit techniques are "one time fixes"[zz] and thus this article explores the results of a research program investigating "the performance of reinforced concrete bridge columns where the main objective is to control damage and ensure fast rehabilitation with minimum disruption to the traffic flow."[aaa] The article reports on strategies to ensure post

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[uu] Corradi, M and Tedeschi, C and Binda, L and Borri, A. *Experimental Evaluation of Shear and Compression Strength of Masonry Wall Before and After Reinforcement: Deep Repointing.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 463.
[vv] Corradi, M and Tedeschi, C and Binda, L and Borri, A. *Experimental Evaluation of Shear and Compression Strength of Masonry Wall Before and After Reinforcement: Deep Repointing.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 465.
[ww] Corradi, M and Tedeschi, C and Binda, L and Borri, A. *Experimental Evaluation of Shear and Compression Strength of Masonry Wall Before and After Reinforcement: Deep Repointing.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 471.
[xx] Deam, B and King, A. *The Seismic Behaviour of Timber Structures: State of the Art.* In Pacific Timber Engineering Conference, Timber Research and Development Advisory Council, Australia, 1994, vol 1, p 220.
[yy] Deam, B and King, A. *The Seismic Behaviour of Timber Structures: State of the Art.* In Pacific Timber Engineering Conference, Timber Research and Development Advisory Council, Australia, 1994, vol 1, p 220.
[zz] Dutta, Anindya and Mander, John B and Kokorina, Tatiana. *Retrofit for Control and Repairability of Damage.* In *Earthquake Spectra*, Earthquake Engineering Research, United States of America, 1999, vol 15, no 4, p 657.
[aaa] Dutta, Anindya and Mander, John B and Kokorina, Tatiana. *Retrofit for Control and Repairability of Damage.* In *Earthquake Spectra*, Earthquake Engineering Research, United States of America, 1999, vol 15, no 4, p 657.

earthquake serviceability (see Figures 145 and 146), and columns with retrofitted lap splices (see Figure 147).

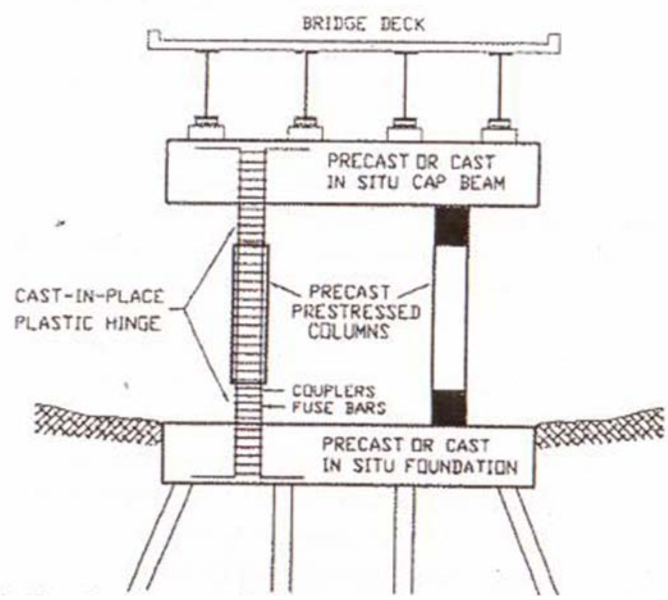

Figure 145
Control and Repairability of Damage: Design Detail for New Structure
Source: Dutta, Anindya and Mander, John B and Kokorina, Tatiana. *Retrofit for Control and Repairability of Damage.* In *Earthquake Spectra*, Earthquake Engineering Research, United States of America, 1999, vol 15, no 4, p 660.

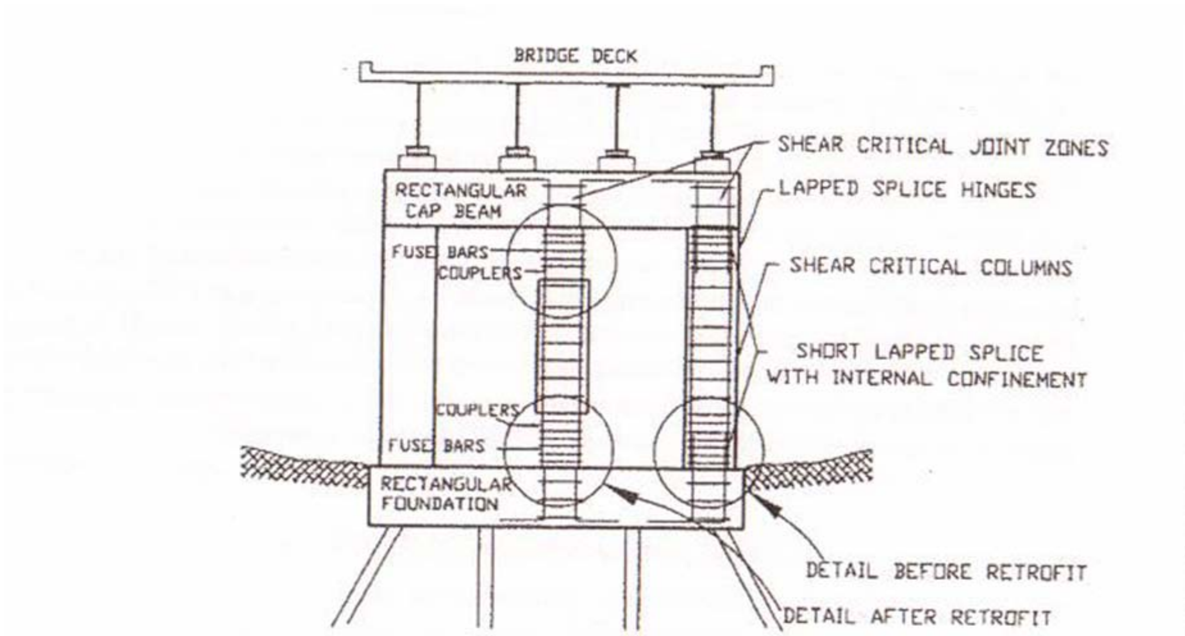

Figure 146
Retrofit Control and Repairability of Damage: Design Detail for Existing Structure
Source: Dutta, Anindya and Mander, John B and Kokorina, Tatiana. *Retrofit for Control and Repairability of Damage.* In *Earthquake Spectra*, Earthquake Engineering Research, United States of America, 1999, vol 15, no 4, p 660.

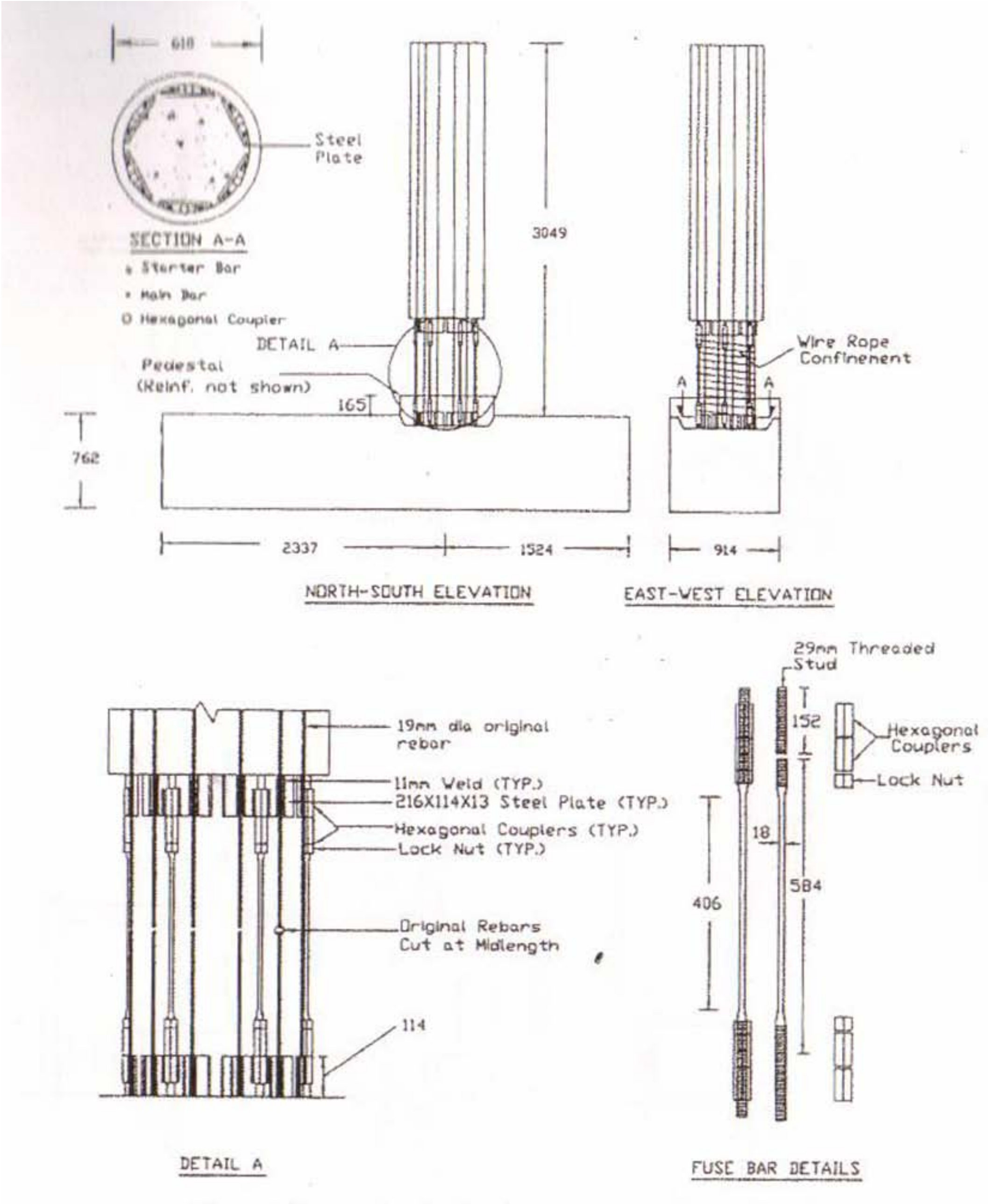

Figure 147
Construction Details of the Retrofitted Lap Splice Specimen
Source: Dutta, Anindya and Mander, John B and Kokorina, Tatiana. *Retrofit for Control and Repairability of Damage.* In *Earthquake Spectra*, Earthquake Engineering Research, United States of America, 1999, vol 15, no 4, p 660.

Analysis of the fatigue life follows under differing loading conditions. Although this resource does not address dwelling foundation retrofitting, it does demonstrate the importance of connections and the ability of retrofitting to extend use of the structure through the event of an earthquake; two aspects which fall closely in line with this report and cement the importance of retrofitting.

El Maaddawy, Tamer and Soudki, Khaled. *Strengthening of Reinforced Concrete Slabs with Mechanically-Anchored Unbonded FRP System*. In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, pp 444-455.

This article examines the use of a mechanically-unbonded fibre reinforced polymer system to increase flexural strength of reinforced concrete slabs. This is often necessary due to inadequate maintenance, excessive loading, change in use or exposure to adverse environmental conditions.[bbb] The test specimen was a “1800mm long, 500mm wide… 100mm deep [slab]…singly reinforced at tension side by three No. 10 deformed steel bars with a concrete clear cover of 20mm.”[ccc] The anchor used consisted of “a steel plate, 100 x 130 x 10mm, having four holes, each of 15mm diameter…placed below the CFRP strip and held in place using four M12 bolts.”[ddd] The deformation characteristics, failure modes and tests results are discussed in depth. The report concludes that this system “increased the yield and the ultimate loads by about 38% and 46% respectively.”[eee] It also improved the slab deflection, strength and stiffness. This relates to this report as it develops retrofit techniques to enhance concrete slabs, which may prove beneficial in the upgrading of dwelling foundations here in New Zealand.

Herbert, P D and King, A B. Racking Resistance of Bracing Walls in Low-rise Buildings Subject to Earthquake Attack. BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 1998, no. 78, vol. 1.

This study report examines the racking resistance testing of wall bracing elements, both how it is assessed here in New Zealand and internationally. Following this a three-phase experiment was conducted, testing bracing panels under “various loading protocols, including monotric and reverse cyclic loading.”[fff] The result of this investigation is the “quantification of the mass that the test panel can dependably restrain.”[ggg] The investigation concludes that current bracing ratings are “non-conservative”[hhh] and need to be reduced.

Holcroft, Guy. An Investigation of 62 Coastal Subfloors for Fastener Corrosion. BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 1996, no. 72.

This study report examines a sample of houses looking at the corrosion of their subfloor fasteners; the houses were located on William Street, Petone and The Parade, Paekakariki, chosen for their close proximity to the sea. The report strongly emphasises the importance of keeping salt out of the subfloor area whilst not compromising ventilation. Concrete perimeter walls with vents, or slats with 20mm or less gaps are both adequate solutions. Humidity is also a contributing factor, with surrounding vegetation increasing humidity and corrosive effects, thus again ventilation is very important. No correlation could be established between distance from house to the ocean and the

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[bbb] El Maaddawy, Tamer and Soudki, Khaled. *Strengthening of Reinforced Concrete Slabs with Mechanically-Anchored Unbonded FRP System.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 444.
[ccc] El Maaddawy, Tamer and Soudki, Khaled. *Strengthening of Reinforced Concrete Slabs with Mechanically-Anchored Unbonded FRP System.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 445.
[ddd] El Maaddawy, Tamer and Soudki, Khaled. *Strengthening of Reinforced Concrete Slabs with Mechanically-Anchored Unbonded FRP System.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 446.
[eee] El Maaddawy, Tamer and Soudki, Khaled. *Strengthening of Reinforced Concrete Slabs with Mechanically-Anchored Unbonded FRP System.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 454.
[fff] Herbert, P D and King, A B. Racking Resistance of Bracing Walls in Low-rise Buildings Subject to Earthquake Attack. BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 1998, no. 78, vol. 1, p iii.
[ggg] Herbert, P D and King, A B. Racking Resistance of Bracing Walls in Low-rise Buildings Subject to Earthquake Attack. BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 1998, no. 78, vol. 1, p iii.
[hhh] Herbert, P D and King, A B. Racking Resistance of Bracing Walls in Low-rise Buildings Subject to Earthquake Attack. BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 1998, no. 78, vol. 1, p 21.

extent of the corrosion on subfloor elements.[iii] This study report serves to reinforce the importance of connections and their quality and maintenance in the subfloor area, a notion which has come to be of paramount consideration in this report.

International Code Council. *International Building Code*. International Code Council, Inc., United States of America, 2006.

This reference is divided into thirty five chapters covering from use and occupancy classification to interior finishes, fire protection systems, wood, steel and masonry. Each section gives detailed descriptions of the topic and building element at hand, information on associated construction and its processes and member tables where applicable. Construction details are not given; rather codes of practice are outlined.

International Organisation for Standardisation. *Light Timber Frame Construction – Comparison of Four National Design Documents.* ISO/IEC, Sydney, 2008.

This technical report compares four national design documents on light frame timber construction. These include the Australian *AS1684 Residential Timber-Framed Construction*, Canadian *Engineering Guide for Wood Frame Construction 2004*, New Zealand's *NZS3604 Timber Framed Buildings 1999* and American *Wood Frame Construction Manual 2001*. These standards are compared across loads and load factors, lateral load systems design, connection design, and member design including roofs, walls and floors. The section on floors is the most relevant to this report, however although comparisons are carefully documented (see Figure 148) no seismic retrofit details or practices are touched on in this or in any other section.

Provision	Canadian Engineering Guide for Wood Frame Construction EN = Engineered PR = Prescriptive	US Wood Frame Construction Manual EN = Engineered PR = Prescriptive	Australian Residential Timber-Frame Construction CA= Cyclonic Areas NC= Non-Cyclonic	New Zealand Standard Timber Framed Buildings	References
3D. Member Design: Floors					
3D.1 Floor Members (Joists, Components)	Floor member designed for gravity loads, and in the case of diaphragm design for lateral loads; Serviceability criteria include deflection and vibration performance; bearing provisions; Strength design includes system factors	Floor member designed for gravity loads, and in the case of diaphragm design for lateral loads; Serviceability criteria includes deflection, bearing design	Floor member designed as bending member under gravity loads; for permanent and transient, and point loading: single span, continuous, or cantilevered spans; Serviceability includes deflection and dynamic behaviour criteria; Bearing provisions; Design includes load distribution and strength sharing factors	Floor members pre-engineered for given spans and loads	CAN: 6.1 US: 2.3.1.1 AUST: DC4.1 NZ: 7.1
3D.2 Floor Framing Details	Joists supported by walls, lintels or beams, with minimum 38 mm bearing length: bottoms of joists restrained from twisting by nailing, strapping, blocking, bridging or hangers; Prescriptive Code limits on notching and boring of framing, or design required	Joists bear on beams, girders, ledgers or walls, or are supported by hangers; End restraint provided at joist ends to resist about 33 N·m twisting moment; Lateral stability rules provided; Notching and boring provisions	Joists bear on beams, walls, or bearers (headers) that support loads from wall as well as the floor; Minimum 30 mm bearing per joist; Lateral stability prescriptive rules; Cuts, holes and notches restricted in size and location	Joists bear on supports, with minimum bearing of 32 mm; Lateral stability provisions; Tolerances given for: -deviation of 5 mm per 10m length in plan, or 10mm max deviation; -horizontal deviation of 5mm per 10 m length, max deviation = 10 mm; prescriptive rules given for notches and holes	CAN: 6.3.2, 11 US: 2.3.1.2, 2.3.1.3, 2.3.1.4, 2.3.1.5, 2.3.1.1.1 AUST: NC/CA4.1-4.2 NZ: Tab 2.1, 7.1

Figure 148
Table Comparing Member Design: Floor Members

[iii] Holcroft, Guy. An Investigation of 62 Coastal Subfloors for Fastener Corrosion. BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 1996, no. 72, p 9.

Source: International Organisation for Standardisation. *Light Timber Frame Construction – Comparison of Four National Design Documents.* ISO/IEC, Sydney, 2008, p 36.

Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007.

This thesis is a detailed study of foundation and subfloor bracing in New Zealand conditions. Beginning with an extensive analysis of geological and geographical conditions as seen in New Zealand, the thesis explores soil behaviour and movement in earthquakes. Following this a reading of New Zealand earthquakes in history was conducted, examining the rise of official recognition that construction detailing "should be appropriate to withstand induced seismic forces."[jjj] The thesis follows this by outlining six foundation types, including an internally piled foundation, a full piled foundation, a partial foundation wall, a full foundation wall, a full foundation wall/internal piles and a slab on ground; of which these six types identified have been integrated into the structure of this report, ensuring details identified are relevant to New Zealand conditions and New Zealand foundation types.

Typical subfloor issues are identified, including configuration issues where asymmetry and discontinuity within design were seen to "crush and bend significantly"[kkk] in areas of discontinuity (see Figure 149).

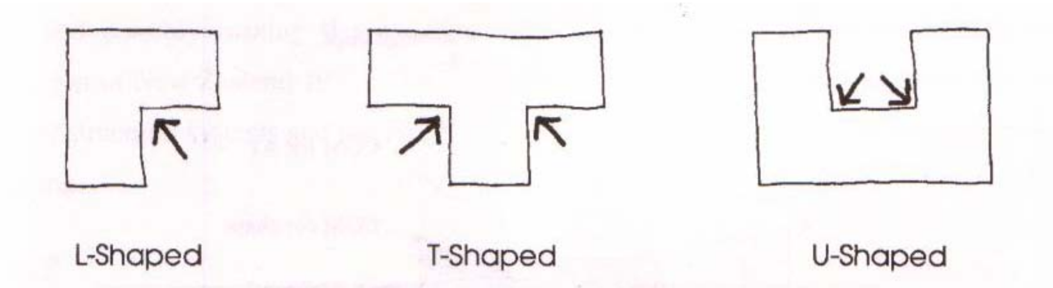


Figure 149
Design layouts involving discontinuity
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 75.

Anchors is a subsequent issue, where heavy elements such as "concrete porches, steps, pathways or chimney bases"[lll] can provide lateral resistance if well integrated into the design, or cause damage if not satisfactorily fixed. Vertical eccentricities too cause discontinuities when transferring inertial forces from the superstructure to the ground. This causes damage at the points of discontinuity.

A sample of 100 houses for study was then identified and methodology explained in detail. Bracing deficiencies are explored and a striking number of dwellings fall short of the standard due to lack of bracing (see Figures 150, 151 and 152).

[jjj] Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 44.
[kkk] Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 75.
[lll] Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 77.

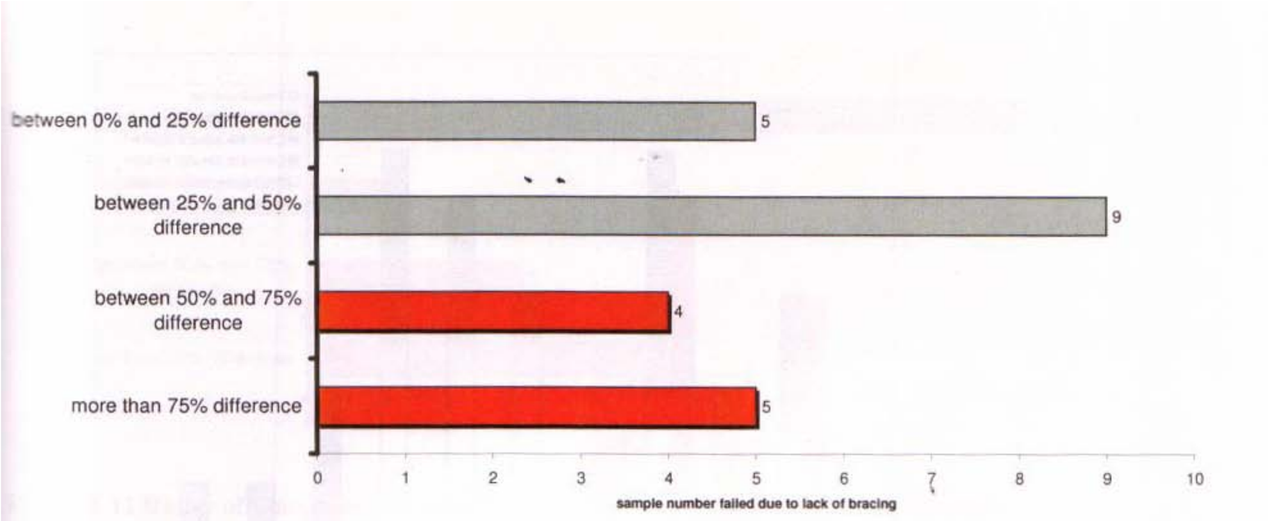


Figure 150
Range of Inadequate Bracing distribution Excluding all Anchors
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 111.

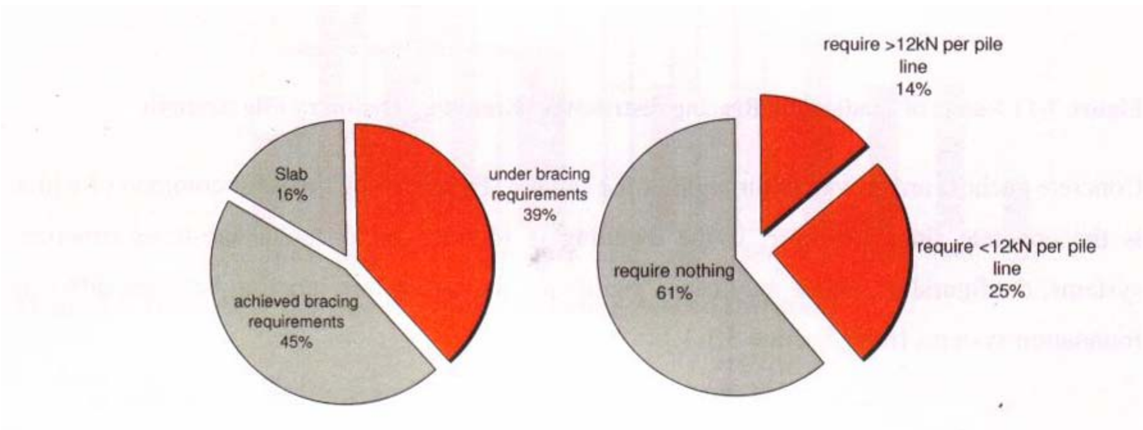


Figure 151
Left: Percentage of Adequate and Inadequate Foundations Excluding all Non-Designed Bracing, Right: Percentage of Dwellings requiring Bracing under and over 12kN
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 114.

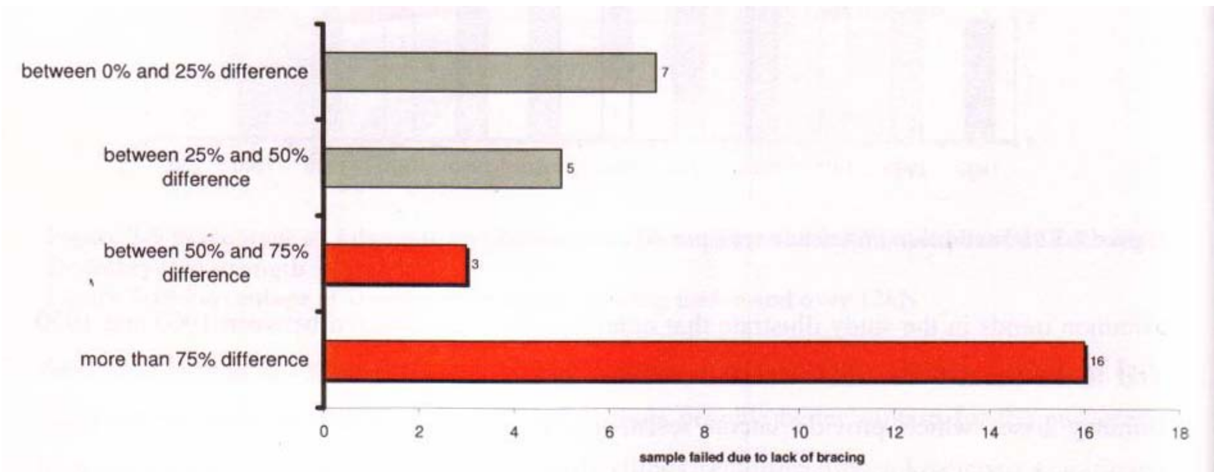


Figure 152

Range of Inadequate Bracing Distribution Excluding all Non-Designed Bracing
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 114.

This closely relates to the scope of this report where adequate detailing is emphasised as a preventative measure to minimise damage; where so many dwellings fall short of adequate the need is clear for satisfactory retrofit solutions to ensure safety and minimisation of domestic damage post earthquake. This is further reinforced in the section of this thesis examining the overall condition of foundations in the sample, where it is established that "40% of dwellings are structurally deficient."[mmm] Configuration issues too are very prevalent (see Figure 153) and timber deterioration a persistent issue (see Figure 154 and 155).

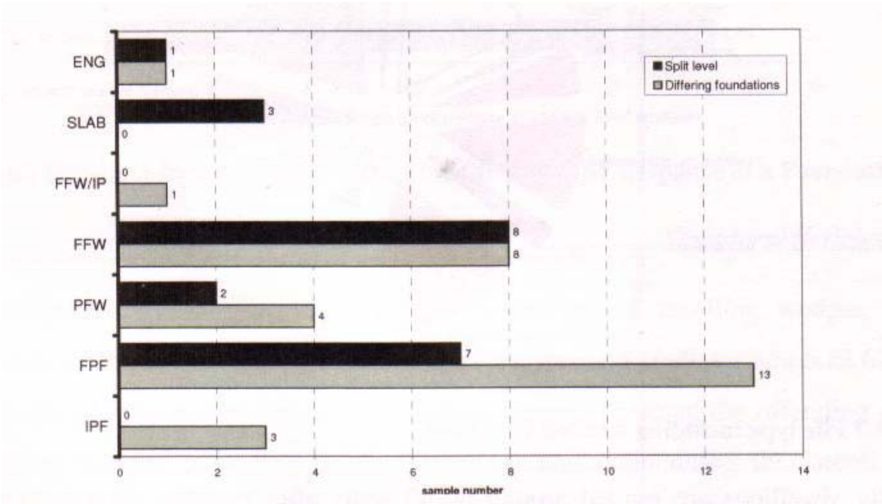


Figure 153
Configuration Issues for Each Foundation type in the sample
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 136.

[mmm] Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 134.

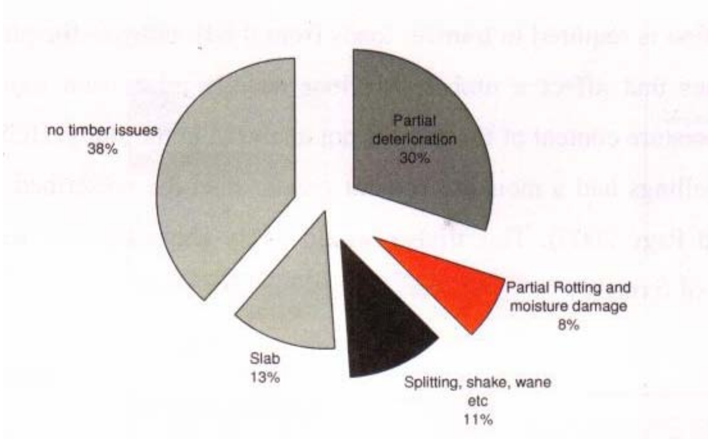


Figure 154
Damage Observed in Subfloor Timbers
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 138.

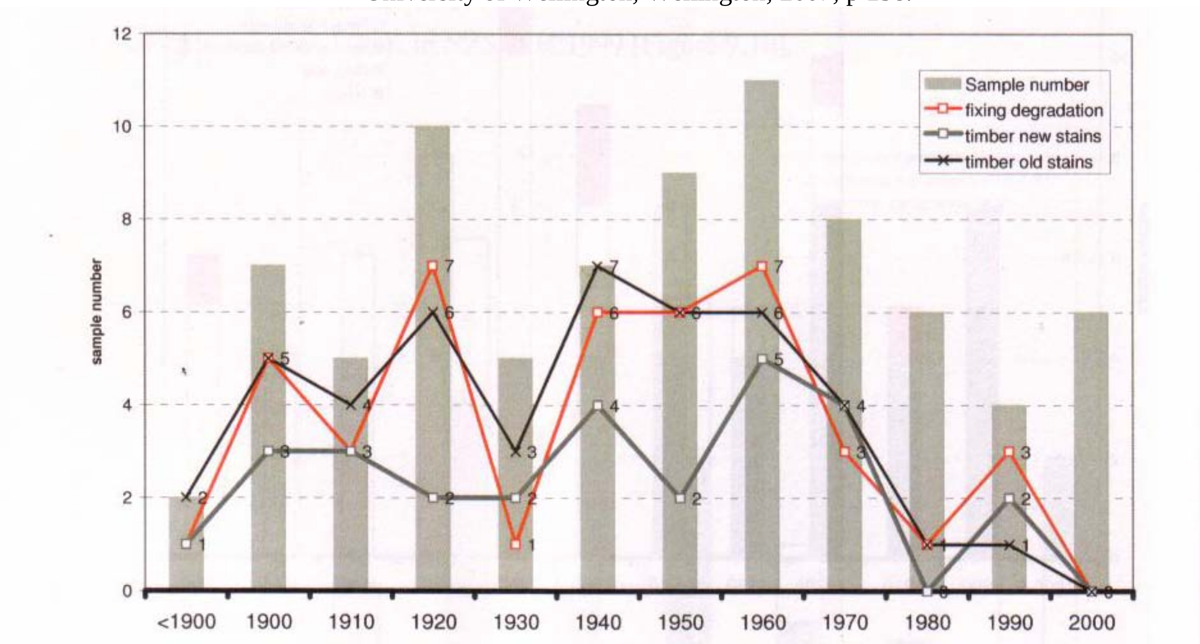


Figure 155
Sub-Floor Timbers with signs of higher Moisture Content and Degradation
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 138.

This raises issues of the importance of proper maintenance and the need for acceptable retrofit details to ensure the safety of these dwellings and reduce their damage post-earthquake. Connections are of paramount consideration with degradation occurring over time and their maintenance a necessary task (see Figure 156). This relates to moisture and ventilation issues which will exacerbate corrosion, and the older samples have significant ventilation issues (see Figure 157).

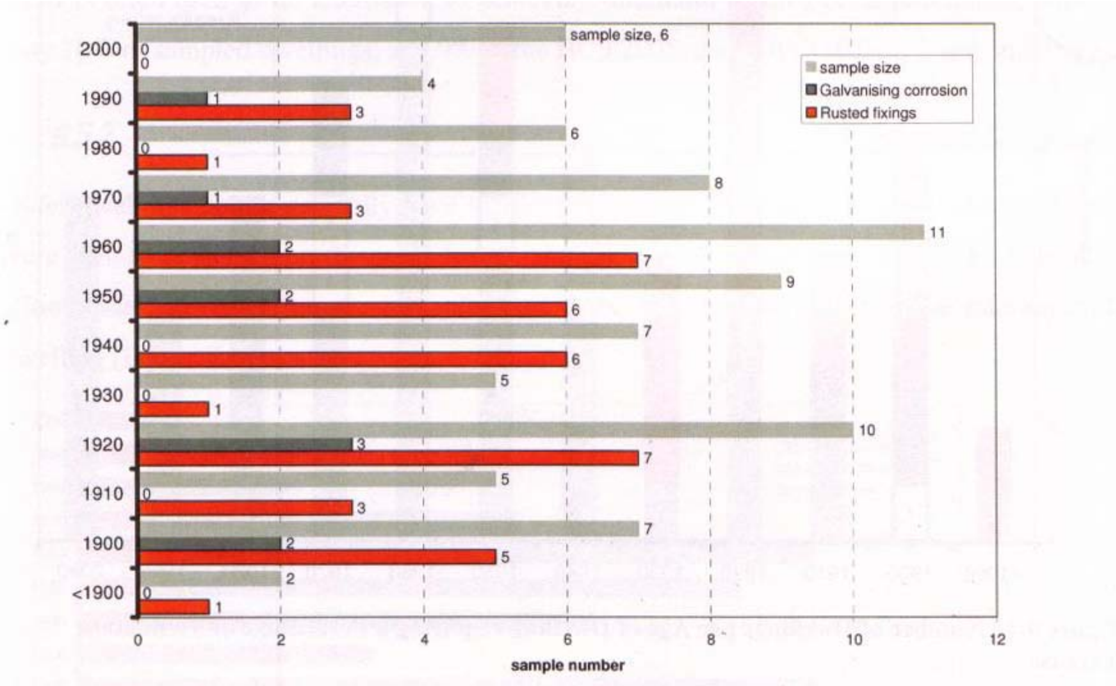


Figure 156
Fixing Degradation per Age of Dwelling
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 139.

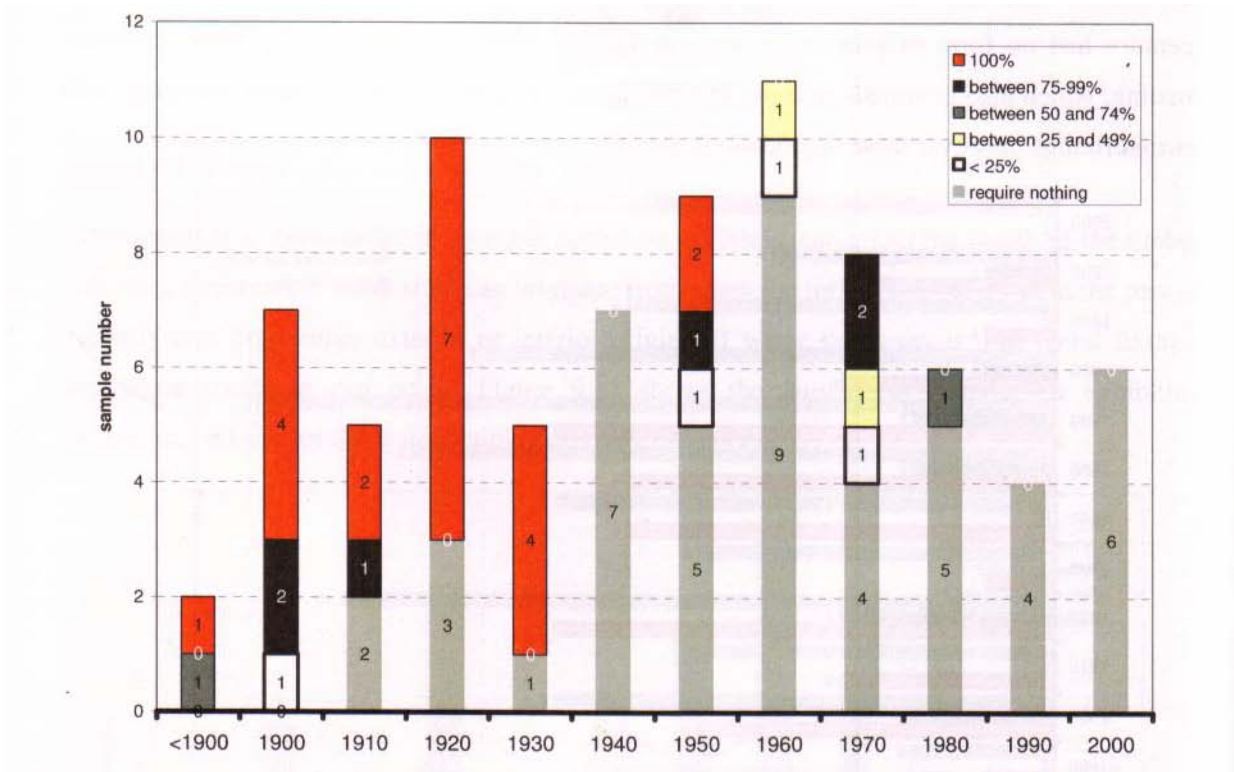


Figure 157
Number of Dwellings per Age of Dwelling requiring a Percentage of Ventilation increase
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 140.

An extensive investigation of the costs and benefits of remedial action was conducted in this thesis, where pre-earthquake maintenance and retrofitting of details to reduce dwelling damage in earthquake is recommended. This would ensure "more dwellings will remain habitable through the upgrade of foundations, which could save around 13 000 evacuations and limit the total number of deaths and injuries (see Figure 158) from severe shaking and falling objects."[nnn]

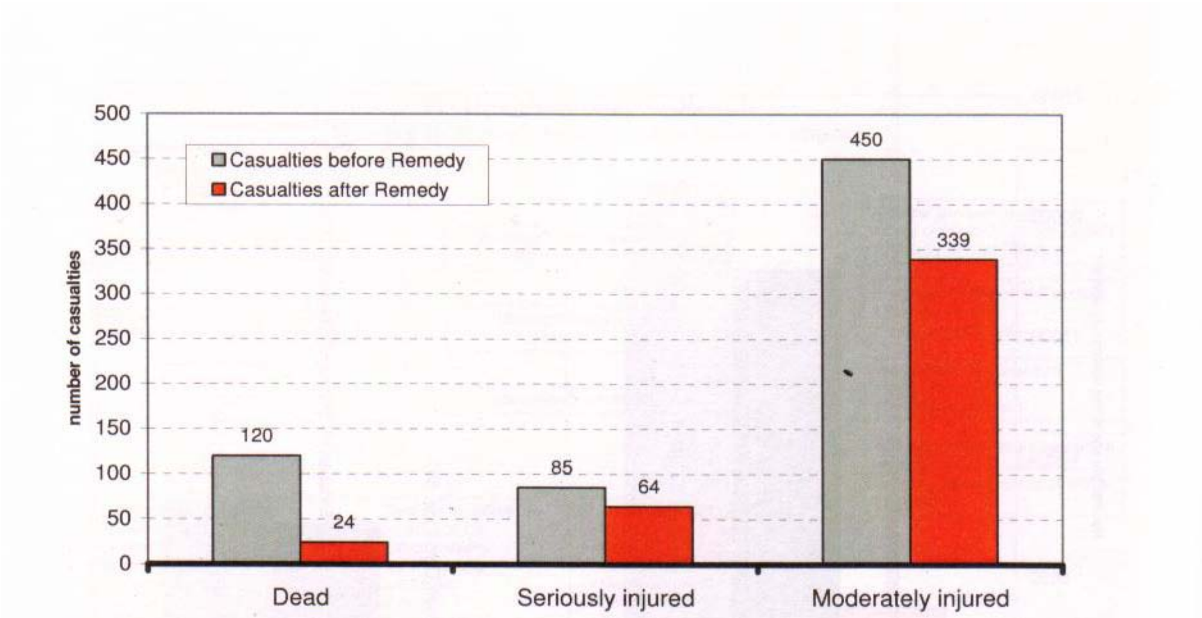


Figure 158
Number of Casualties and Deaths Before and After applying Remedial Measures for a Night time Earthquake Scenario
Source: Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 140.

The thesis explores social responsibility, emphasising that "it is only in a proactive society, ranging from authorities to communities, that we will mitigate the unnecessary damage of dwellings, caused by weak and inadequate foundations."[ooo]

[nnn] Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 222.

[ooo] Irvine, James. *Foundation and Subfloor Bracing Analysis: The Cost Benefit of Upgrading.* Thesis, Victoria University of Wellington, Wellington, 2007, p 235.

Liu, Chin-Tsung, and Huang, Jong-Shin. *Highly Flowable Reactive Powder Mortar as a Repair Material.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, pp 1043-1050.

This article outlines the testing of a reactive powder mortar with a flow value of 200% and a compressive strength of 75MPa, subjected to a series of slant shear, rebar pull out and tensile strength tests. The article begins by introducing problems associated with epoxy resins, such as a mismatch in strength and stiffness between the epoxy resin and concrete, the expensive cost and thermal ageing in high heat and humidity.[ppp] The reactive powder mortar is composed of “type II Portland Cement, quartz sand, quartz powder, silica fume, super-plasticizer and water.”[qqq] Differing mix proportions were tested and the mixing process documented.
The mix was then tested in slant shear tests, rebar pull out tests and tensile strength tests (see Figures 159, 160 and 161).

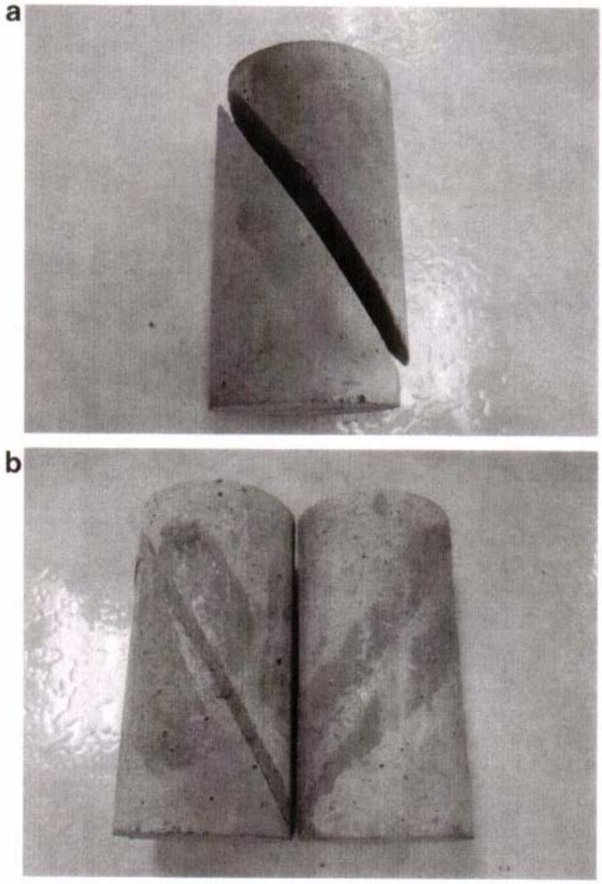


Figure 159
Cylindrical Specimens for Slant Shear Tests: (a) without and (b) with a diagonal Reactive Powder Mortar bonding layer

[ppp] Liu, Chin-Tsung, and Huang, Jong-Shin. *Highly Flowable Reactive Powder Mortar as a Repair Material.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 1043.
[qqq] Liu, Chin-Tsung, and Huang, Jong-Shin. *Highly Flowable Reactive Powder Mortar as a Repair Material.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 1044.

Source: Liu, Chin-Tsung, and Huang, Jong-Shin. *Highly Flowable Reactive Powder Mortar as a Repair Material.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 1046.

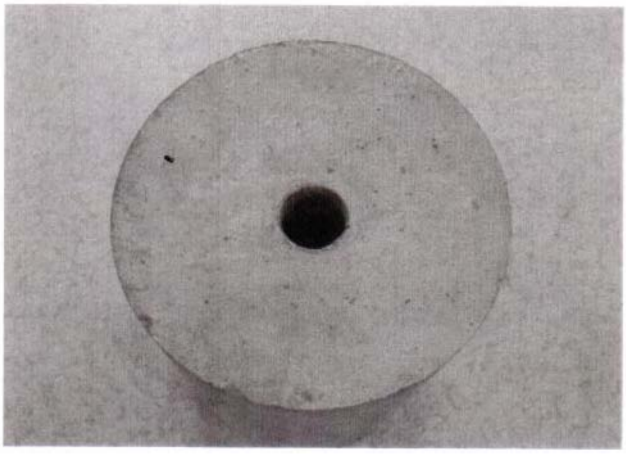


Figure 160
A Precast Hollow-core Concrete Cylinder Specimen for Rebar Pull Out Tests
Source: Liu, Chin-Tsung, and Huang, Jong-Shin. *Highly Flowable Reactive Powder Mortar as a Repair Material.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 1046.

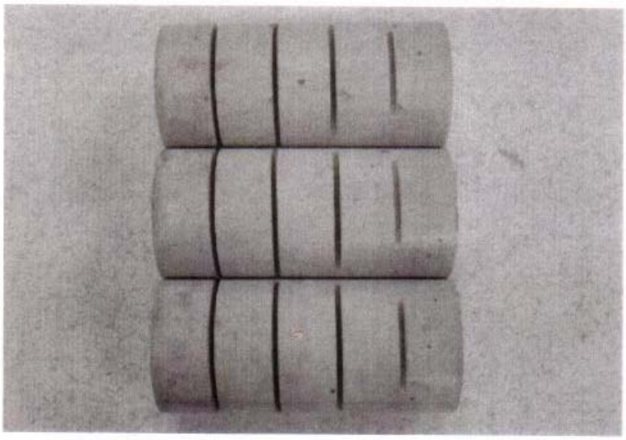


Figure 161
Cylinder Specimens with Four Notches of Same Width But Different Depths for Tesnile Strength Tests
Source: Liu, Chin-Tsung, and Huang, Jong-Shin. *Highly Flowable Reactive Powder Mortar as a Repair Material.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, p 1047.

The study concludes that this mortar has a slant shear strength comparable to epoxy resin, provides a higher rebar pull out force and a higher tensile strength.[rrr] This mortar is relevant to this report as it has the possibility to be used in the seismic retrofit of dwelling foundation and is proven to be an adequate repair material for concrete structures.

Mosallam, Ayman S and Mosalam, Khalid M. *Strengthening of Two-Way Concrete Slabs with FRP Composite Laminates.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2003, vol 17, pp 43-54.

[rrr] Liu, Chin-Tsung, and Huang, Jong-Shin. *Highly Flowable Reactive Powder Mortar as a Repair Material.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2008, vol 22, pp 1049-1050.

This article outlines an experiment to repair unreinforced and reinforced concrete slabs with fibre reinforced polymer composite strips. The test procedure is outlined, covering the testing of 10 full scale unreinforced and reinforced concrete slabs fitted with carbon epoxy and E-glass/epoxy composites[sss] (see Figure 162). Details of the slab are given (see Figure 163).

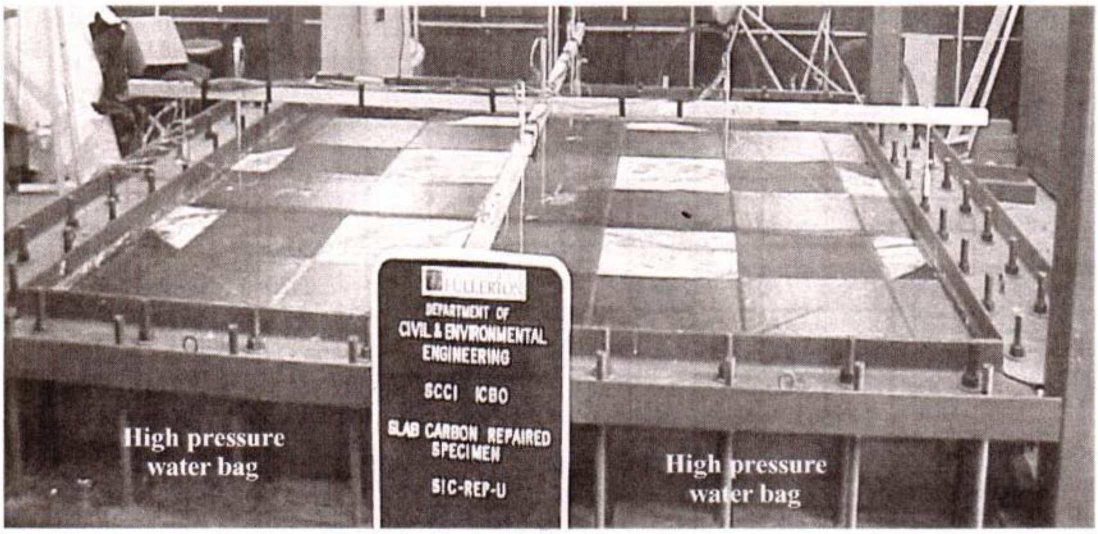


Figure 162
Details of Experimental Setup
Source: Mosallam, Ayman S and Mosalam, Khalid M. *Strengthening of Two-Way Concrete Slabs with FRP Composite Laminates.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2003, vol 17, p 45.

[sss] Mosallam, Ayman S and Mosalam, Khalid M. *Strengthening of Two-Way Concrete Slabs with FRP Composite Laminates.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2003, vol 17, p 44.

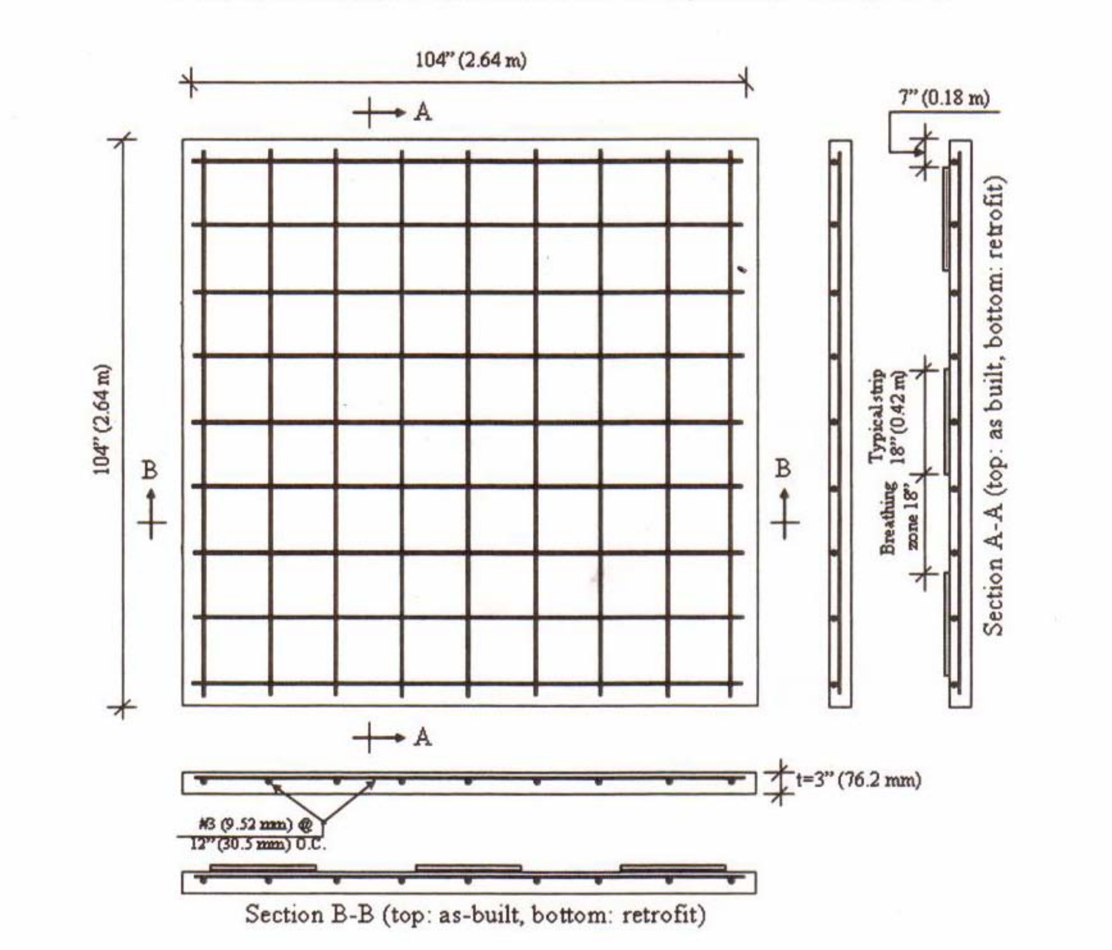


Figure 163
Details of Two-Way Reinforced Concrete Slabs (also same geometry for unreinforced)
Source: Mosallam, Ayman S and Mosalam, Khalid M. *Strengthening of Two-Way Concrete Slabs with FRP Composite Laminates.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2003, vol 17, p 46.

The test results are thoroughly analysed and the findings presented. The experiment concludes that the fibre reinforced polymer systems succeed in "upgrading the structural capacity of both two-way unreinforced and reinforced concrete slabs."[ttt] This retrofit repair restores the original capacity of the damaged slabs, and further, increases the strength of the slabs "to an average increase of more then 540% the original capacity of the as-built slabs."[uuu] It is also noted that when failure did occur, it was preceded by large deflections which gives prior warning before imminent failure. This study presents a retrofit repair technique for concrete slabs which may prove relevant and useful in the seismic retrofitting of slab on grade foundations, a foundation type which is acknowledges as one difficult to repair. Thus, this article is very relevant to this report and sheds new light on developments in the construction industry.

[ttt] Mosallam, Ayman S and Mosalam, Khalid M. *Strengthening of Two-Way Concrete Slabs with FRP Composite Laminates.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2003, vol 17, p 53.
[uuu] Mosallam, Ayman S and Mosalam, Khalid M. *Strengthening of Two-Way Concrete Slabs with FRP Composite Laminates.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2003, vol 17, p 53.

Pampanin, Stefano. *Role of Residual Displacements in Performance-Based Seismic Assessment, Design and Retrofit of Reinforced Concrete Buildings and Bridge Structures; Assessment and Mitigation Strategies*. University of Canterbury, Christchurch, 2006.

This resource outlines a project undertaken to develop a "rational performance-based design procedure for design assessment and retrofit able to account for and reduce the impact of damage resulting from residual deformation."[vvv] Three main tasks were involved in this: assessment of residual deformation in existing and newly designed structures; development of mitigation strategies for cast-in-situ concrete; and development and refinement of a new technological solution to reduce this residual deformation. This third task examines high performance seismic resisting precast concrete frame systems and similar applications in bridge piers. The new technological solution involves controlled rocking systems as a fuse, effectively a selective weakening as a retrofit strategy. By saw cutting the "longitudinal bottom reinforcement of a gravity load dominated beam or of a shear dominated wall"[www] the selective weakening was most effective. This technique is devised for large scale reinforced concrete structures and thus is perhaps not applicable in the retrofitting of dwelling subfloors and foundations here in New Zealand.

Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, pp 365-377.

This article reports on experiments conducted to retrofit concrete and masonry structures with jackets of composite fibres bonded with a polymer matrix to enhance shear strength, flexural ductility or lap splice performance.
Deficiencies of concrete structures in recent California earthquakes are first discussed including inadequate flexural strength, flexural ductility and shear strength. The experiment scope is then outlined. For columns "active confinement is achieved by placing a specified thickness of the composite jacket material over the region of the column to be confined, and pressure grouting the gap between the column and the jacket with either epoxy or cement grout"[xxx] (see Figures 164 and 165). This is a method suitable for retrofit pre-earthquake or repair post-earthquake.

[vvv] Pampanin, Stefano. Role of Residual Displacements in Performance-Based Seismic Assessment, Design and Retrofit of Reinforced Concrete Buildings and Bridge Structures; Assessment and Mitigation Strategies. University of Canterbury, Christchurch, 2006, p 5.
[www] Pampanin, Stefano. Role of Residual Displacements in Performance-Based Seismic Assessment, Design and Retrofit of Reinforced Concrete Buildings and Bridge Structures; Assessment and Mitigation Strategies. University of Canterbury, Christchurch, 2006.
[xxx] Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 365.

Figure 164
Circular Column Retrofitted with Fibreglass/Epoxy Composite Jackets
Source: Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 367.

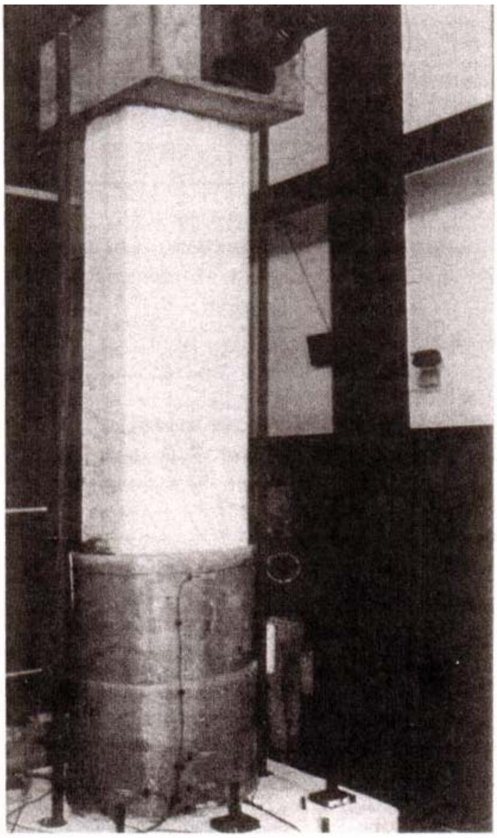


Figure 165
Rectangular Column Retrofitted with Fibreglass/Epoxy Composite Jackets
Source: Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 367.

The results of testing indicate "very satisfactory performance of the retrofitted columns"[yyy] (see Figure 166).

[yyy] Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 368.

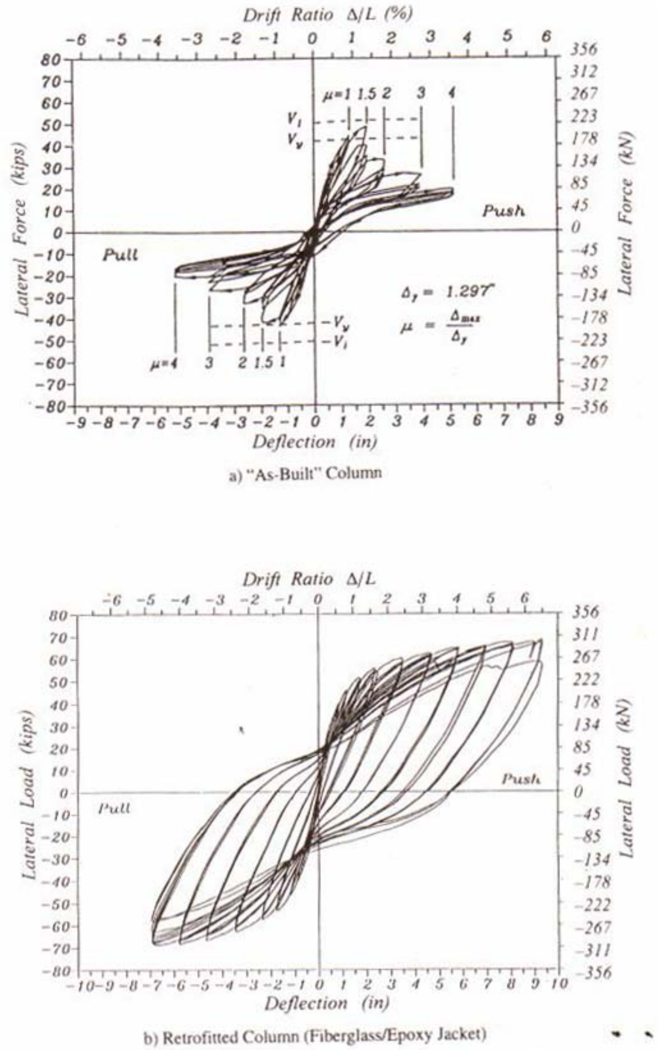


Figure 166
Lateral Force Displacement Response
Source: Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 368.

The columns are also studied in terms of shear, as the shear strength of many buildings and bridges has proved to be inadequate in the event of an earthquake. The test is outlines (see Figures 167 and 168) and the results presented, concluding that the retrofitted column "developed extremely stable hysteresis loops…[and] good ductile response with lateral strength exceeding that corresponding to ideal flexural capacity."[zzz]

[zzz] Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 371.

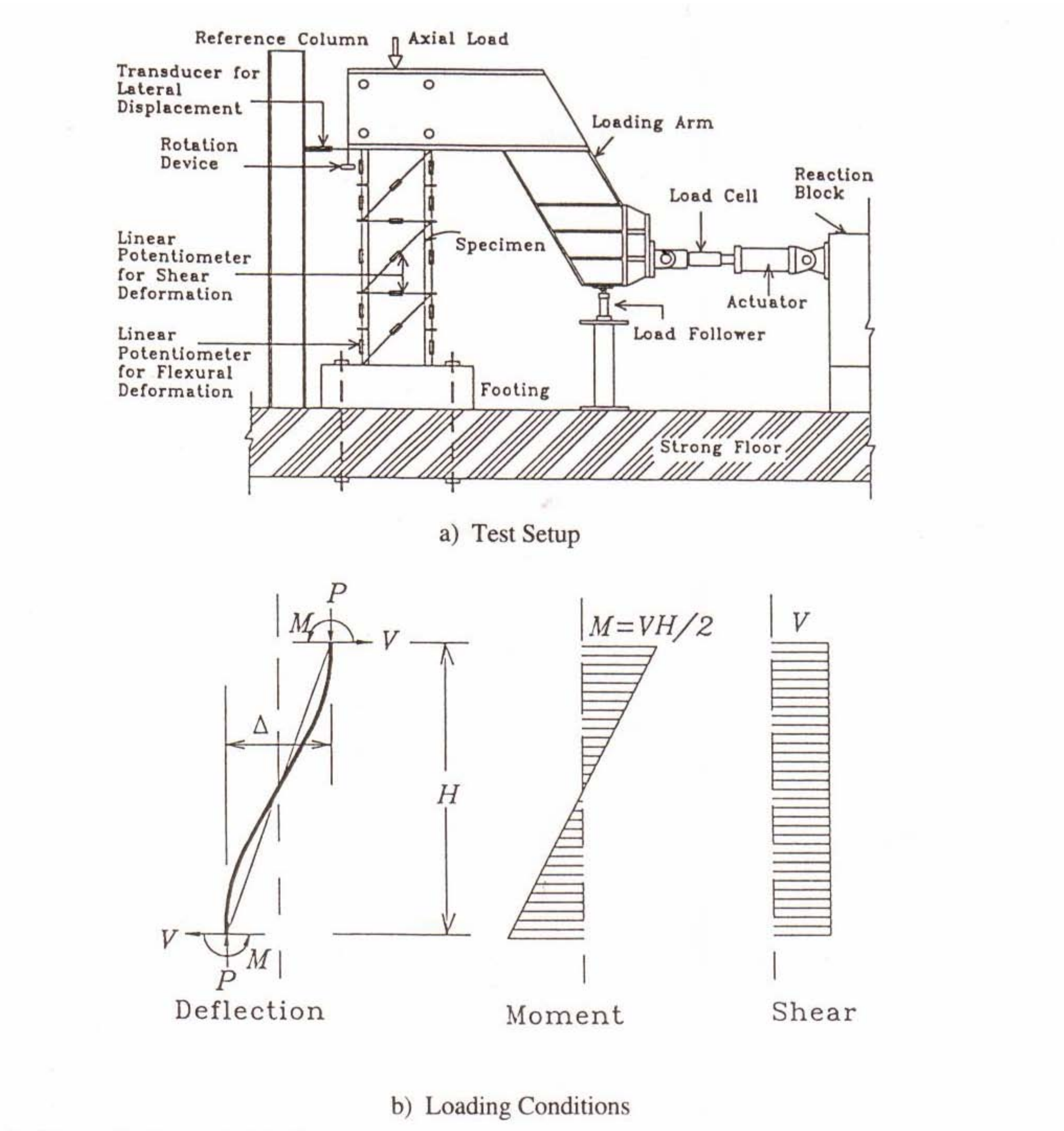


Figure 167
Test Setup for Shear-Dominated Columns
Source: Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 371.

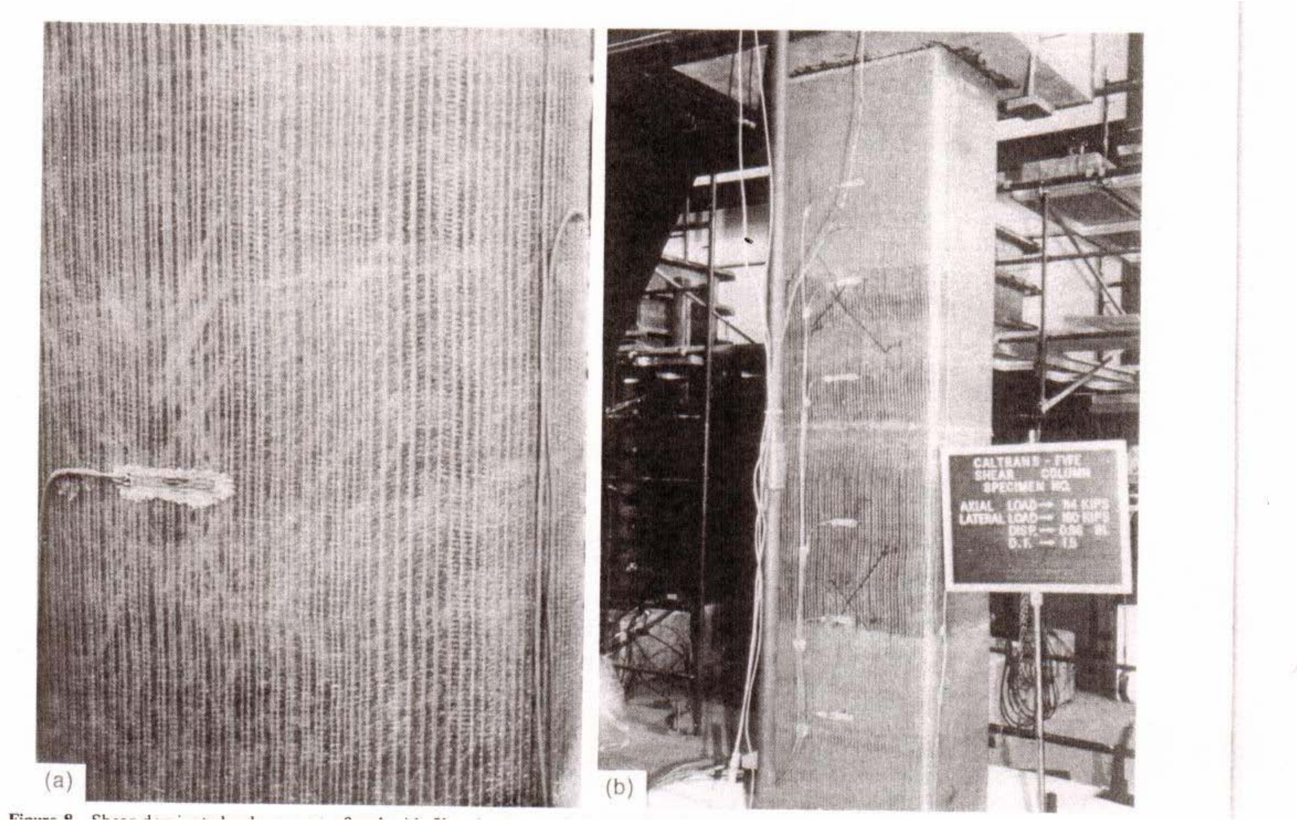


Figure 168

Shear-Dominated Columns Retrofitted with Fibreglass/Epoxy Jackets

Source: Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 372.

Masonry walls are also examined, using this technique for repair (see Figures 169 and 170).

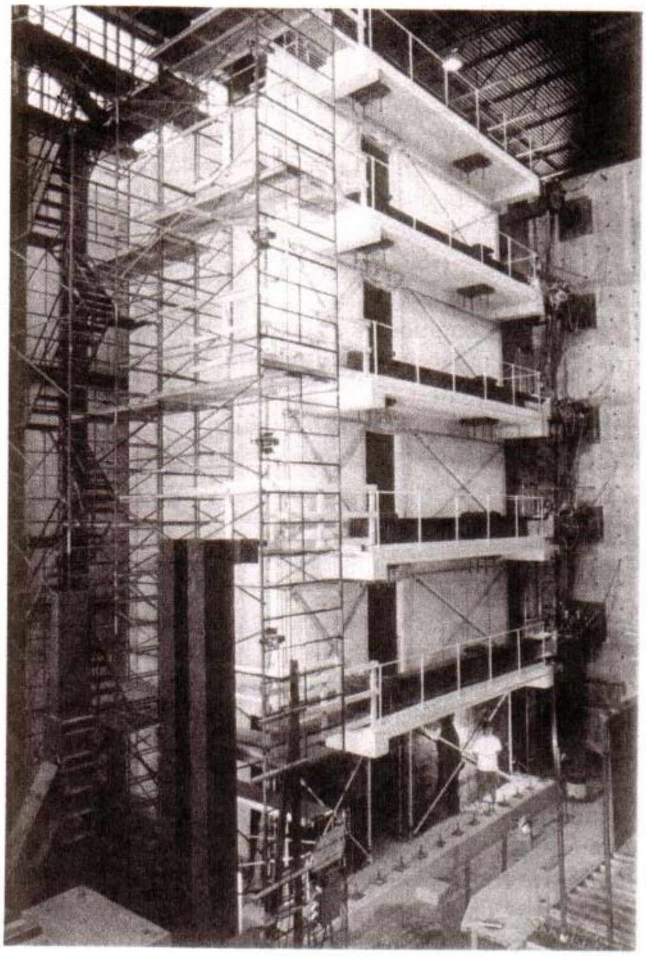


Figure 169
View of Full Scale Five Storey Carbon Overlay Repair Test
Source: Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 375.

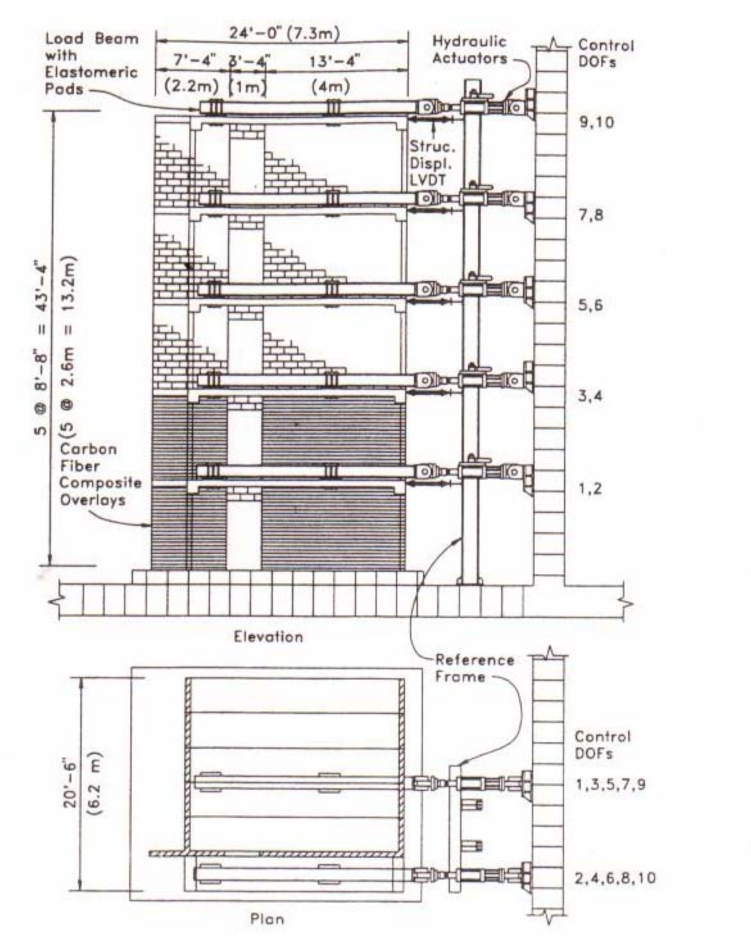


Figure 170
Repaired Five Storey Masonry Research Building
Source: Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 375.

This showed that a single layer of the carbon fabric overlay applied to each side of the structural walls "contributed significantly to doubling the inelastic deformation capacity."[aaaa] Shear deformations were halved following repair. This study demonstrates that composite material jackets are extremely effective in both retrofit and repair situations as well as being economically competitive. This is a technique relevant to this report as it may prove useful at a smaller scale in dwelling retrofit, where piles are damaged or foundation walls would be inadequate in their performance in a seismic event.

Radford, DW and Van Goetham, D and Gutkowski, RM and Peterson, ML. *Composite Repair of Timber Structures*. In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2002, vol 16, pp 417-425.

[aaaa] Priestley, MJN and Seible, F. *Design of Seismic Retrofit Measures for Concrete and Masonry Structures.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 1995, vol 9, iss 6, p 375.

This article examines a study conducted aiming to improve damaged railroad bridge span timbers by inserting pultroded composites.[bbbb] Fibreglass pultroded rods are inserted from the bottom to the top of the beam in areas of damage. Adhesive is used to bond the reinforcing rods to the timber and also to fill adjacent cracking in the beam.

Drawbacks of prior repair strategies are analysed in the article, including "replacement of timbers, epoxy repair approaches, the addition of reinforcing plates to the sides of exposed timbers, and the addition of a fibreglass wrap (bandage) around damage locations."[cccc] Unfortunately, each of these methods had drawbacks, such as the fibreglass wrap can only be applied to exposed timbers and the structural performance of plates degrades over time.

The proposed repair strategy uses a high performance, low cost material which can be readily bonded to wood (see Figure 171). The testing method is outlined and described in detail and the results discussed (see Figure 172).

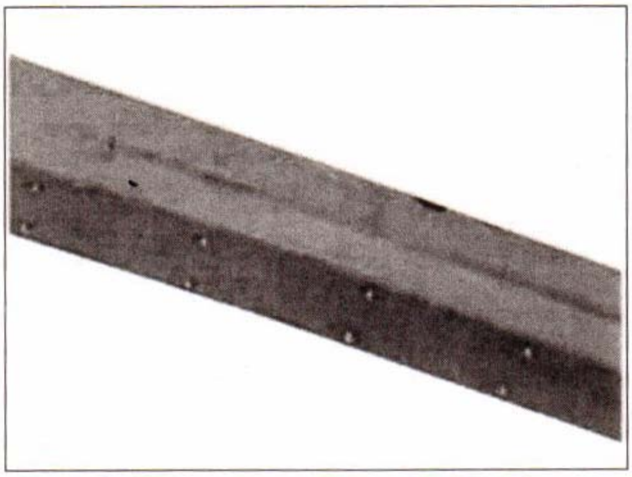


Figure 171
Proposed Shear Spike Repair Concept
Source: Radford, DW and Van Goetham, D and Gutkowski, RM and Peterson, ML. *Composite Repair of Timber Structures*. In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2002, vol 16, p 419.

[bbbb] Radford, DW and Van Goetham, D and Gutkowski, RM and Peterson, ML. *Composite Repair of Timber Structures*. In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2002, vol 16, p 417.

[cccc] Radford, DW and Van Goetham, D and Gutkowski, RM and Peterson, ML. *Composite Repair of Timber Structures*. In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2002, vol 16, p 418.

Failure performance test results

Category	Sample	Modulus (GPa)	Strength (MPa)	Strain (%)
2×4 Baseline beam	B5	10.2	50.84	0.57%
	B6	10.4	74.08	0.98%
	B7	8.92	63.55	0.97%
2×2 Nails (only)	2	5.34	43.19	1.22%
	3	3.97	46.79	1.98%
	5	2.80	33.71	1.51%
2×2 Fiberglass rods	F6	6.57	33.27	1.13%
	F4	8.01	45.22	1.39%
	F3	5.70	43.19	1.22%
2×2 Fiberglass shear plates	P7	8.70	55.46	0.71%
	P8	10.7	63.70	0.65%
	P16	10.2	67.98	0.82%
2×2 Epoxy-bonded	9	8.12	44.46	0.59%
	10	7.15	52.01	0.74%

Figure 172
Failure Performance Test Results
Source: Radford, DW and Van Goetham, D and Gutkowski, RM and Peterson, ML. *Composite Repair of Timber Structures*. In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2002, vol 16, p 422.

The results of this experiment indicate that the fibreglass insertions recapture "both stiffness and strength of the undamaged material. Enhanced repair performance is directly related to the number and position of the shear reinforcing rods."[dddd] The addition of the epoxy adhesive further increases the success and performance of the repair, and improves stiffness and strength in areas of damage. The combination of fibreglass insertions and epoxy is substantially more effective than either method applied alone.

Although this is a method designed for very deep beams, it has potential for application in seismic retrofitting of dwelling subfloors where beams or joists have been damaged but cannot be removed and replaced. On a smaller scale this method represents a retrofit repair able to reinstate the original strength and stiffness of the member.

Saiid Saiidi, M and Sanders, David and Acharya, Suresh. *Seismic Retrofit of Spread Footings Supporting Bridge Columns with Short Dowels.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2001, vol 15, iss 4.

[dddd] Radford, DW and Van Goetham, D and Gutkowski, RM and Peterson, ML. *Composite Repair of Timber Structures*. In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2002, vol 16, p 425.

This article reports on a study developing and testing a seismic retrofit method for bridge spread footings. This retrofit included "the enlargement of plan view and dimensions and the thickness, addition of top steel and placement of dowels to connect the existing and new concrete. The column to footing connection was retrofitted with a steel jacket connected to the footing by bolts."[eeee] The testing program is outlined and the response of the retrofitted column discussed (see Figure 173).

Comparison of the as-built and retrofitted footing response under column load of 756 kN (170 kips)

	as-built footing	Retrofitted footing
Ratio of measured footing to column flexural capacity	0.73	1.21
Maximum footing bar strain (microstrains)	5200	2100
Drift capacity (%)	3.4	7.8

Figure 173
Comparison of Footings
Source: Saiid Saiidi, M and Sanders, David and Acharya, Suresh. *Seismic Retrofit of Spread Footings Supporting Bridge Columns with Short Dowels.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2001, vol 15, iss 4.

This retrofitted detail was successful in reducing damage in the footing. The footing strength and deformation capacity increased and the damage was minimised. Although this study documents the retrofit of a bridge foundation, some of the techniques applied may prove useful in the retrofit of dwelling foundations in New Zealand.

Sadakata, K and Wang, H and Hokosawa, S. *Wooden Frame Structure Constructed by New Type Connector.* In Pacific Timber Engineering Conference, Timber Research and Development Advisory Council, Australia, 1994, vol 2, pp 785-794.

This conference paper describes a new joint, named TEMBIN-KAMA Joint, and its use in portal frame structures. This portal frame test is a single storey portal frame, on span length is 500cm,

[eeee] Saiid Saiidi, M and Sanders, David and Acharya, Suresh. *Seismic Retrofit of Spread Footings Supporting Bridge Columns with Short Dowels.* In Construction and Building Materials, Elsevier Science Ltd., United States of America, 2001, vol 15, iss 4.

storey height is 340cm. The column base is fixed to a concrete foundation through a base plate.[ffff] This detail (see Figure 174) was developed from a traditional Japanese jointing method, and a comparison is conducted between this jointing method and conventional web-type and flange-type connecting styles.

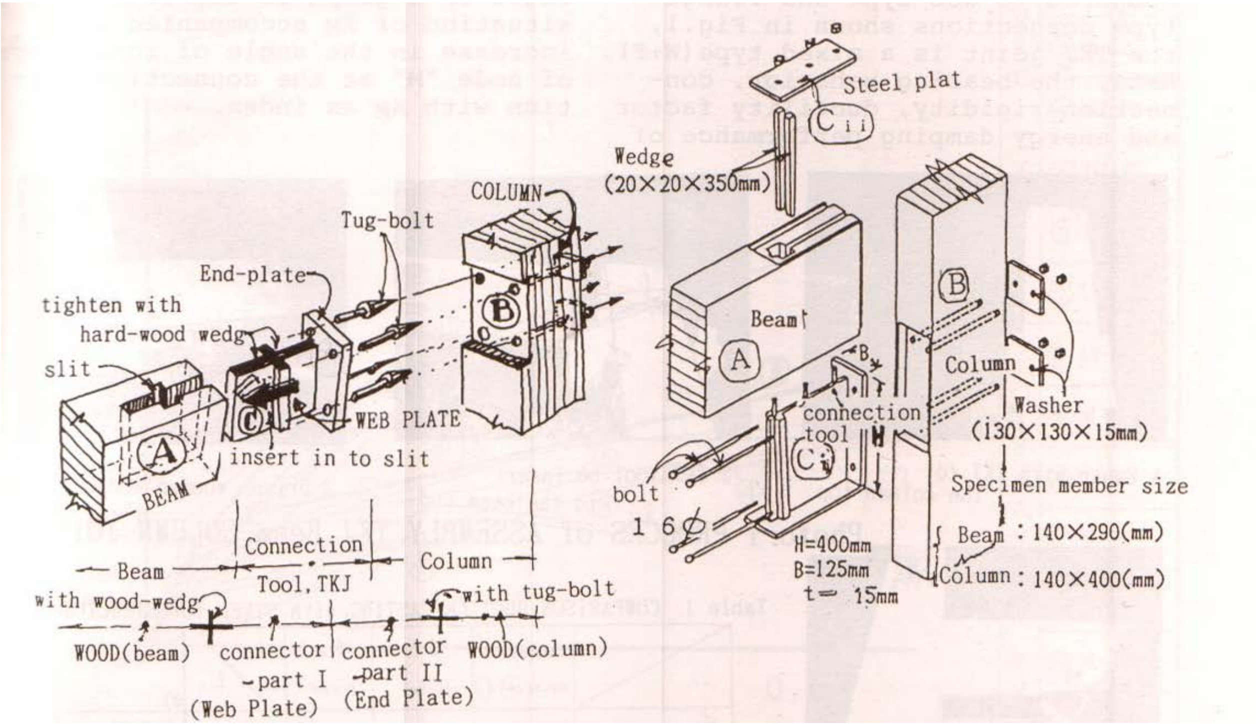


Figure 174
Mechanical Conception of New Connector (left) and Detail of New Connector (right)
Source: Sadakata, K and Wang, H and Hokosawa, S. *Wooden Frame Structure Constructed by New Type Connector.* In Pacific Timber Engineering Conference, Timber Research and Development Advisory Council, Australia, 1994, vol 2, p 787.

The results of the testing show that this new connector can "provide all the ductility factor, … moment resistance rigidity, … and rigid connected factor… which are equal to or higher than the previous values obtained [by the conventional connectors]."[gggg] This conference paper reinforces the notion of exploration in detailing and development of new solutions, which is closely in line with seismic retrofitting of dwelling subfloors and foundations.

Scoggins, John. *Seismic Support for Old Foundations*. In Journal of Light Construction, Builderburg Partnership, Washington, DC, 1991, pp 42-45.

This article begins by introducing the need to strengthen existing wood framed dwellings in the California area. Recent earthquakes heightened this need by highlighting the poor condition of the dwellings, particularly in the foundations. The author notes that in some cases, "it is just a matter of time before the whole house is sitting on the ground."[hhhh]

[ffff] Sadakata, K and Wang, H and Hokosawa, S. *Wooden Frame Structure Constructed by New Type Connector.* In Pacific Timber Engineering Conference, Timber Research and Development Advisory Council, Australia, 1994, vol 2, p 785.
[gggg] Sadakata, K and Wang, H and Hokosawa, S. *Wooden Frame Structure Constructed by New Type Connector.* In Pacific Timber Engineering Conference, Timber Research and Development Advisory Council, Australia, 1994, vol 2, p 794.
[hhhh] Scoggins, John. *Seismic Support for Old Foundations*. In Journal of Light Construction, Builderburg Partnership, Washington, DC, 1991, pp 42-43.

Foundations are first evaluated by drilling a test whole in the concrete, block, brick or stone to test if the material is strong enough to support a bolt. Connections are then examined, followed by damage to wooden members. If a cripple wall is present it must have panel sheathing for bracing and adequate connections. Selection of connectors for retrofit is important. A firm masonry foundation that has good accessibility but poor anchors may be retrofitted by drilling holes through the plates into the foundation, inserting lengths of steel rod, epoxied into place (see Figure 175). Epoxy is ideal as expansion bolts may crack the older, more brittle concrete.

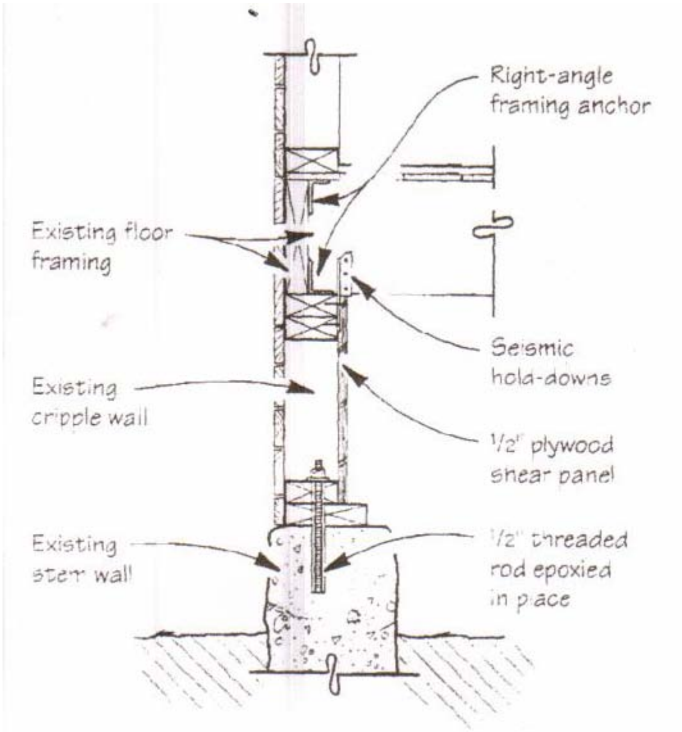


Figure 175
Where there is good access, the least expensive retrofit involves threaded rod anchors epoxied into place, plywood shear panelling, and framing anchors between the top of the cripple wall and the floor framing
Source: Scoggins, John. *Seismic Support for Old Foundations.* In Journal of Light Construction, Builderburg Partnership, Washington, DC, 1991, p 43.

Once the anchors and bolts are in place, structural sheathing can be installed around the cripple wall and at the sides of any access doors or vent openings, in accordance with guidelines provided by the city of Santa Barbara.[iiii] The length of each panel should also be at least twice its height. Three-inch holes are then drilled into the plywood at the top and bottom of each bay for ventilation. These are covered with hardware cloth. A Simpson H1s or H5s is then installed to secure the cripple wall to every second joist.

In limited access retrofits, where 2x12 joists are used there will be enough space to use a Hilti TE15 right angle hammer drill. A Simpson RFB retrofit bolt or epoxied threaded rod anchor can then be installed. Where the joists are smaller, a Simpson FA6 or FA8 can be used, an "L-shaped 12-gauge steel connector that rests on top of the plate and laps over the side of the stem wall."[jjjj]

When the foundation is not strong enough to hold bolts, a new concrete stem wall will be poured (see Figure 176). Four rebar dowels are drilled and places in the old stem wall at 4' centres. New cripple walls can then be installed around the perimeter and bolted to the foundation. Metal brackets connect the floor joists to the cripple walls.

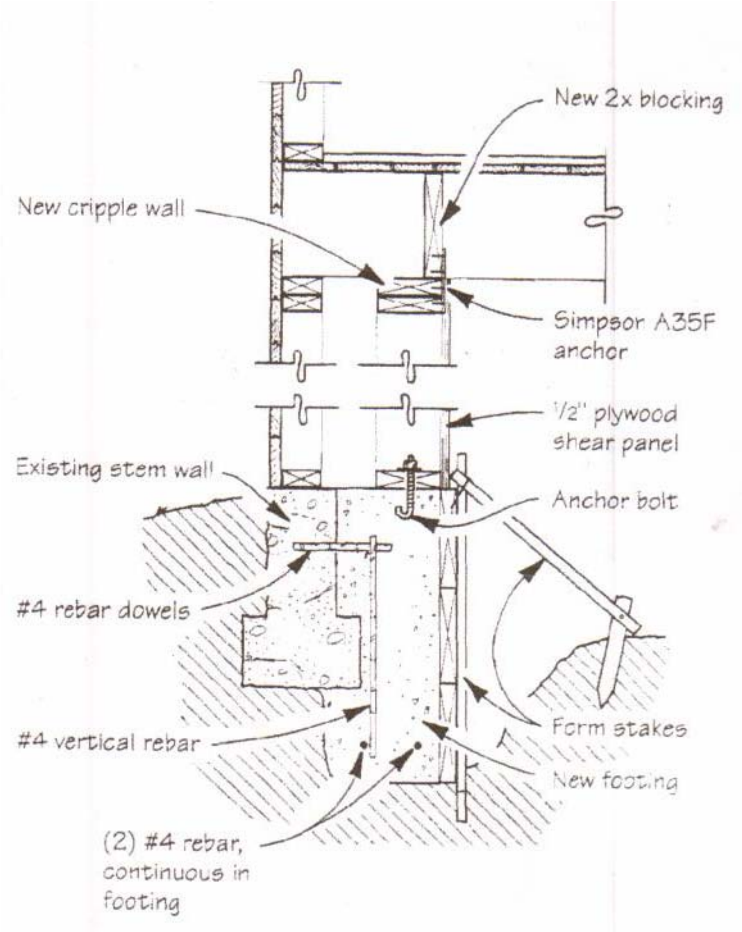


Figure 176
Pouring a New Stem Wall
Source: Scoggins, John. *Seismic Support for Old Foundations*. In Journal of Light Construction, Builderburg Partnership, Washington, DC, 1991, p 44.

[iiii] Scoggins, John. *Seismic Support for Old Foundations*. In Journal of Light Construction, Builderburg Partnership, Washington, DC, 1991, p 44.
[jjjj] Scoggins, John. *Seismic Support for Old Foundations*. In Journal of Light Construction, Builderburg Partnership, Washington, DC, 1991, p 44.

When a dwelling is supported on posts and piers, anchors are rarely present and posts attached to the above girders with only nails. Here, a possible retrofit measure is to install new pier footings between existing posts and replace any posts located under girder splices (see Figure 177). Simpson H-series clips are used to tie the floor joists to the girders.

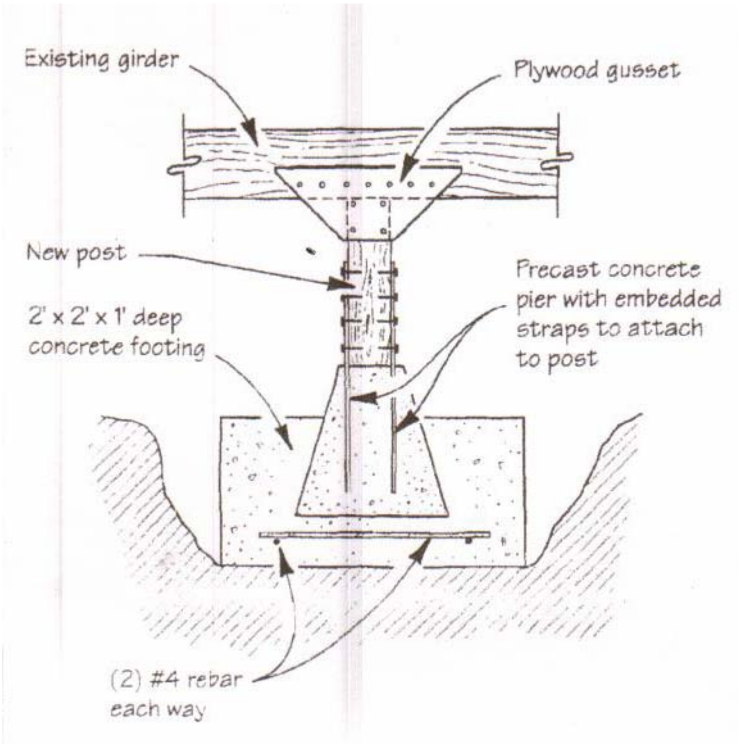


Figure 177
Reinforced Post Footing
Source: Scoggins, John. *Seismic Support for Old Foundations.* In Journal of Light Construction, Builderburg Partnership, Washington, DC, 1991, p 45.

This article presents a clear and concise retrofit measure as applied in the California area. The connectors used and the process is thoroughly detailed and may prove useful in New Zealand masonry wall foundations and jack stud foundations.

Shelton, R. *Masonry Veneer Wall Ties.* In Pacific Timber Engineering Conference, Timber Research and Development Advisory Council, Australia, 1994, vol 1, pp 298-307.

This conference paper presents a test method for masonry veneer ties to assess their compliance with the building code in terms of their seismic performance. The purpose of a veneer tie is outlined, including preventing transfer of external moisture; allowing in-plane differential movement between veneer and frame; avoiding cracking of the veneer; restraining the veneer from being dislodged under seismic action; and being economical to produce and efficient to install.[kkkk] The test method setup is outlined and the veneer tie is subjected to axial tension and compression loading, shear loading and in-plane loading through a series of cyclic displacements. A detailed outline of each of these measures is documented as well as how to determine the properties of

[kkkk] Shelton, R. *Masonry Veneer Wall Ties.* In Pacific Timber Engineering Conference, Timber Research and Development Advisory Council, Australia, 1994, vol 1, p 299.

individual specimens. Although this conference paper does not cover seismic retrofit, it does reinforce the importance of connections, durability and fitness for purpose which aligns closely with seismic retrofit for dwelling subfloors and foundations.

Shih, J and Ju, S and Rowlands, RE. Stress Analysis of Bolted Wood Connections. In Pacific Timber Engineering Conference, Timber Research and Development Advisory Council, Australia, 1994, vol 2, pp 676-679.

This conference paper explores the stresses in a single-bolted connector of Douglas fir. Bolted connectors are common in timber construction but also a common site of structural failure. The properties of Douglas fir are outlined, and followed by a description of two techniques to determine stresses in a bolted connection: Moire Analysis and Finite Element Analysis. The results of the study illustrate that stresses in the region of contact between the bolt and the wood are affected by friction, which is influenced by relative geometry. A computer based calculation can be used to assess the stresses for individual situations. This sturdy is relevant to this report as it is important to understand the forces experienced in bolted joints as these are common in a retrofit situation where nail plates are inadequate.

Slade, Graham P. ***Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.*** **Thesis, Victoria University of Wellington, Wellington, 1979.**

This thesis covers an extensive study of earthquakes in New Zealand, beginning with a history of earthquakes, early New Zealand earthquakes and major New Zealand earthquakes. This is then developed into several sections related to construction, including *Conference on 'The Use of Timber in Building Construction'*; *Early 20th Century Earthquakes*; *The First New Zealand Standard*; *New Zealand Standard 1900*; and then a section *A Code for the Future*. In this section an analysis of the San Fernando Valley, USA, earthquake of 1971 and the damage incurred was conducted. The damage was due to insufficiency of walls with enough rigidity to resist horizontal forces, improper or insufficient connection of studs to sill plates, rotation in the plane of the wall, uplift of the entire wall, outward movement of the wall and use of short or cripple studs (called jack studs in New Zealand).[llll] These types of damage can, too, be expected to occur in New Zealand earthquakes. Braces are then examined, with the most probable failure being a lack of braces, although fixing of braces tends to be a point of failure and the angle often too steep resulting in failure (see Figure 178 and 179).

[llll] Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, pp 69-70.

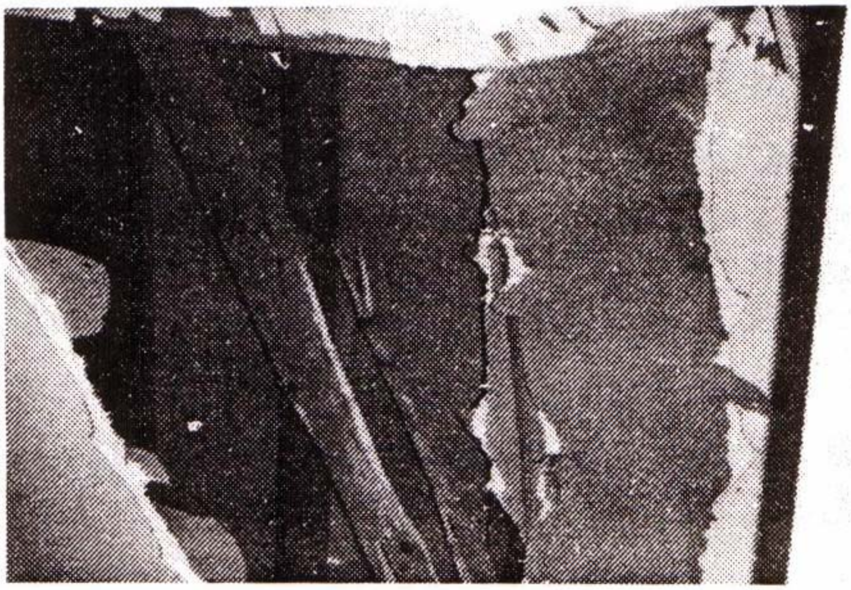


Figure 178
Failure of Diagonal Bracing in Tension
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, p 71.

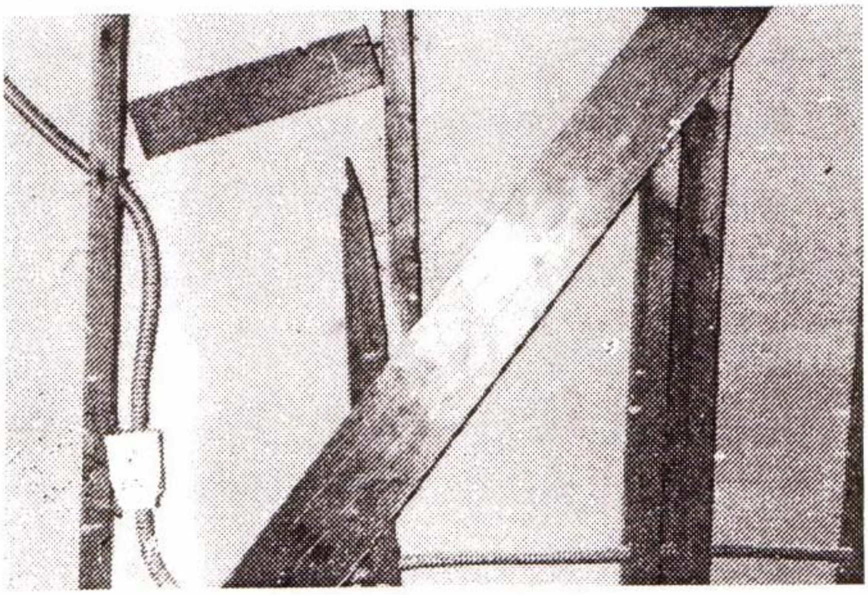


Figure 179
Failure of Diagonal Bracing Through Pullout – result of inadequate fixing
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, p 71.

Many of the houses damaged in the 1971 San Fernando earthquake are similar in construction to New Zealand houses.[mmmm] Thus, similarities in damage will occur (see Figures 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192 and 193). This reiterates the need for retrofit details to increase seismic performance in houses here in New Zealand.

[mmmm] Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, p 73.

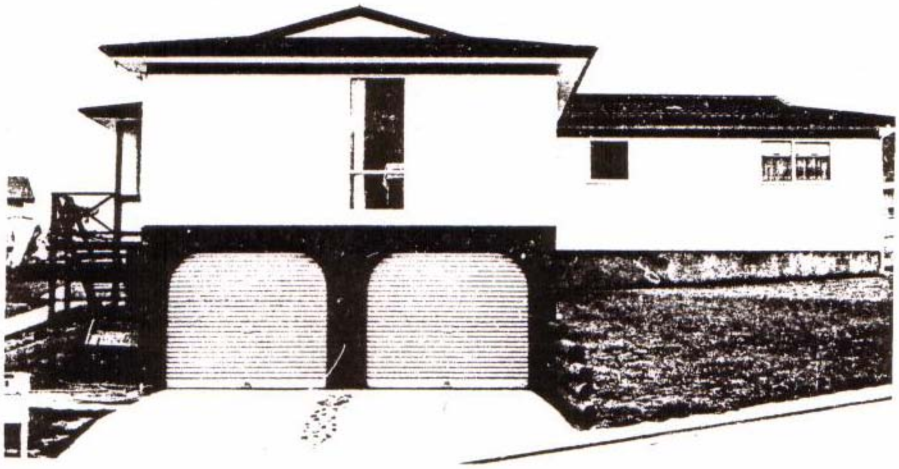


Figure 180
Split Level House in Wellington
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, p 73.

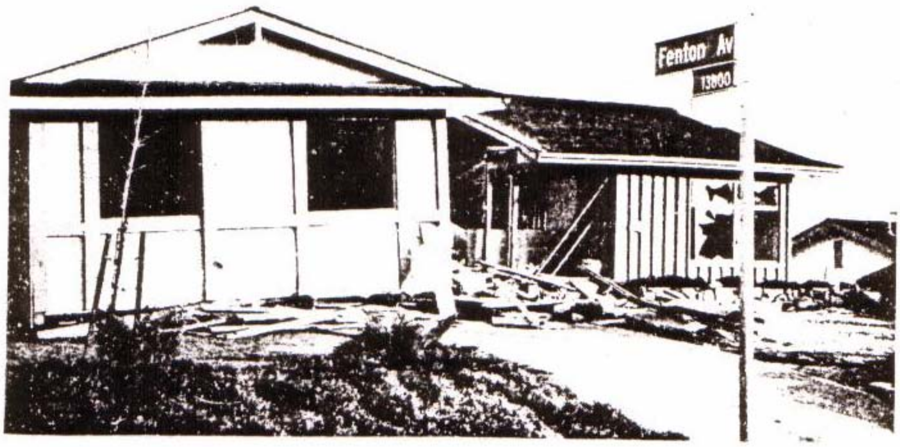


Figure 181
Split Level House in San Fernando: The top storey of this house collapsed to the ground. The double garage door below provided inadequate bracing to the front wall
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, p 73.

Figure 182
Split Level House in Wellington
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report*. Thesis, Victoria University of Wellington, Wellington, 1979, p 74.

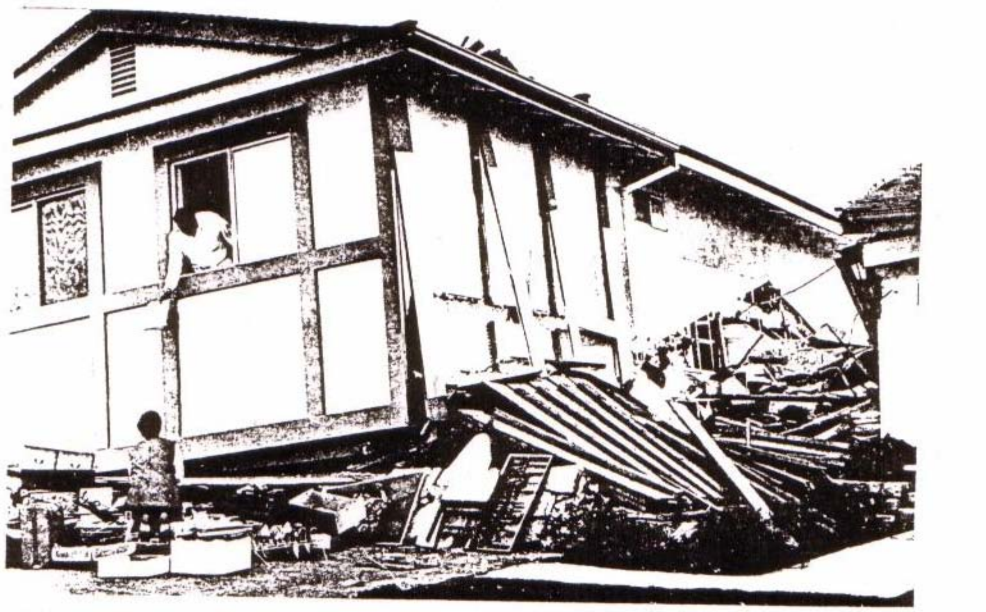


Figure 183
Split Level House in San Fernando: Double garage doors below cause failure
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report*. Thesis, Victoria University of Wellington, Wellington, 1979, p 74.

Figure 184
Split Level House in San Fernando: Double garage doors below cause failure
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, p 74.

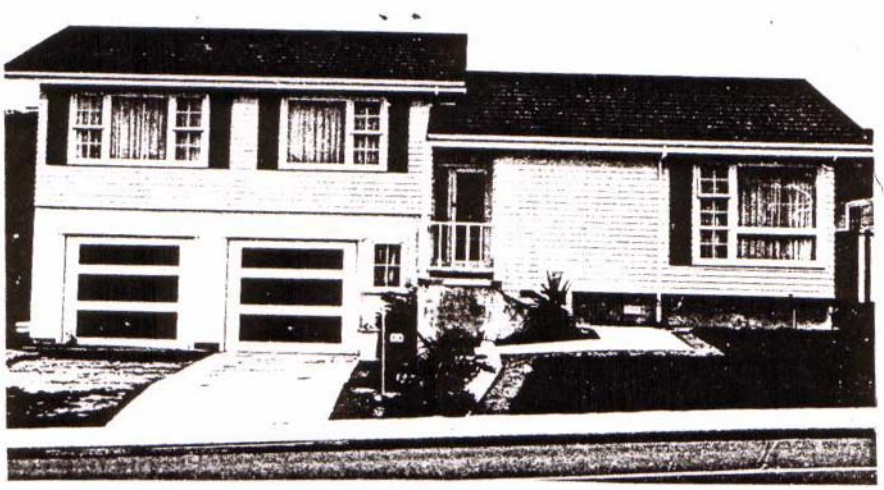


Figure 185
Split Level House in Wellington
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, p 75.

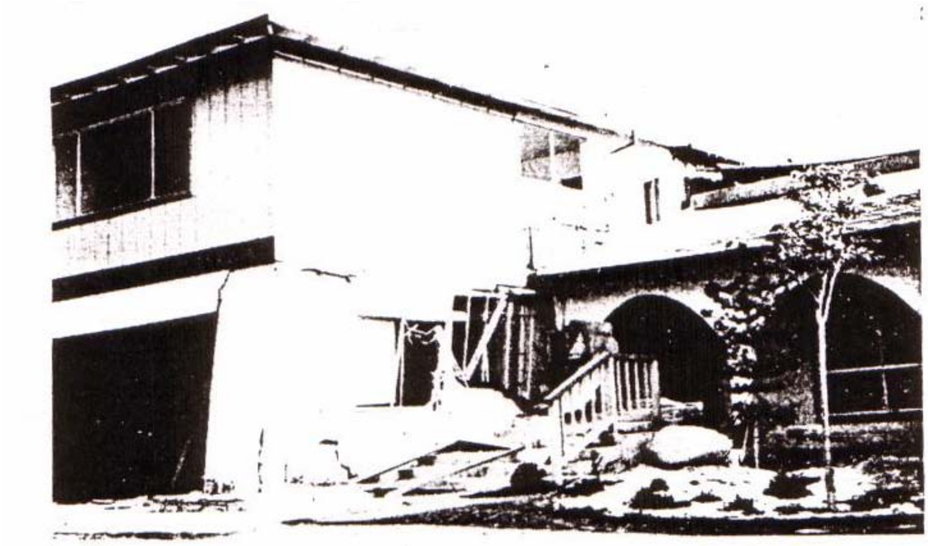


Figure 186
Split Level House in San Fernando
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, p 75.

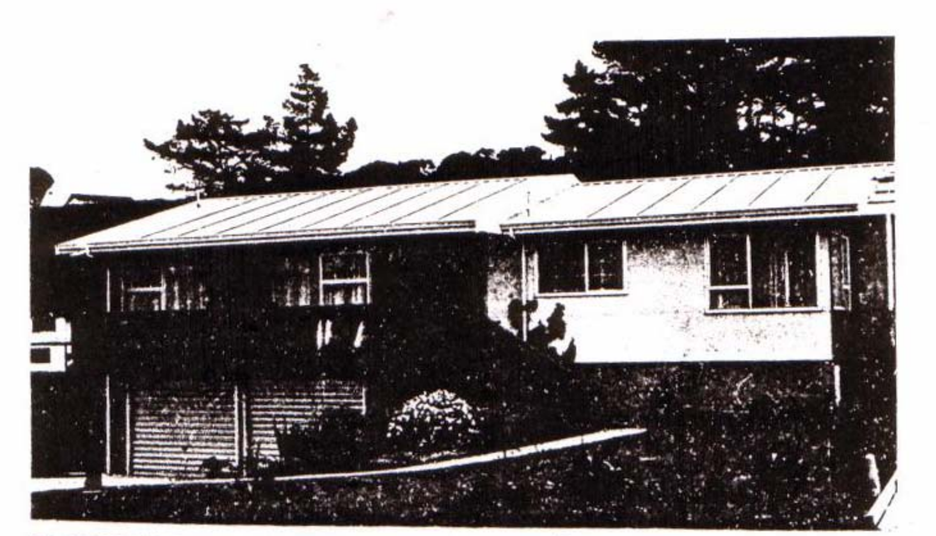


Figure 187
Split Level House in Wellington
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, p 75.

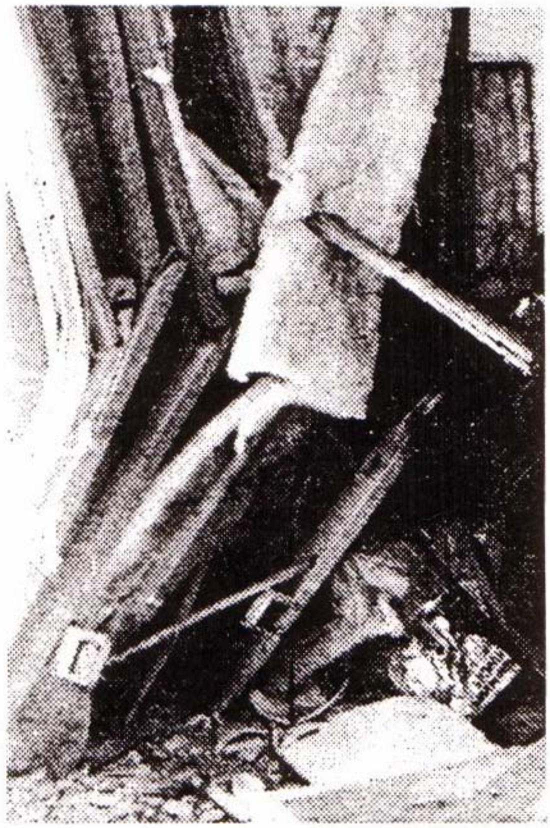


Figure 188
Detail of Damage to the Front Wall of a Double Garage
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report*. Thesis, Victoria University of Wellington, Wellington, 1979, p 76.

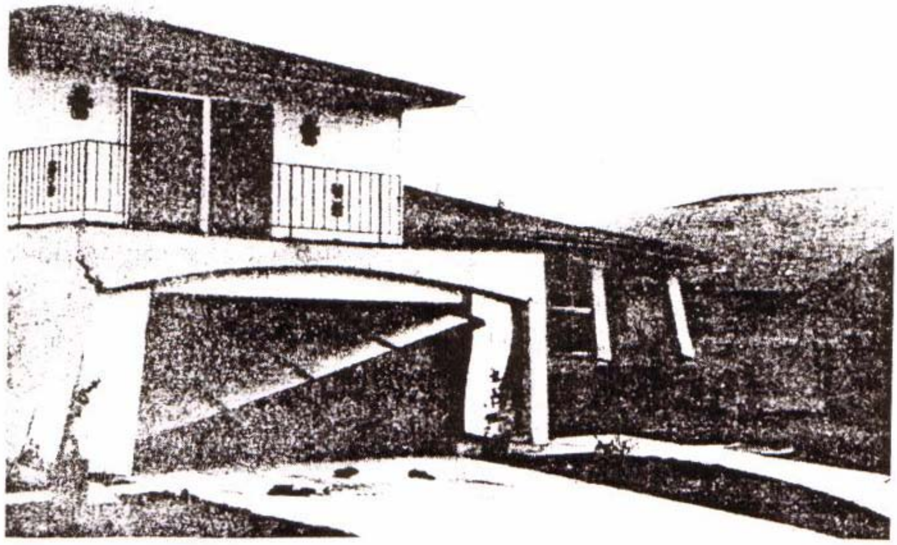


Figure 189
Damage to Split level House in San Fernando
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report*. Thesis, Victoria University of Wellington, Wellington, 1979, p 76.

Figure 190
Damage to Split level House in San Fernando
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, p 76.

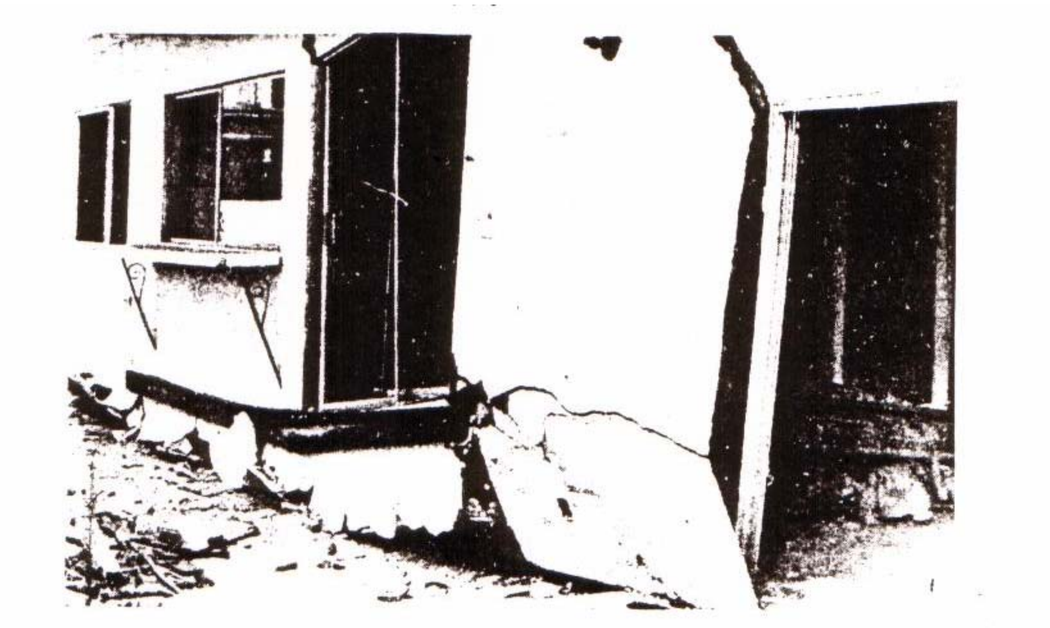


Figure 191
Jackstud Failure: Problems occurring in Murchison in 1929 still occur in San Fernando in 1971
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, p 77.

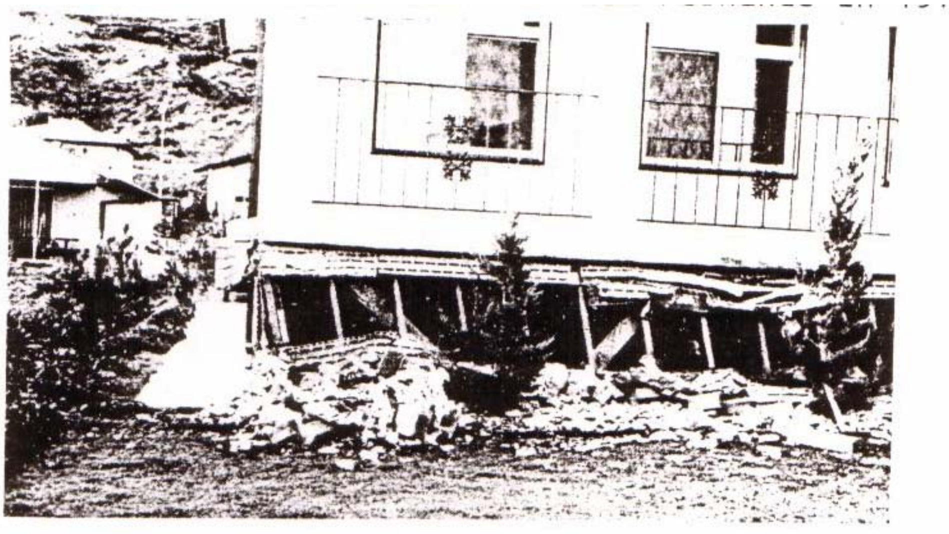


Figure 192
Jackstud Failure
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, p 77.

Figure 193
Failure of Houses Under Construction: Linings provide most wall bracing, lack of lining indicates its importance for bracing
Source: Slade, Graham P. *Domestic Detailing for Earthquakes Past and Present Practice: A Research Report.* Thesis, Victoria University of Wellington, Wellington, 1979, p 77.

Technical Committee B/204. *BS8103: Structural Design of Low Rise Buildings*. BSI, England, 1996, part 3: code of practice for timber floors and roofs for housing.

This resource is divided into three sections including code of practice, annexes and tables. Within *Code of Practice*, areas such as flooring, spans, trussed rafter pitched roofs, flat roof decking and transportation are covered. The tables and annexes provided each relate closely to the topic at hand. Within the section on flooring, loading, materials and fixing recommendations, spans, sizes and spacings are covered, with appropriate tables for member selection. Some typical assembly details are given however these do not relate closely to this report, and as foundations and subfloors are not covered in this standard it becomes a useful resource for design of flooring and roofs but less relevant in terms of seismic retrofit detailing of the dwelling subfloor.

The American Wood Council. *National Design Specification for Wood Construction ASD/LRFD.* American Forest and Paper Association, Inc., United States of America, 2005.

This reference is divided into sixteen chapters covering design provisions and equations, a range of timber products, a range of connection types, shear walls and diaphragms and fire design of wood members. This is supplemented with span tables, spacing requirement tables, bolt selection tables and reference design values tables for various timber members. The resource is useful in terms of design but less relevant to this report examining details for seismic retrofit.

The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes*. Association for Science Documents and Information, Tokyo, 1980, vol 1.

This document is divided into two parts, part one giving data for assessing seismic zone and the engineering design considerations for seismic design, part two covering non-engineered construction. This section examines structural performance of buildings under earthquakes; factors affecting damage; typical damage and failure; earthquake resistant design and construction of buildings; and repair, restoration and strengthening of buildings. Each sub section is then divided into chapters of building areas or elements, such as bearing walls, non-bearing walls, wall connections, frame elements, roofs and floors. Following this buildings in clay mud or adobe are also examined and the structural properties of materials, including structural timber, steel and plain and reinforced concrete. There is a table provided in part two which is relevant to this report detailing categories of damage and their post earthquake actions (see Figure 194). By understanding the consequences of an earthquake, retrofitting and seismic detailing may be better planned and implemented.

	Damage Category	Extent of Damage in General	Suggested Post-Earthquake Actions
0	No damage	No damage	No action required
I	Slight Non-Structural Damage	Thin cracks in plaster, falling of plaster bits, in limited parts.	Building need not be vacated. Only architectural repairs needed.
II	Slight Structural Damage	Small cracks in walls, falling of plaster in large bits over large areas; damage to non-structural parts like chimneys, projecting cornieces, etc.: The load carrying capacity of the structure is not reduced appreciably.	Building need not be vacated. Architectural repairs required to achieve durability.
III	Moderate Structural Damage	Large and deep cracks in walls; widespread cracking of walls, columns, piers and tilting or falling of chimneys. The load carrying capacity of structure is partially reduced.	Building needs to be vacated, to be reoccupied after restoration and strengthening. Structural restoration and seismic strengthening are necessary after which architectural treatment may be carried out.
IV	Severe Structural Damage	Gaps occur in walls; inner or outer walls collapse; failure of ties to separate parts of buildings. Approximately 50 percent of the main structural elements fail. The building takes a dangerous state.	Building has to be vacated. Either the building has to be demolished or extensive restoration and strengthening work has to be carried out before reoccupation.
V	Collapse	A large part or whole of the building collapses.	Clearing the site and reconstruction.

Figure 194
Categories of Damage
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 13.

Strengthening of existing buildings is covered, where the main items related to seismic strengthening are noted as "modification of roofs, substitution or strengthening of floors, planar modifications and strengthening of walls, strengthening of foundations."[nnnn] Repair materials are then covered, including shot-crete to achieve added capability in walls and other elements; epoxy resins for injection into small cracks; epoxy mortar; gypsum cement mortar; quick setting cement mortar; and mechanical anchors to provide shear and tension resistance.[oooo]

[nnnn] The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 58.
[oooo] The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, pp 59-60.

Techniques to restore original strength are then explored. Small cracks can be repaired with pressure injection of epoxy (see Figure 195). This may be of use in a retrofit where foundation walls are damaged or ill-prepared for seismic activity.

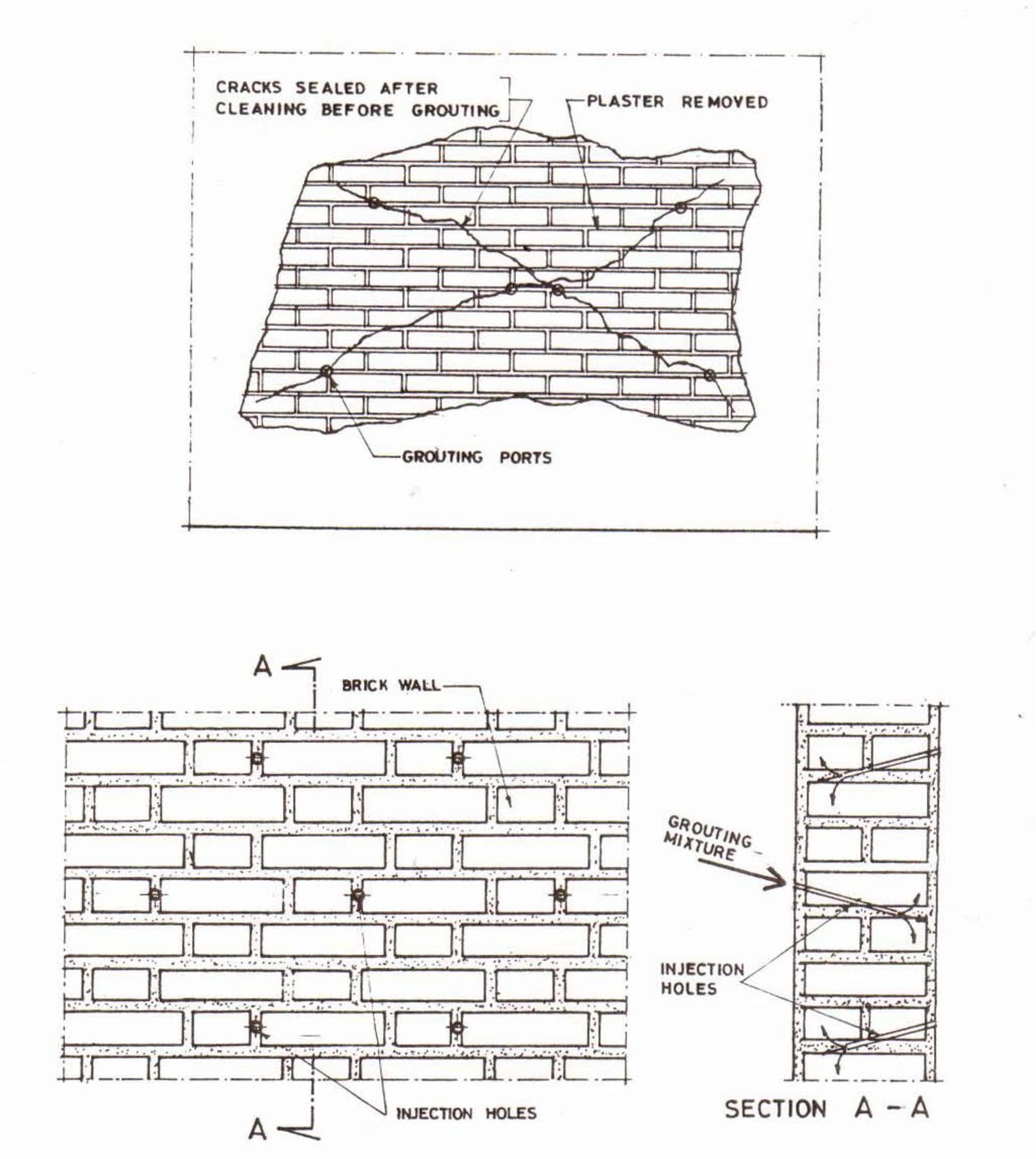


Figure 195
Strengthening of Existing Masonry Wall by Grouting
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 61.

Large cracks can be mitigated with a cover of mortar for protection and reinforcement, or with steel mesh nailed or bolted to the wall.[pppp]

[pppp] The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 62.

Stiffening of existing wooden slabs to increase their seismic performance can be achieved by nailing new planks to the original (see Figure 196) or by placing a new concrete slab (see Figure 197). Connection to the wall must also be considered (see Figure 198).

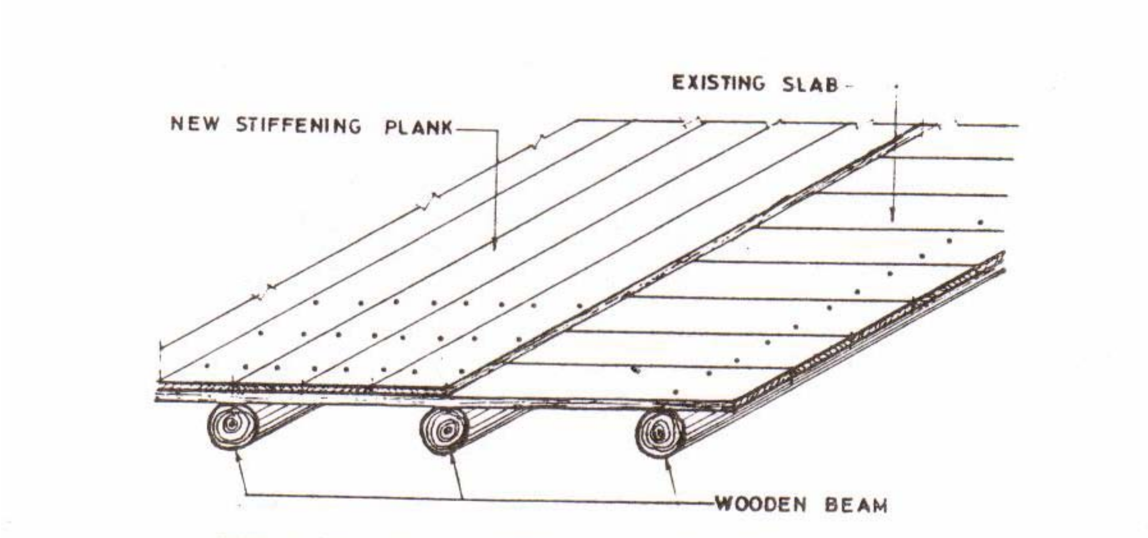


Figure 196
Stiffening of Wooden Floor by Wooden Planks
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 68.

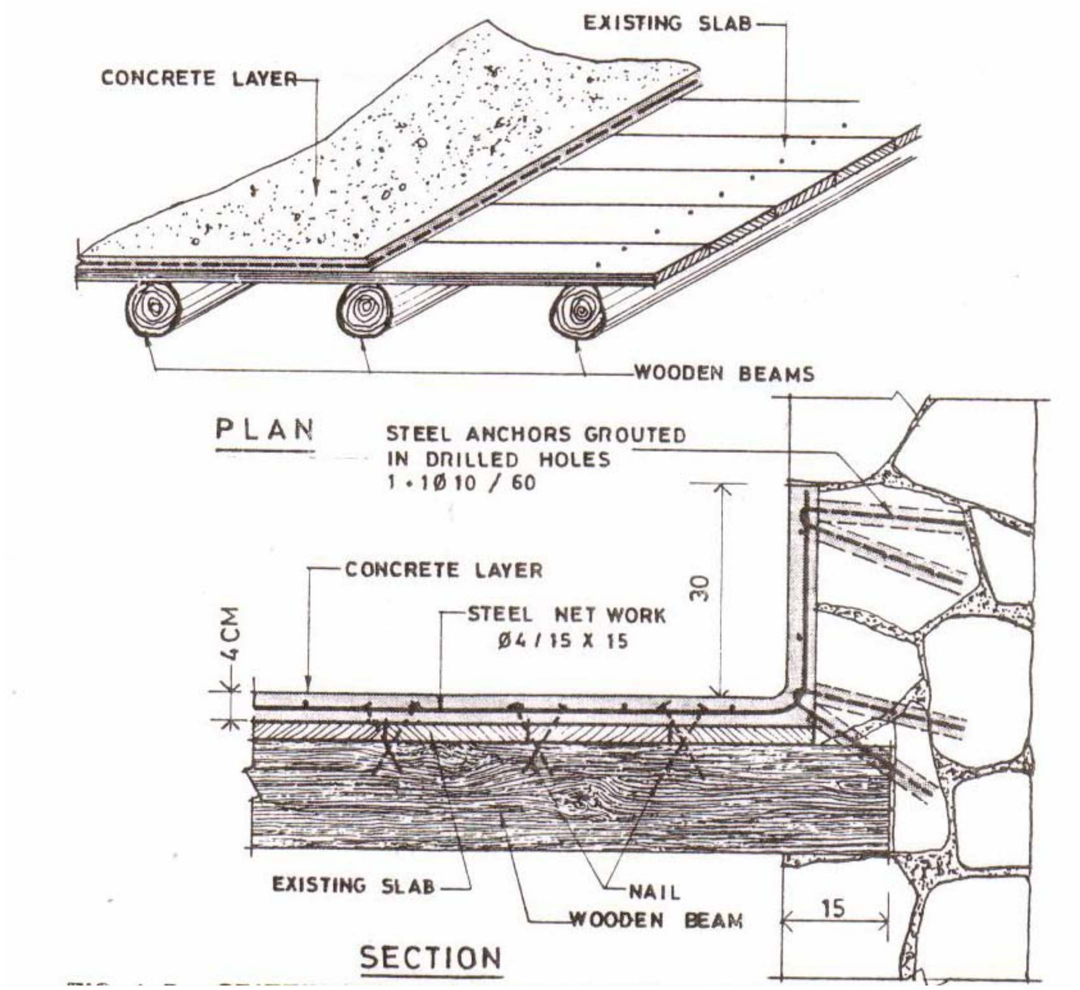


Figure 197
Stiffening of Wooden Floor by Reinforced Concrete Slab and Connection to Wall
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 68.

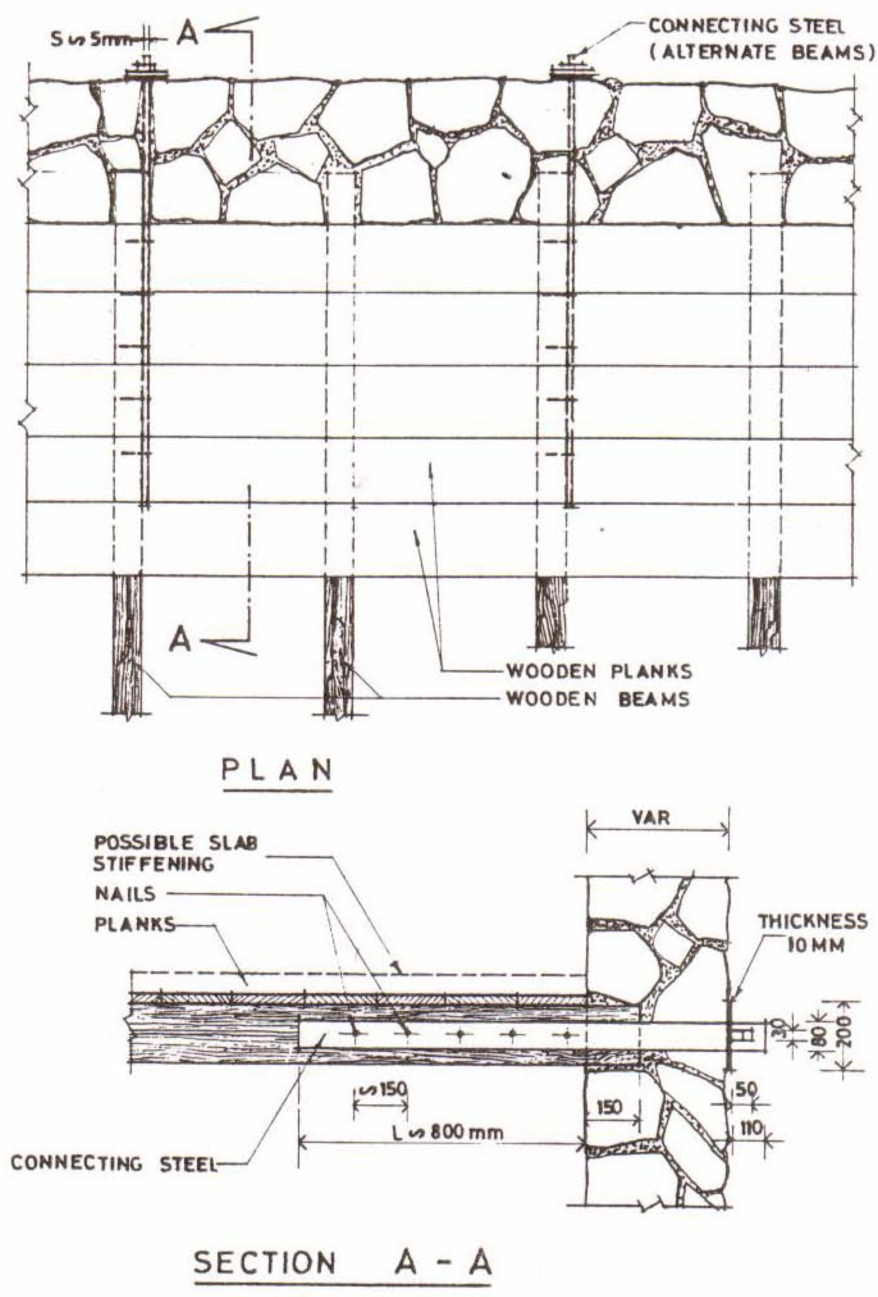


Figure 198
Connection of Floor to Wall
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 69.

Where foundation walls may have poor connections, two steel meshes can be placed on either side of the wall and thick cement mortar applied over top to improve the connection of these walls (see Figure 199).

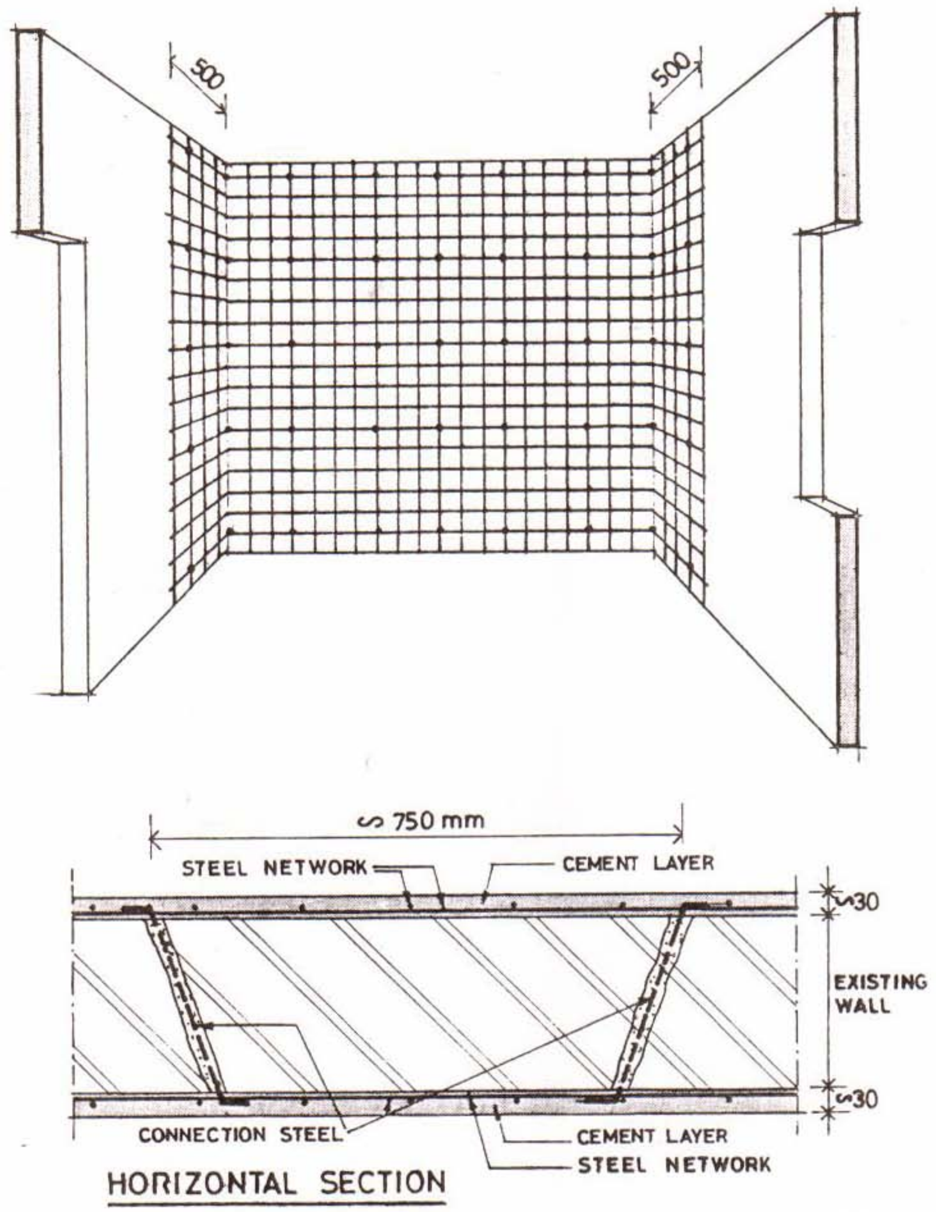


Figure 199
Vertical Reinforced Concrete Covering Plates
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 74.

Prestressing may also be useful to increase shear strength of walls, carried out by placing two steel rods on the two sides of the wall and stretching them by turnbuckles (see Figure 200).

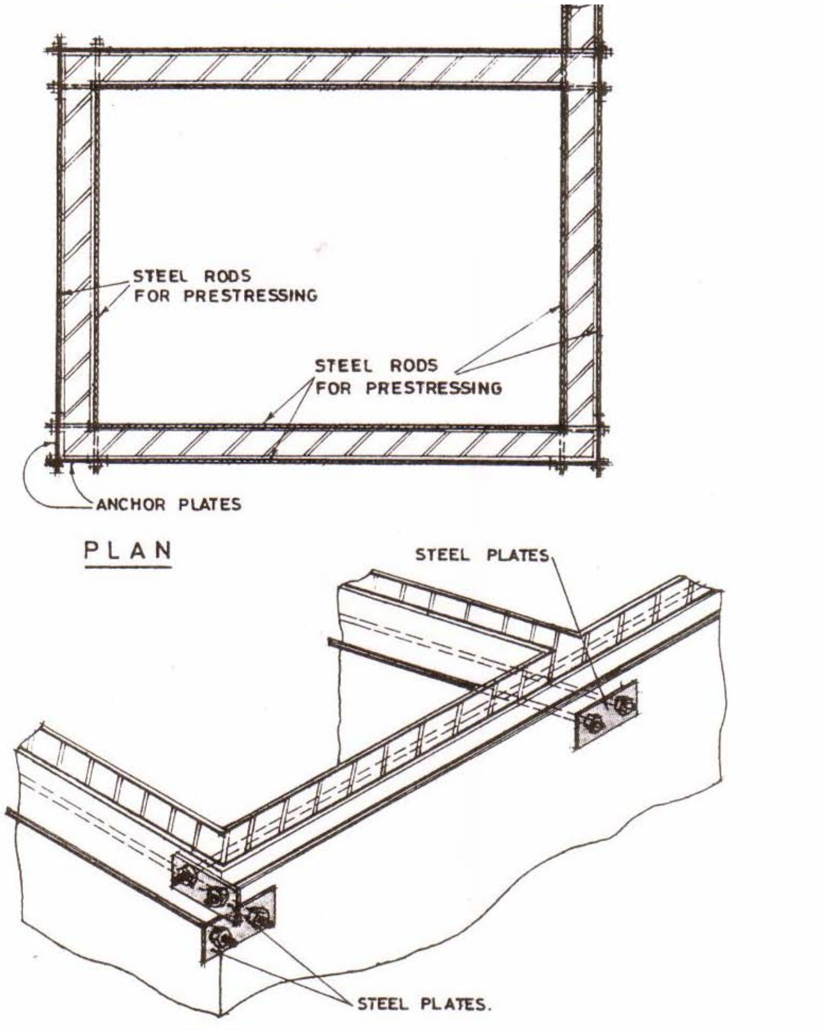


Figure 200
Strengthening of Walls by Prestressing
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 75.

Foundation walls may also be strengthened with reinforced concrete strips (see Figures 201 and 202).

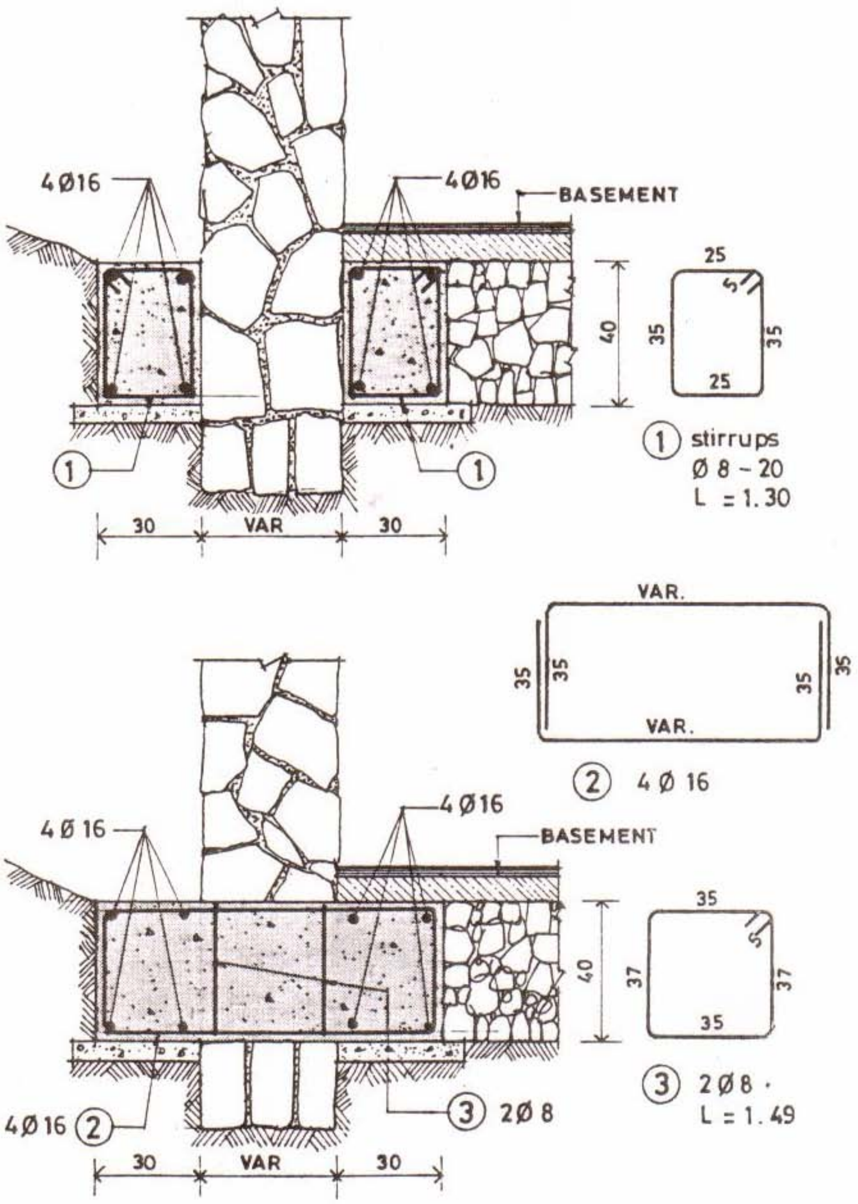


Figure 201
Strengthening of Existing Foundation
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 81.

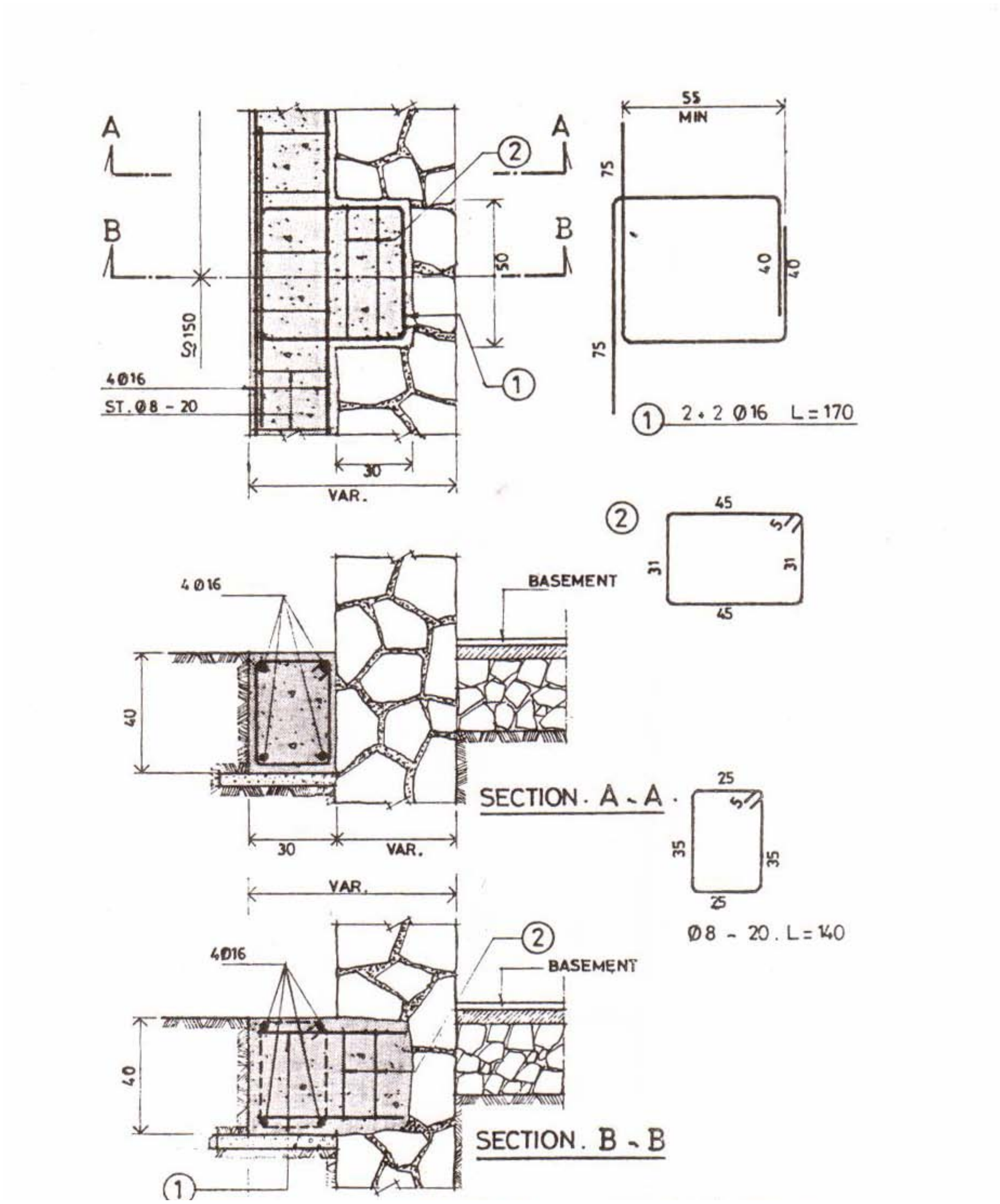


Figure 202
Strengthening of Existing Foundation: Strip on Outside Only
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 82.

Where foundation piles are inadequate and need to be strengthened, jacketing may be used, providing an additional cage of lateral and longitudinal tie reinforcement (see Figures 203 and 204).

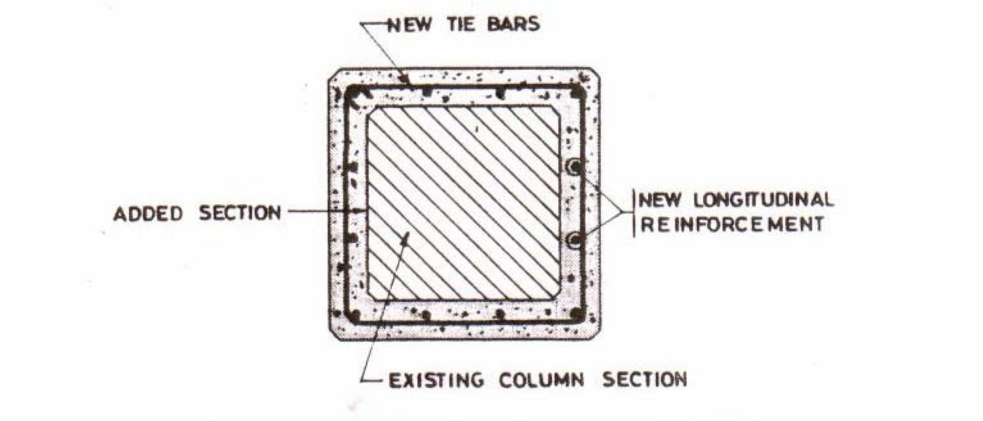


Figure 203
Jacketing a Concrete Column
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 79.

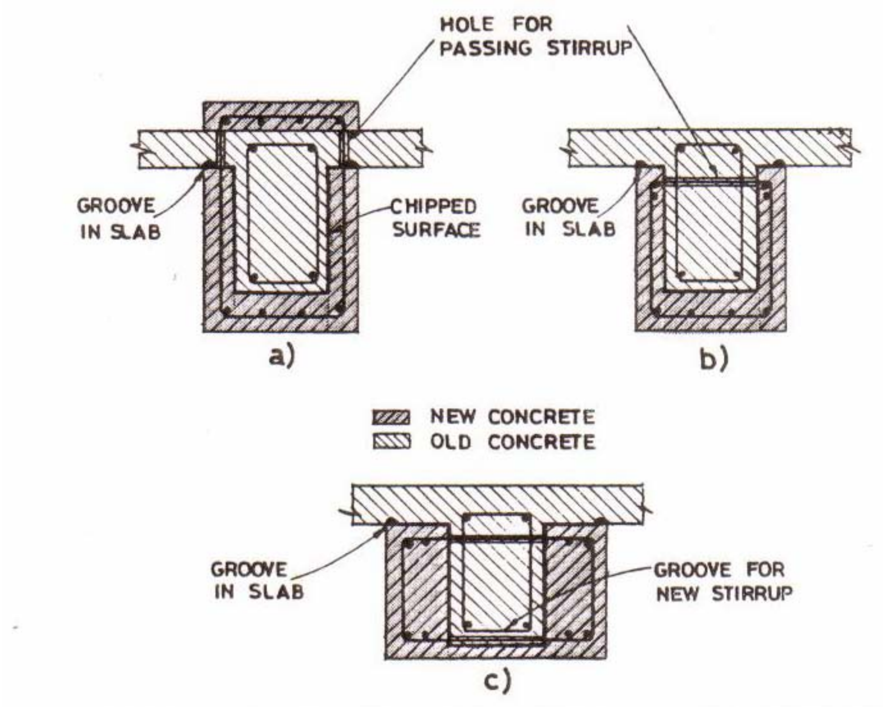


Figure 204
Increasing the Section and Reinforcement of Existing Beams
Source: The International Association for Earthquake Engineering. *Basic Concepts of Seismic Codes.* Association for Science Documents and Information, Tokyo, 1980, vol 1, p 79.

This resource provides a range of possible strengthening techniques for various subfloor and foundation elements, thus it is very relevant to this report.

Thurston, S J. *Design Strength of Various House Pile Foundation Systems*. BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 1993, no. 46.

This study report examines design loads for pile foundations, braced pile design loads and tests common New Zealand pile systems in terms of earthquake and wind loading performance. The test method is documented including testing shallow cantilevered piles bolted to bearers, shallow cantilevered piles fastened to bearers with Type L connectors, shallow cantilevered piles fastened to bearers with Type T connectors, braced piles – brace from pile to pile, and braced piles – brace from pile to bearer. The study report concludes that "an elastic system does not obtain a significant reduction in earthquake load by the increase in building period from its ability to sustain large deflections."[qqqq] Further, noting that "providing details to ensure a greater building ductility is a more efficient process."[rrrr] This report cements the notion that connections and their nature are of paramount consideration in retrofitting of subfloor and foundation details. Thus, this report further emphasises the importance of ideal connections and their role in seismic performance.

Thomas, G C and Irvine, J D. *The Adequacy of House Foundations for Resisting Earthquakes: the Cost-Benefit of Upgrading; EQC Non-Biennial Project 6UNI/530*. Victoria University of Wellington, Wellington, 2007.

This report explores retrofitting of foundations and subfloor in a systematic, methodical and thorough manner, exploring the factors contributing to the need for retrofitting to the costs and benefits of such measures. It is noted that on average in New Zealand "we experience a large earthquake (one that exceeds Magnitude 7) every 10 years"[ssss] thus New Zealand is particularly prone to earthquake damage, and yet many dwellings within New Zealand would suffer significantly should the event of an earthquake occur. The report by Thomas and Irvine outlines the six foundation types as used to structure this report, and then a methodology of a survey of Wellington dwellings is outlined. This examines "existing bracing potential, the connections and fittings between all framing members, the general condition and an overall comparison between the current standard NZS3604:1999 and the built foundation."[tttt] The results of this survey are then analysed and possible remedial measures outlined. The report then extends further, developing anticipated maximum and minimum repair costs and tables to apply these (see Figures 205 and 206).

[qqqq] Thurston, S J. *Design Strength of Various House Pile Foundation Systems*. BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 1993, no. 46, p 17.
[rrrr] Thurston, S J. *Design Strength of Various House Pile Foundation Systems*. BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 1993, no. 46, p 17.
[ssss] Thomas, G C and Irvine, J D. *The Adequacy of House Foundations for Resisting Earthquakes: the Cost-Benefit of Upgrading; EQC Non-Biennial Project 6UNI/530*. Victoria University of Wellington, Wellington, 2007, p 11.
[tttt] Thomas, G C and Irvine, J D. *The Adequacy of House Foundations for Resisting Earthquakes: the Cost-Benefit of Upgrading; EQC Non-Biennial Project 6UNI/530*. Victoria University of Wellington, Wellington, 2007, p 23.

Foundation type	TOTAL No. Dwellings affected before remedy	TOTAL Assets at risk of damage and Collapse before Remedy $M	TOTAL No. Dwellings affected after remedy	TOTAL Assets at risk of damage and Collapse after Remedy $M	Total Cost of Remedial action $M	Total Saving from the application of remedies $M
Internal Piled	4209	$226	3172	$80	$26.8	**$146**
Full Piled	16161	$892	13009	$368	$78.6	**$524**
Partial Wall	5285	$208	4266	$92	$26.5	**$116**
Full Wall	12149	$336	11079	$248	$105.1	**$88**
Full Wall/Intern.	5036	$140	4204	$86	$11.0	**$54**
SLAB	6944	$251	6494	$225	$0.0	**$26**
ENG	1894	$73	1698	$61	$0.0	**$12**
TOTALS	**51678**	**$2,125**	**43922**	**$1,159**	**$248**	**$966**

Figure 205
Statistics Before and After Application of Remedial Measures
Source: Thomas, G C and Irvine, J D. *The Adequacy of House Foundations for Resisting Earthquakes: the Cost-Benefit of Upgrading; EQC Non-Biennial Project 6UNI/530.* Victoria University of Wellington, Wellington, 2007, p 38.

Foundation type	Light damage cost / benefit	Maximum Moderate damage cost / benefit	Maximum Extensive damage cost / benefit	Collapse cost / benefit	Overall Average cost/ benefit ratio
Internal Piled	-8.93	0.91	0.11	0.05	0.29
Full Piled	-7.84	1.44	0.19	0.04	0.44
Partial Wall	-7.99	0.80	0.10	0.04	0.26
Full Wall	-17.00	2.24	0.59	0.00	0.78
Full Wall/Intern.	-3.06	0.24	0.08	0.00	0.09
SLAB	0.00	0.00	0.00	0.00	0.00
ENG	0.00	0.00	0.00	0.00	0.00

Figure 206
Maximum and Minimum Cost/Benefit Values for all ranges of Damage
Source: Thomas, G C and Irvine, J D. *The Adequacy of House Foundations for Resisting Earthquakes: the Cost-Benefit of Upgrading; EQC Non-Biennial Project 6UNI/530.* Victoria University of Wellington, Wellington, 2007, p 38.

The report concludes that "the very low cost/benefit ratio suggests that it is economically justifiable to remedy foundation defects in dwellings."[uuuu] Further, these remedial repairs have the potential to "save almost $1Billion in post earthquake repairs and mitigate the unknown costs of temporary shelter and aid requirements for the home owner and communities."[vvvv] This cements the importance of retrofitting and ensures the benefits are clearly communicated.

Thurston, S J. *Torsional Response of House Subfloor Systems.* BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2001, no. 105.

This study report examines the notion that the layout of bracing piles in a house piled foundation as stipulated by NZS3604:1999 may still result in asymmetrical layouts which can lead to a strong

[uuuu] Thomas, G C and Irvine, J D. *The Adequacy of House Foundations for Resisting Earthquakes: the Cost-Benefit of Upgrading; EQC Non-Biennial Project 6UNI/530.* Victoria University of Wellington, Wellington, 2007, p 38.
[vvvv] Thomas, G C and Irvine, J D. *The Adequacy of House Foundations for Resisting Earthquakes: the Cost-Benefit of Upgrading; EQC Non-Biennial Project 6UNI/530.* Victoria University of Wellington, Wellington, 2007, p 43.

eccentricity, whilst still being acceptable under NZS3604:1999. The report outlines the testing procedure, including differing pile layouts across rectangular houses and L-shaped houses. The report concludes with a recommendation that the "minimum bracing rating required [by Section 5.4.2.3(a) of NZS3604:1999] be doubled."[wwww] Further, it stipulates connection details, such as recommending "where joints land on stringers, that continuous blocking be used between the joists over the stringers and the flooring be nailed to this edge at 150mm centres"[xxxx] to transmit bracing ratings from floor to wall. Again the connection forms an integral part of the seismic performance of the building, reinforcing the notion that adequate performance is derived from the nature and quality of its connections.

Timber Framing Committee. *NZS3604:1999 Timber Framed Buildings.* Standards New Zealand, Wellington, 1999.

This standard covers timber framed buildings across many aspects, aiming to provide a verification method for construction and a resource for timber building in New Zealand. The standard is divided into twenty sections, covering areas of a dwelling such as floors, walls, posts and roof framing, and providing additional sections on particular loading scenarios and soil types. The resource is supplemented with tables to define sizes and spans of members in timber construction. Most relevant to this report is Section 6: Foundation and Subfloor Framing. Within this section notes and details on the construction of many aspects of the dwelling foundation and subfloor are covered, including ordinary piles, driven timber piles, cantilever piles and braced pile systems. Unfortunately many of the details provided are not suitable for retrofitting due to their construction and lack of accessibility to implement in a retrofit. However, details of braced pile systems may prove useful in retrofitting to minimise damage post earthquake (see Figures 207, 208, 209).

[wwww] Thurston, S J. *Torsional Response of House Subfloor Systems*. BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2001, no. 105, p 20.

[xxxx] Thurston, S J. *Torsional Response of House Subfloor Systems*. BRANZ Study Report, Building Research Association of New Zealand, Judgeford, 2001, no. 105, p 20.

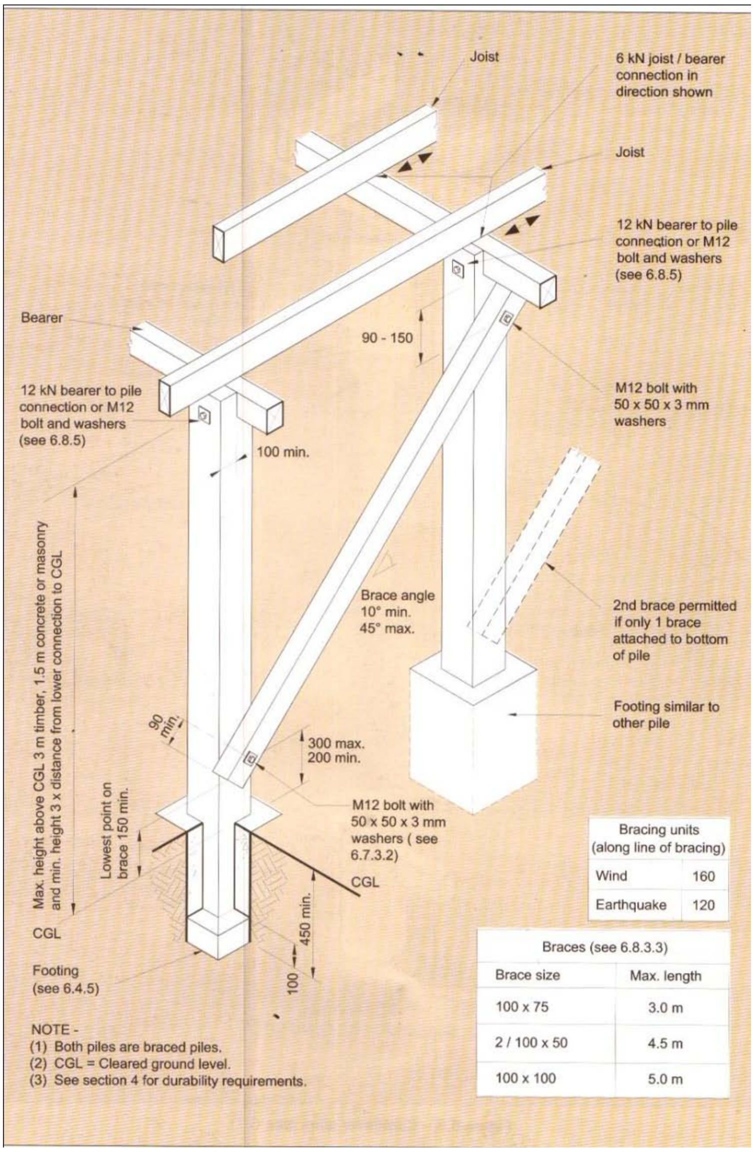


Figure 207
Braced Pile System – Brace Connected to Pile
Source: Timber Framing Committee. *NZS3604:1999 Timber Framed Buildings*. Standards New Zealand, Wellington, 1999, Section 6, p 18.

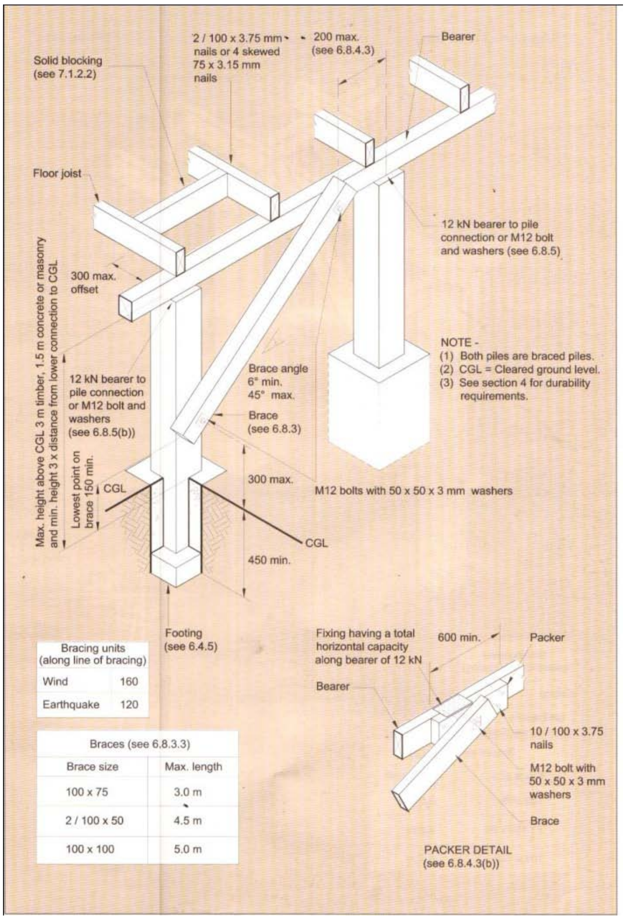


Figure 208
Braced Pile System – Brace Connected to Bearer
Source: Timber Framing Committee. *NZS3604:1999 Timber Framed Buildings*. Standards New Zealand, Wellington, 1999, Section 6, p 19.

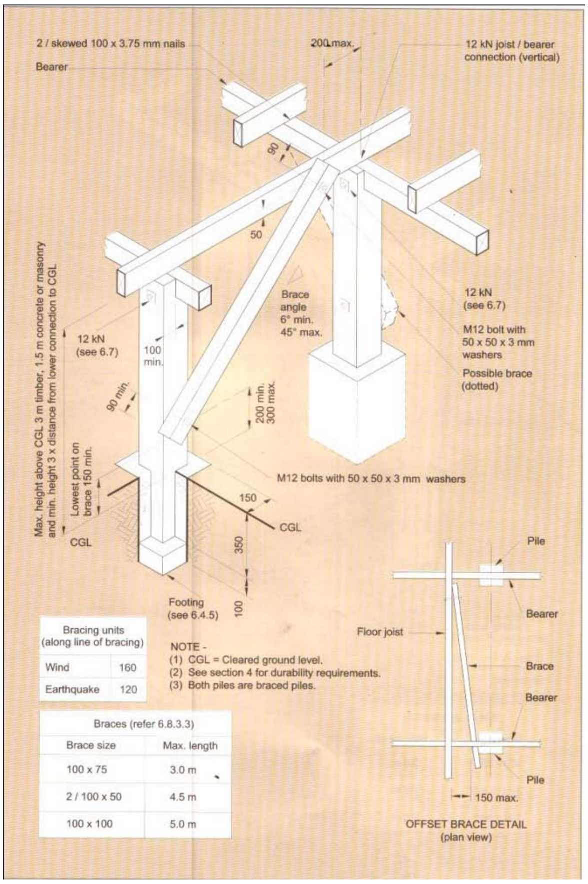


Figure 209
Braced Pile System – Brace Connected to Joist
Source: Timber Framing Committee. *NZS3604:1999 Timber Framed Buildings*. Standards New Zealand, Wellington, 1999, Section 6, p 20.

Todd, Diana and Carina, Nicholas and Chung, Riley M and Lew, H S and Andrew, Taylor W and Walton, William D and Cooper, James D and Nimis, Roland. *1994 Northridge Earthquake: Performance of Structures, Lifelines and Fire Protection Systems*. NIST Special Publication, National Institute of Standards and Technology, United States of America, 1994, no 862.

This book examines seismic performance of buildings and bridges, lifeline systems and post earthquake fires. Within the section on buildings, single and multi-family residences are considered as well as commercial and institutional buildings. This book documents the damage sustained to these structures post earthquake, however, offers little practical and applicable advice for retrofitting to better performance. Suggestions for improving practice are provided across the buildings, bridges and lifeline systems sections. Recommendations are given for improving building, bridge and lifeline performance however, again no details or construction notes are provided, rather general principles.

Yong, Chen and Tsoi, Kam-ling and Feibi, Chen and Zhenhuan, Gao and Qijia, Zou and Zhangli, Chen (Eds.). *The Great Tangshan Earthquake f 1976: An Anatomy of Disaster*. Pergamon Press, Oxford, 1988.

This book is divided into four chapters examining differing aspects of the Tangshan earthquake. These are: *Damage of the Tangshan Earthquake* which looks at earthquake intensity and damage to buildings, lifeline engineering and geological and surface features; *Administration of Emergency Measures* which looks at natural disaster relief efforts, emergency measures implemented, restoration of community life and social problems caused by the quake; *The Tangshan Earthquake: Seismological Features* which examines foreshocks and aftershocks and the tectonic setting of Tangshan; and *Earthquake Prediction in China* which looks at earthquake prediction efforts at Tangshan and future prospects of earthquake prediction. Although this resource yields little information on foundation retrofitting, it does cement the need for this process of retrofitting through its depiction of the destruction of way of life and paralysis which resulted post earthquake. Lifelines were damaged, water and electricity cut off and disease rampant. This can be mitigated, to a degree, through retrofitting as outlined in this report.

Yttrup, PJ and Juniper, PM. *Small Diameter Timber Piles as Used in Australia*. In Proceedings of the Second Pacific Timber Engineering Conference, Centre for Continuing Education, University of Auckland, Auckland, 1989, vol 3, pp 41-44.

This conference paper examines small diameter timber piles as being used in Australia in footing systems in areas of soft or filled ground or expansive soils. The study conducts 31 pile load tests and the bearing capacity is analysed. Pile behaviour was also studied in a residential brick veneer house in Belmont, Victoria where these piles were found to be "economical and successful under very extreme conditions."[yyyy] The use of small diameter timber piles driven to correct depths perform adequately in expansive soils. Although this study does not relate to the retrofit of foundations, it does reinforce ideal construction practices and catering of construction solutions to site conditions, two principles in line with seismic retrofit of dwelling foundations in New Zealand.

[yyyy] Yttrup, PJ and Juniper, PM. *Small Diameter Timber Piles as Used in Australia.* In Proceedings of the Second Pacific Timber Engineering Conference, Centre for Continuing Education, University of Auckland, Auckland, 1989, vol 3, p 43.

Electronic Texts:

http://ares.tu.chika-u.jp
Muraoka, Nanae and Yamazaki, Fumio. ***Evaluation of the Effects of Seismic Retrofit for Reinforced Concrete School Buildings using Microtremor Observation.***

This article examines seismic strengthening of retrofitted buildings by two methods: microtremor observation and a numerical analysis. The two buildings examined were strengthened by external braces and by adding a frame, respectively. The article begins by observing the brittle nature of many buildings in Japan and the need to retrofit. The buildings to be tested are then described and the testing methods detailed. This involves a series of equations, and the use of a GEODAS for microtremor observation. The study concludes that both methods are useful to confirm the effect of structural strengthening, however, microtremor observation is perhaps most useful as it can measure the dynamic characteristics of a structure, including non-structural elements and taking into account soil-structure interaction. Although this article does not provide retrofit details and considers buildings on a larger scale than would be comparable to New Zealand dwellings, this article is relevant as it emphasises the need to understand seismic behaviour of buildings and the effect of seismic retrofit.

http://db.nzsee.org.nz/Paper02
Johnston, DM and Becker, JS and Saunders, W and Wright, K and Coomer, M and Leonard, G and Paton, D. Surviving future disasters in New Zealand.
Presented as part of the NZSEE Conference, New Zealand, 2009.

This article explores opportunities to improve New Zealand's capacity to respond to and move on from future disasters. This ranges from land use planning to public education, social policy, training and empowerment strategies.[zzzz]
Strategies for surviving future disasters begin with improved policy and planning. This involves improving links between planners and emergency managers, identifying buildings as rick from earthquakes and assisting Councils to reduce risk. Building community resilience involves the active involvement of formal and informal community networks in hazard education, developing leadership and trust where communities are supported by institutions and developing participation and empowerment where communities are directly involved in identifying risks and solutions. Effective warning systems are essential, as is developing emergency management capacity and improved disaster recovery. This article emphasises that strength lies in communities and this must be harnessed for disaster resilience. This relates to this report through the encouraging of effective strategies for surviving future disasters in New Zealand, the very purpose of seismic retrofit.

http://db.nzsee.org.nz/Paper08
Bradley, BA and Cubrinovski, M and Dhakal, RP and MacRae, GA. Probabilistic Seismic Performance Assessment of a Bridge-Foundation-Soil System.
Presented as part of the NZSEE Conference, New Zealand, 2009.

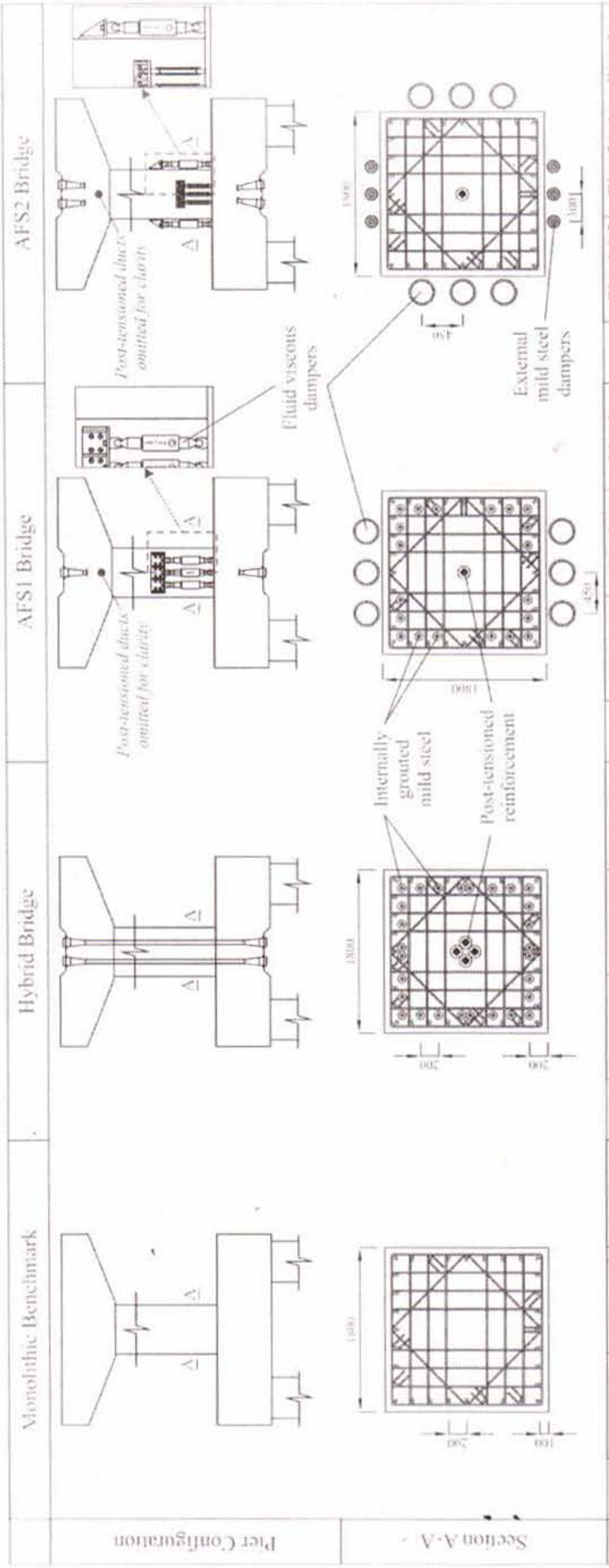
[zzzz] http://db.nzsee.org.nz/Paper02

This paper examines the "probabilistic seismic performance assessment of an actual bridge-foundation-soil system, the Fitzgerald Avenue twin bridges."[aaaaa] Details of the structure of this bridge are documented and its site conditions investigated. A computational model was then created to subject to testing. The model is subjected to differing earthquake accelerations and the foundation soil response and the bridge and pile response measured. The model is subjected to twenty differing ground motions at nine different intensity levels to obtain probabilistic relationships between engineering demand parameters and the peak ground acceleration.[bbbbb] This method is useful to compute the demand hazard for the various engineering demand parameters. Although not specifically relating to seismic retrofit of foundations and subfloor, this article emphasises the understanding of the critical components of a structure influencing its seismic performance and understanding of soil foundations, which is very relevant to this report.

http://db.nzsee.org.nz/Paper30
Mariott, DJ and Pampanin, S and Bull, D and Palermo, A. A probabilistic seismic loss assessment of advanced post-tensioned precast bridge systems
Presented as part of the NZSEE Conference, New Zealand, 2009.

This paper examines the performance of three post-tensioned, reinforced concrete bridges and compares and contrasts these to a monolithic bridge construction. A seismic loss assessment is carried out for each bridge, providing a means to directly compare the performance of each bridge. Each of the four bridges are described and their dimensions illustrated. The bridges are analysed in terms of: ground motion hazard: the ground shaking intensity at a site; seismic response of a structure; component damage: expressed as a damage measure including bar buckling ad concrete spalling; and loss: monetary loss resulting from repair costs, casualties and time to reinstate the function of the structure. Bridge pier configurations, section details, reinforcement, costing and performance limit states are given (see Figure 210).

[aaaaa] http://db.nzsee.org.nz/Paper08
[bbbbb] http://db.nzsee.org.nz/Paper08



		Monolithic Benchmark			Hybrid Bridge			AFS1 Bridge			AFS2 Bridge		
		Pier 1&5	Pier 2&4	Pier 3	Pier 1&5	Pier 2&4	Pier 3	Pier 1&5	Pier 2&4	Pier 3	Pier 1&5	Pier 2&4	Pier 3
Materials	ρ_{ms}	1.16%	1.16%	1.16%	1.09%	1.09%	1.09%	0.78%	0.78%	0.78%	0.61%	0.61%	0.61%
	ρ_{pt}	-	-	-	0.38%	0.38%	0.43%	0.14%	0.14%	0.19%	0.20%	0.22%	0.29%
	FVD	-	-	-	-	-	-	980kN	980kN	980kN	980kN	980kN	980kN
Cost	S_{PT}	-	-	-	$12,800	$18,500	$29,500	$4,500	$6,500	$12,600	$6,500	$10,700	$20,000
	S_{MISC}	-	-	-	$12,700	$12,700	$12,700	$12,700	$12,700	$12,700	$12,700	$12,700	$12,700
	S_{damper}	-	-	-	-	-	-	$77,780	$77,780	$77,780	$77,780	$77,780	$77,780
	S_{total}			-			$155,600			$487,400			$507,200
Struc limit states	Δ_{serv}	0.091m	0.091m	0.091m	0.144m	0.240m	0.408m	0.136m	0.225m	0.371m	0.135m	0.229m	0.386m
	Δ_{design}	0.259m	0.259m	0.259m	0.392m	0.630m	0.985m	0.380m	0.626m	0.748m	0.361m	0.563m	0.883m
	$\Delta_{ultimate}$	0.373m	0.373m	0.373m	0.499m	0.793m	1.345m	0.657m	0.963m	1.413m	0.515m	0.780m	1.195m
	$\Delta_{collapse}$	0.459m	0.459m	0.459m	0.558m	0.907m	1.563m	0.720m	1.071m	1.599m	0.647m	1.001m	1.573m

Figure 210
Bridge Attributes
Source: http://db.nzsee.org.nz/Paper30

The study concludes that all three post-tensioned bridges returned a lower loss than the monolithic bridge system. A detailed life cycle analysis based on cost of construction, maintenance and repair, the advanced hybrid bridge systems are the most successful. Although this article does not relate to seismic retrofit of dwellings specifically, the consideration of emerging technologies is emphasised, as well as quality of construction, which is very relevant.

http://db.nzsee.org.nz/Paper36
Brabhaharan, P and Kirkcaldie DK, and Gregg, G. Earthquake strengthening and ground improvement of the Cobham Bridge, Wanganui.
Presented as part of the NZSEE Conference, New Zealand, 2009.

The State Highway 3 Cobham Bridge provides access across the Wanganui River, designed in 1959 by the Ministry of Works and constructed in 1962. The structure and dimensions of this bridge are carefully outlines in this article, and the peak ground accelerations determined. The ground conditions were examined and three boreholes, eight static cone penetration tests and lab classification tests were carried out to provide valuable data and information for retrofit design. The structure was assessed, probable member strengths derived and pile bearing and pull out capacity investigated. Two dimensional computer models were used to investigate "the longitudinal behaviour of the bridge as a whole…the longitudinal response of the abutments, the transverse response of a typical pier, a central pier and the abutments."[ccccc] Ground improvement measures employed for seismic strengthening included stone columns and wick drains, and replacement of ground with compacted gravel between the abutment and the first pier.[ddddd] The wick drains facilitate dissipation of the pore pressures in the ground and provide drainage. The central two piers were strengthened for shear by through bolting the pier walls with bolts anchored against steel straps at either wall face.[eeeee] Linkage bolts were also installed to "upgrade the linkage of the superstructure to the abutment, and abutment back walls [were] strengthened with steel RSC sections fixed to their back faces, cantilevering from abutment sill beams, with the linkage bolts anchoring directly to the RSC sections."[fffff]
Although this retrofit does not specifically relate to dwellings, it does explore retrofit measures for New Zealand soil conditions and emphasises connectivity in structures, both of which are very relevant in the seismic retrofit of dwelling subfloors and foundations.

http://db.nzsee.org.nz/Paper39
Loo, WY and Quenneville, P and Chouw, N. Seismic behaviour of timber shear walls with load limiting slip-friction connectors.
Presented as part of the NZSEE Conference, New Zealand, 2009.

[ccccc] http://db.nzsee.org.nz/Paper36
[ddddd] http://db.nzsee.org.nz/Paper36
[eeeee] http://db.nzsee.org.nz/Paper36
[fffff] http://db.nzsee.org.nz/Paper36

This article examines a new kind of connector that has been developed for shear walls, one that relies on the mobilisation of friction across steel plates to resist loading up to a predetermined threshold.[ggggg] Should this threshold be exceeded, sliding between the plates allows the shear walls to displace in an inelastic manner with minimal yielding of timber or nails. This is expected to dramatically decrease post-earthquake damage.
A shear wall is first described and its construction outlined. The load limiting slip-friction connector testing is then documented, testing standard and Midply connectors (a connector is illustrated in Figure 211). The connectors and shear walls were first numerically modelled, then two-storey versions of the shear walls were tested. The study concludes that the slip-friction connectors have the ability to "afford protection against high material stresses developing in the wood structure itself,… efficiently dissipate seismic energy, and… re-centre under moderate vertical loading."[hhhhh] Slip-friction connectors allow the yield strength of the wall to be predicted to a far more accurate degree. This study is relevant to this report in that new possibilities are being developed for connectors to decrease seismic risk, and these emerging technologies must be considered in seismic retrofit.

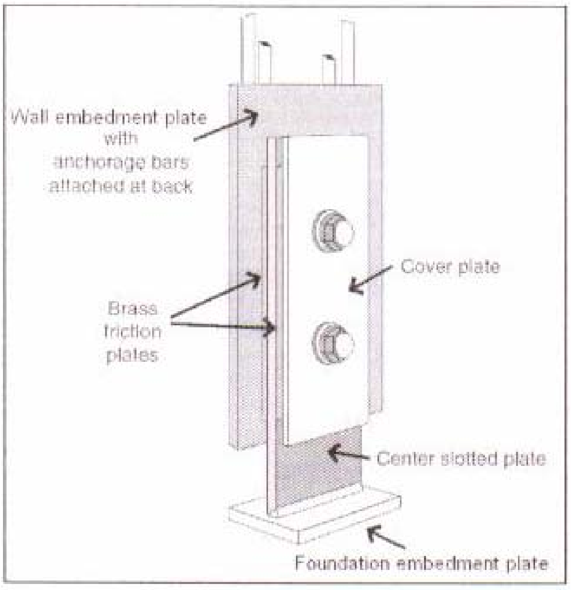


Figure 211
Slip-Friction Connector
Source: http://db.nzsee.org.nz/Paper39

http://db.nzsee.org.nz/Paper43
Arefi, MJ and Pampanin, S and Cubrinovski, M. Effects of SSI on the seismic response of older structures before and after retrofit.
Presented as part of the NZSEE Conference, New Zealand, 2009.

This article examines the behaviour of structures considering the soil-structure interaction. A set of ten historical ground motion records were selected for testing and the test method is outlined and documented. Computational modelling and calculations are use to test structures' response. The

[ggggg] http://db.nzsee.org.nz/Paper39
[hhhhh] http://db.nzsee.org.nz/Paper39

discussion examines the influence of foundation flexibility, ground motions intensity and super-structural strength level. The study concludes that although some trends were observed, the characteristics of the particular earthquake will influence the results and what response may occur in the structure. In most cases, any flexibility in the foundation soil triggers soil-structure interaction effects. Although this article does not explore seismic retrofit of dwellings, it does emphasise consideration of ground conditions, and foundation and soil interaction, which are both very important in the retrofitting of dwelling subfloors and foundations in New Zealand.

http://db.nzsee.org.nz/Paper46
Haskell, JJM and Cubrinovski, M and Bradley, BA. Sensitivity analysis of simplified methods for the design of piles in laterally spreading soils.
Presented as part of the NZSEE Conference, New Zealand, 2009.

This article examines use of the pile, typically used to support a structure where soil quality is poor, transmitting vertical loads to stringer, deeper soils. However, lateral loads may also impose upon pile foundations. This causes widespread damage in earthquakes. Simple methods for pile design have thus been developed. This article emphasises the notion that, instead, the interaction between pile and soil in complex and dynamic, cannot be simplified in this way. This study explores the "effects of variation of the model parameters on the predicted pile response [as] explored via a deterministic sensitivity analysis."[iiiii] The testing method is outlined and results clearly displayed and supplemented with commentary.

The study concludes that the use of simplified deterministic methods is straightforward, yet unreliable, unless the sensitivity of the predicted response to the variation of critical model parameters is considered.[jjjjj] Thus, the effect of parametric variations of the pole response must be explored and will result in a more reliable assessment of pile performance. Although this article does not examine seismic retrofit specifically, it does emphasise quality and care of pile construction. This is very relevant to the New Zealand built environment as so many New Zealand dwellings reside on piled foundations.

http://db.nzsee.org.nz/Paper60
Xu, X and Lo, SH and Tsand, HH and Sheikh, MN. Earthquake Protection by Tire-Soil Mixtures: Numerical Study.
Presented as part of the NZSEE Conference, New Zealand, 2009.

This article documents and explores a new method of utilising scrap tires, otherwise accumulating in disposal stations worldwide, for earthquake protection. This method involves mixing scrap tires with sediments of soil and using this around structures to absorb vibration and provide cushioning. Many of the world's earthquake deaths occur in developing countries, where the low cost of reusing tires could provide benefit where other earthquake technologies render themselves inappropriate due to cost and inaccessibility.
The proposed scheme is shown in Figure 212 where the footing of the building is surrounded by a layer of the tire and soil mixture. As energy dissipation is the primary mechanism attributing to

[iiiii] http://db.nzsee.org.nz/Paper46
[jjjjj] http://db.nzsee.org.nz/Paper46

reducing seismic shaking, and rubber is known for its potential to absorb energy, its use in damping is quite appropriate. The soil and tire mixture demonstrates an increase in shear strength over standard soils and a significant energy dissipating capacity.

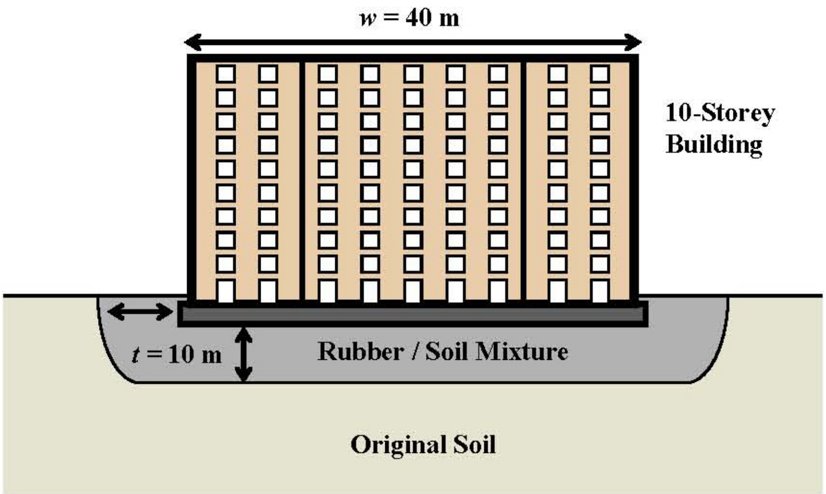


Figure 212
Seismic Isolation by Layer of Tire/Soil Mixture
Source: http://db.nzsee.org.nz/Paper60

To demonstrate the feasibility of the scheme, numerical analyses were conducted (see Figure 213). The model was subjected to three earthquake ground excitations, representing the forces generated in the 1994 Northridge, California earthquake, the 1985 Valparaiso, Chile earthquake and the 1999 Duzce, Turkey earthquake. A fourth force, found by multiplying the California earthquake by two was also used in the testing. The method and results are then discussed in depth. It is noted that using an addition of 10% tire chips or less will not result in an occurrence of liquefaction, and randomly mixing tire chips can reinforce sand, resulting in an increased shear strength. It is also noted that the compressibility of tire chips decreases upon application of load; preloading can thus be employed to mitigate settlement. Studies have also concluded that recycled scrap tire is not a hazardous recycled material.

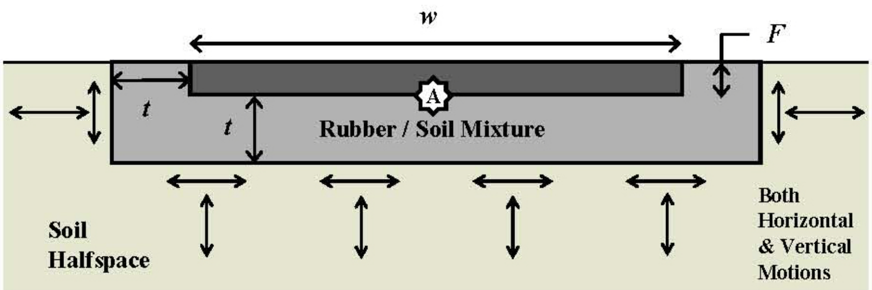


Figure 213
Simplified Model for Element Analysis
Source: http://db.nzsee.org.nz/Paper60

Although this article does not explore seismic detailing, it does investigate a seismic retrofit measure which is inventive and economically viable. Aspects of this method may be relevant to the retrofit of the New Zealand built environment to resist earthquakes.

http://earthquakesafety.com/retrofitting

This website gives information on seismic retrofitting including what is involved and the reasons for retrofitting. The process used to retrofit is outlined in detail, across cripple wall bracing, foundation bolting and foundation hold down brackets. Typical bracing of a cripple wall is detailed (see Figure 214) showing also how the subfloor appears before (see Figure 215) and after the retrofit (see Figure 215) which involved plywood bracing panels and improved connections from the foundations, through the walls, and into the overhead framing of the floor.

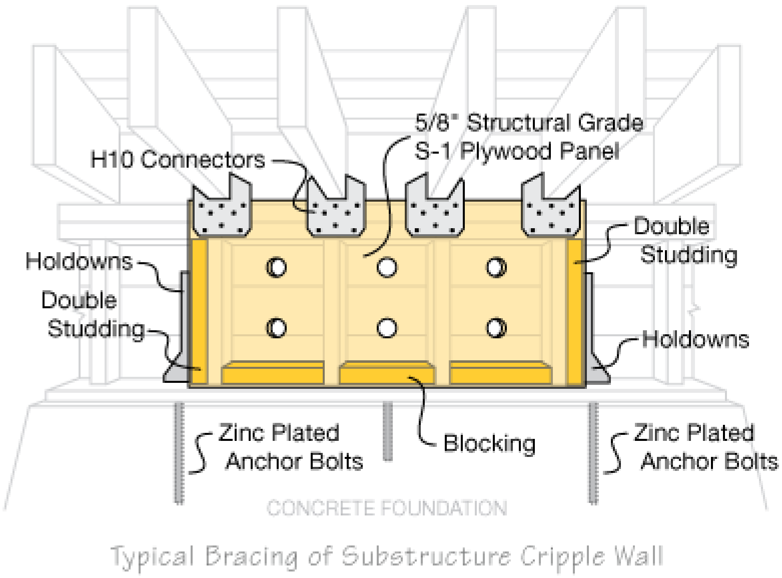


Figure 214
Typical Bracing of Substructure Cripple Wall
Source: http://earthquakesafety.com/retrofitting

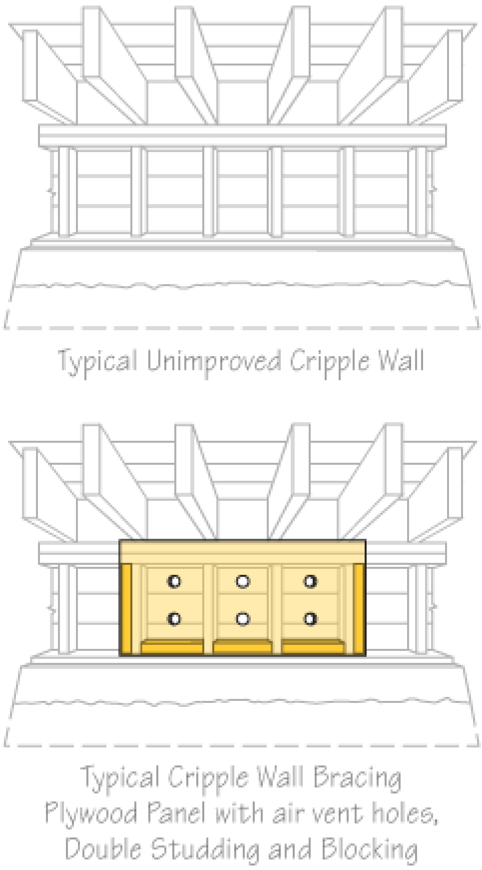


Figure 215
Top: Cripple Wall, Bottom: Retrofitted Cripple Wall

Source: http://earthquakesafety.com/retrofitting

Some houses require additional hold down brackets to anchor the shear walls (see Figure 216), usually installed at the ends of the shear walls. Installation is carried out with a long, deeply set epoxy anchored bolt.

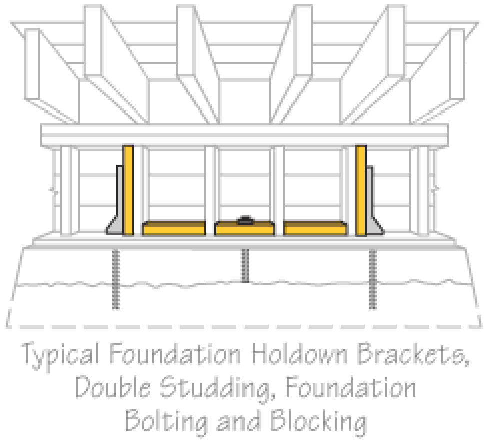


Figure 216
Foundation Hold Down Brackets
Source: http://earthquakesafety.com/retrofitting

Where there is no cripple wall present the anchorage may be improved through bolting angle iron struts into the side of the concrete foundation wall (see Figure 217). These are also bolted to the floor joists and resist both vertical and lateral loads.

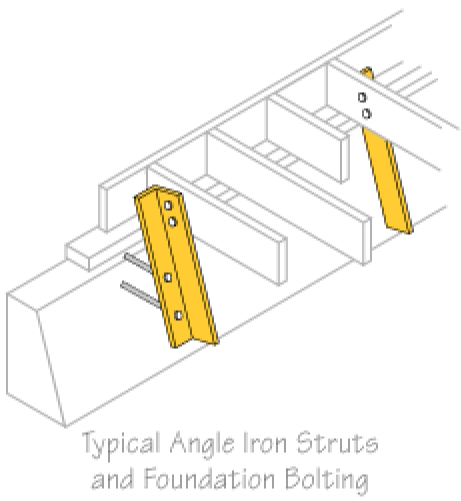


Figure 217
Angle Iron Struts
Source: http://earthquakesafety.com/retrofitting

Foundation bolting improves the connection between the timber framing of the dwelling and the concrete foundation (see Figure 218). Expansion foundation bolts are used where the concrete is in good condition, epoxy set foundation bolts work better in older, weaker foundations or where extreme movement is predicted. This resource is very relevant to this report as it outlines a common process of retrofit measures which may prove applicable in the New Zealand built environment.

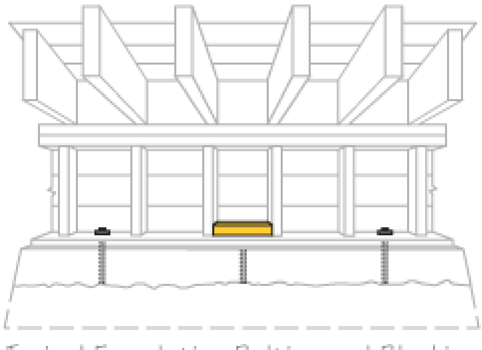


Figure 218
Foundation Bolting
Source: http://earthquakesafety.com/retrofitting

http://foundationexpert.org

This website details Micro Pile reinforcement systems and is a resource compiled by Collins Consulting, Colorado, who specialise in aspects of mechanical and structural design.
A Micro Pile is a pile up to 300mm in diameter, drilled and grouted with centrically placed steel reinforcing consisting of single or multiple bars (see Figure 219). They can be placed with small drilling equipment under limited access or low head room conditions. The reinforcing is solid or hollow bars with continuous outside threads (see Figure 220).

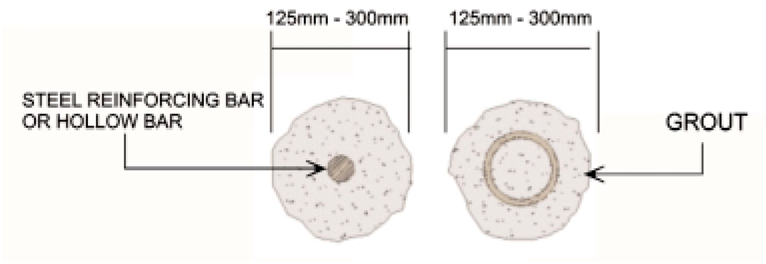


Figure 219
Typical micro pile sections, left with solid bar reinforcing, right with hollow bar reinforcing or casing
Source: http://foundationexpert.org

Figure 220
From left: Threadbars, All-Thread Bars and hollow bars
Source: http://foundationexpert.org

Included in the category of Micro Pile are several other types of pile. The Gewi pile has a gewi bar forming the concentric reinforcing element. The drill hole is filled with cement grout and post-grout tubes are installed at the outer perimeter of the grout body (see Figures 221 and 222).

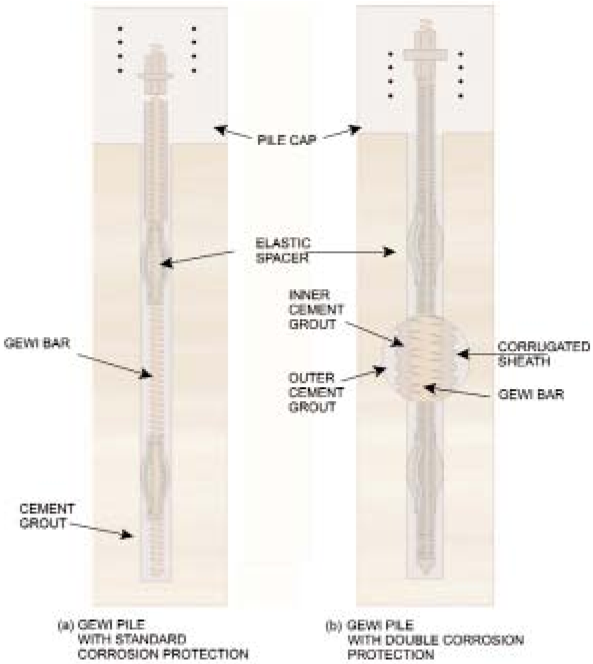


Figure 221
Typical Gewi Pile with standard and double corrosion protected reinforcing bar
Source: http://foundationexpert.org

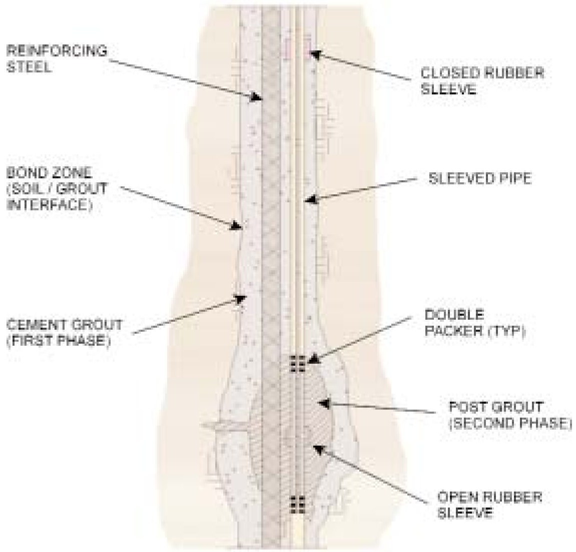


Figure 222
Typical post-grouting system
Source: http://foundationexpert.org

The pin pile uses an outer pipe casing to stabilise the drill hole, filled with single or multiple bars and grout; the casing is partially removed (see Figures 223 and 224).

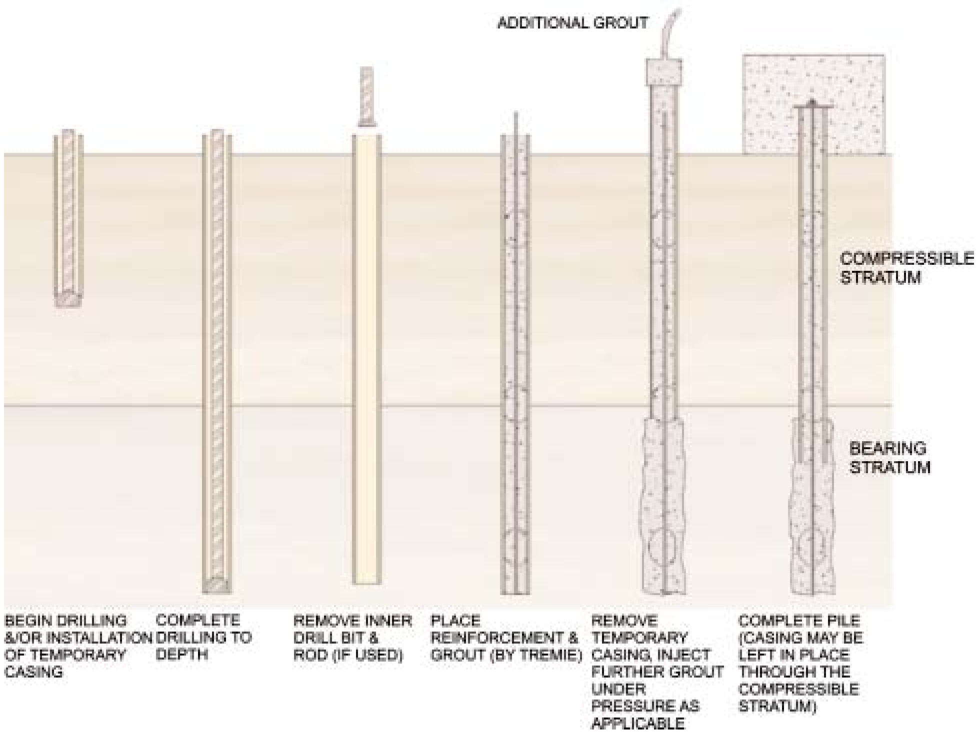


Figure 223
Pin Pile installation sequence
Source: http://foundationexpert.org

Figure 224
Single (left) and multiple bar (right) micro pile reinforcing
Source: http://foundationexpert.org

The Titan/IBO-Injection-bored micro pile uses hollow bars with inside solid bars which can also be post tensioned (see Figure 225).

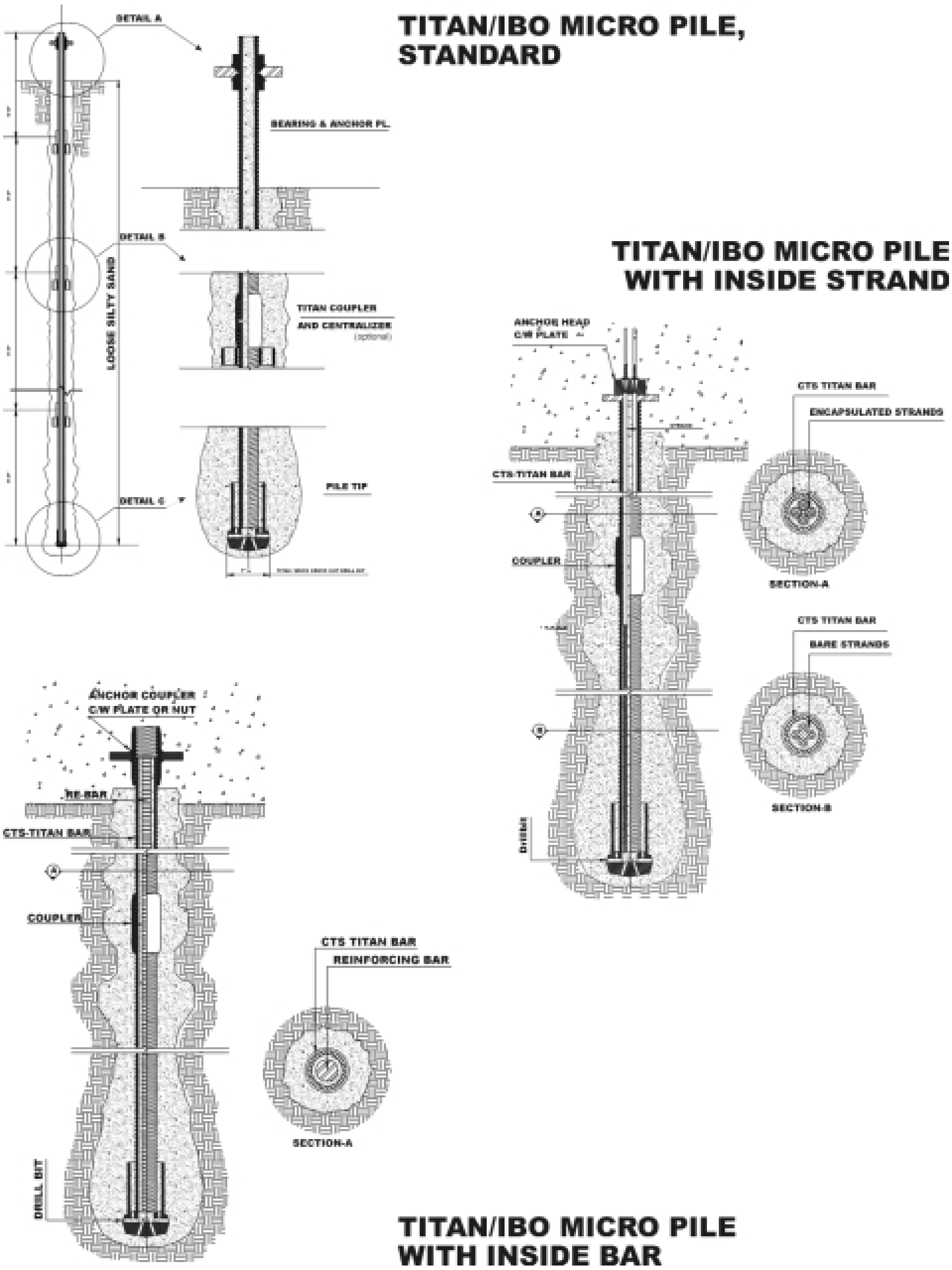


Figure 225
Typical Titan/IBO Details
Source: http://foundationexpert.org

This resource is relevant to this report as it details the new innovations in pile technology innovations which may prove useful in the retrofit of New Zealand dwelling subfloors and foundations.

This website is devoted to a series of foundation retrofit measures commonly carried out in the United States. The information is provided by the California Earthquake Retrofitting Information Center, a non-profit organisation set up by architects and civil engineers to explain the process of retrofitting the home to meet California State Building and Engineering Codes. The first step is to install plates bolting down the sill plate using a 2 x 3inch piece of steel (see Figure 226). The steel anchor plates are specifically designed for this application (see Figure 227). The bolt is a concrete expansion anchor bolt (see Figure 228) and are used around the perimeter (see Figure 229). This resource simply and clearly explains the common retrofit measures in California.

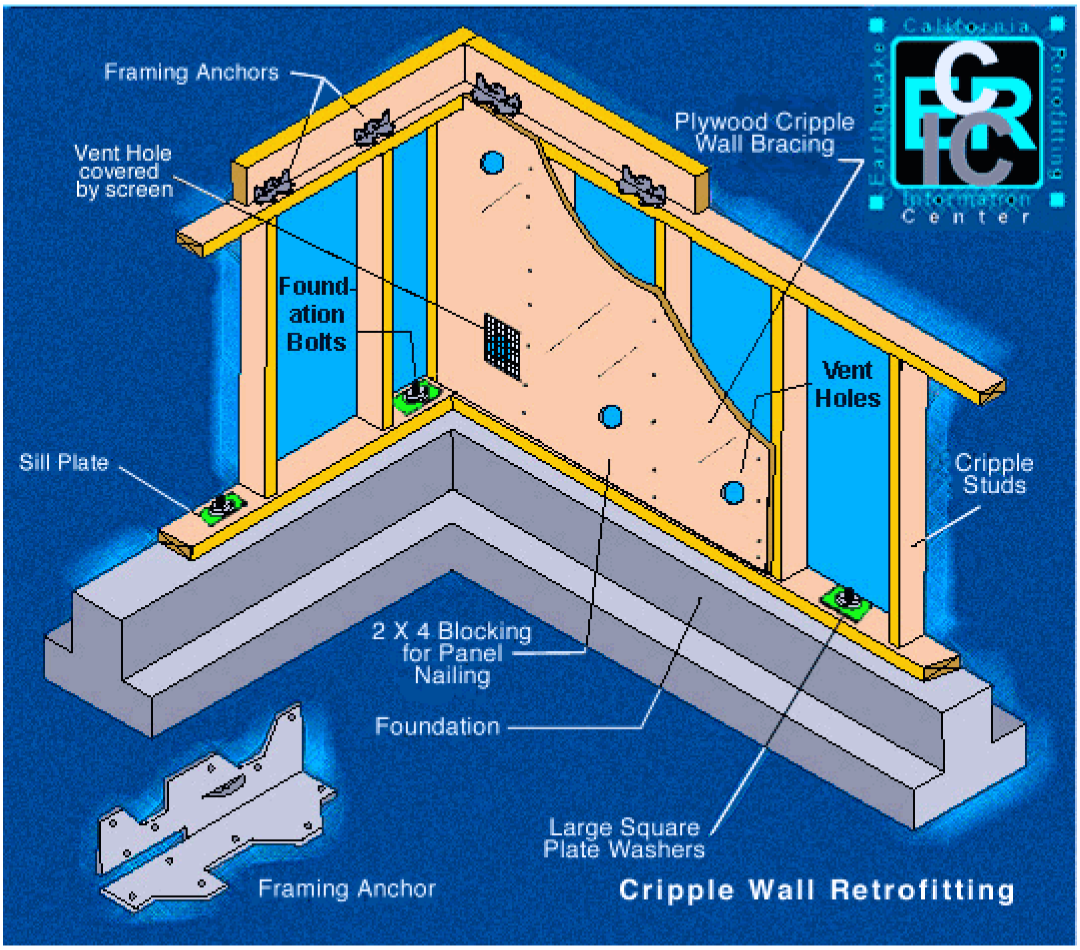


Figure 226
Cripple Wall (Jack Stud) Retrofitting
Source: http://housebolting.com

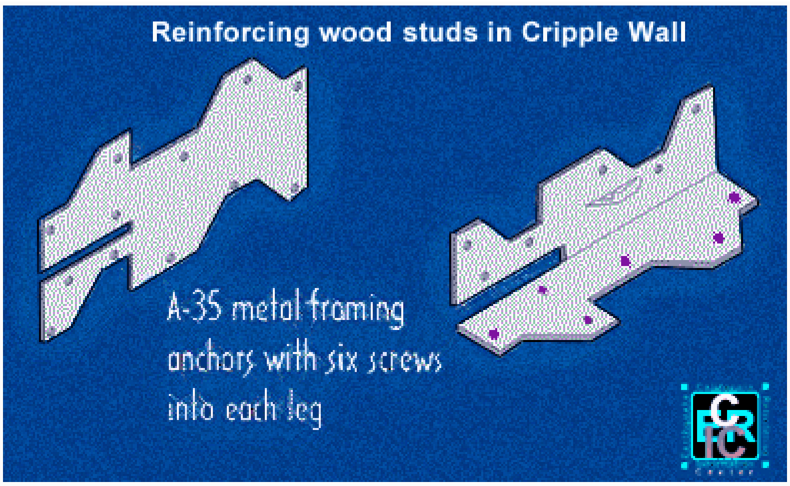


Figure 227
Retrofitting Steel Plates
Source: http://housebolting.com

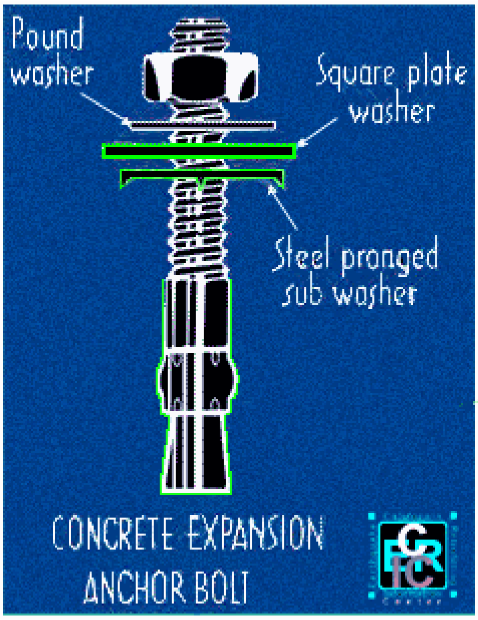


Figure 228
Concrete Expansion Anchor Bolt
Source: http://housebolting.com

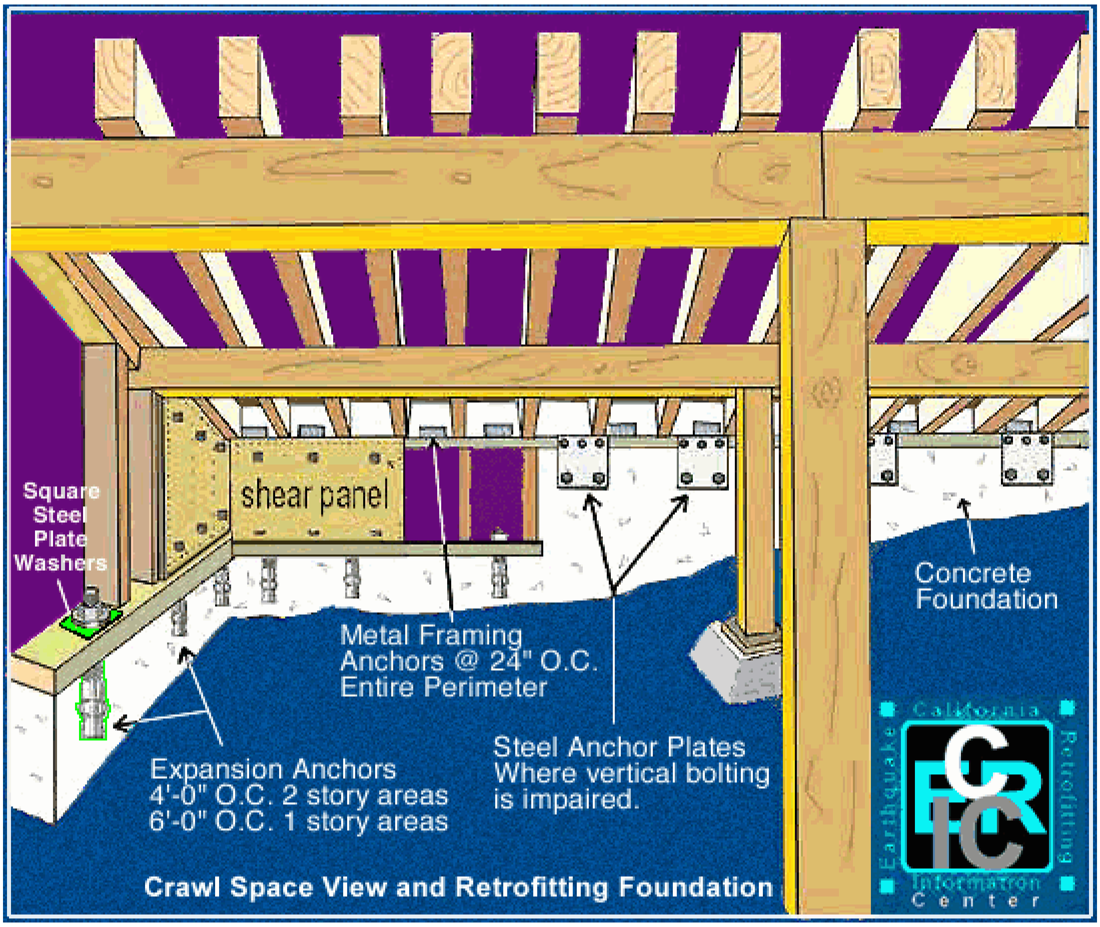


Figure 229
Placement of Concrete Expansion Anchor Bolt
Source: http://housebolting.com

http://kashmirdivision.nic.in/Disaster_Management

This resource is a section of a manual prepared for the restoration and retrofitting of rural structures in Kashmir. Divided into eight steps, this retrofit process is carefully outlined for the typical, two storey, brick or masonry Kashmir house.

Step one is the planning for retrofit, involving assessing the vulnerability of the structure, developing a scheme coordinating retrofit measures and preparing necessary drawings. Step two is the installation of a horizontal seismic belt. The belts may be placed on one or both faces of a wall, and must be connected throughout the structure. Points of tie rods and their anchoring must be determined and structural symmetry and continuity considered. Step three is the installation of vertical reinforcing bars at wall junctions. A shear connector is used at the crossing of a vertical bar and seismic belt. Weld wire mesh may be used in place of a reinforcing bar. Step four is the installation of cast in situ reinforced concrete bond elements. Reinforced concrete shear connectors will be installed for vertical reinforcement and opening encasement. Step five is the anchoring of floor to walls, done at the bottom chord of trusses or significant floor beams. Step six is the additional nailing of floor planks and adding in-plane bracing and struts, nailed to each joist they cross as the underside of a wooden floor. Step seven is the installation of collar beam ties across the top chords of the roof truss and significant rafters. Step eight is the installation of diagonal in-plane bracing in the roof. Symmetry and connections should be considered.

This article gives insight into retrofit measures as conducted in Kashmir and relates to this report in that bracing, structural symmetry and member connections are very important. These aspects too, will be considered in New Zealand dwelling retrofit.

http://ncdr.nat.gov.tw/2icdur
Hayashi, Y and Saratani, A and Morii, T. ***Seismic Risk Evaluation of Wood Houses Considering Aged Deterioration and Long-Term Occurrence Probability of Earthquakes.***

This article presents a method for predicting the probability of earthquake damage and loss of the wooden houses in Japan, considering their age deterioration, maintenance status, seismic performance and loc seismic risk. Two types of seismic risk evaluation are performed: damage probability evaluation of these houses for the predetermined earthquake scenario, and seismic loss evaluation of houses considering long term occurrence probabilities. The equations used in each of these methods are documented and applied to two case study areas: Osaka and Kochi, Japan. The study concludes that a dramatic reduction in seismic loss and damage could be achieved by a long term approach which emphasizes housing with high seismic performance, and through retrofit of houses as a short term measure. This article highlights the importance of preparing for earthquakes and the loss which may result post earthquake. This is relevant to this report to cement the need for seismic retrofit in New Zealand dwellings.

http://opus.bath.ac.nz/16170
Macabuag, J and Smith, A and Redman, T and Battacharya, S. ***Investigating the Use of Polypropylene for Seismic Retrofitting of Masonry Buildings in Developing Countries.***

This article examines the use of a polypropylene packaging strip mesh used to encase unreinforced masonry walls in order to stiffen and prevent or delay the collapse of the wall. The article begins by introducing the need for a retrofit measure for unreinforced masonry, then explains the test method used. Retrofitted and non-retrofitted specimens were tested (see Figure 230) and the tests revealed that all non-retrofitted walls failed in a brittle failure, with no further load being carried, whereas the retrofitted walls "continued to carry load after initial failure"[kkkkk] (see Figure 231).

[kkkkk] http://opus.bath.ac.nz/16170

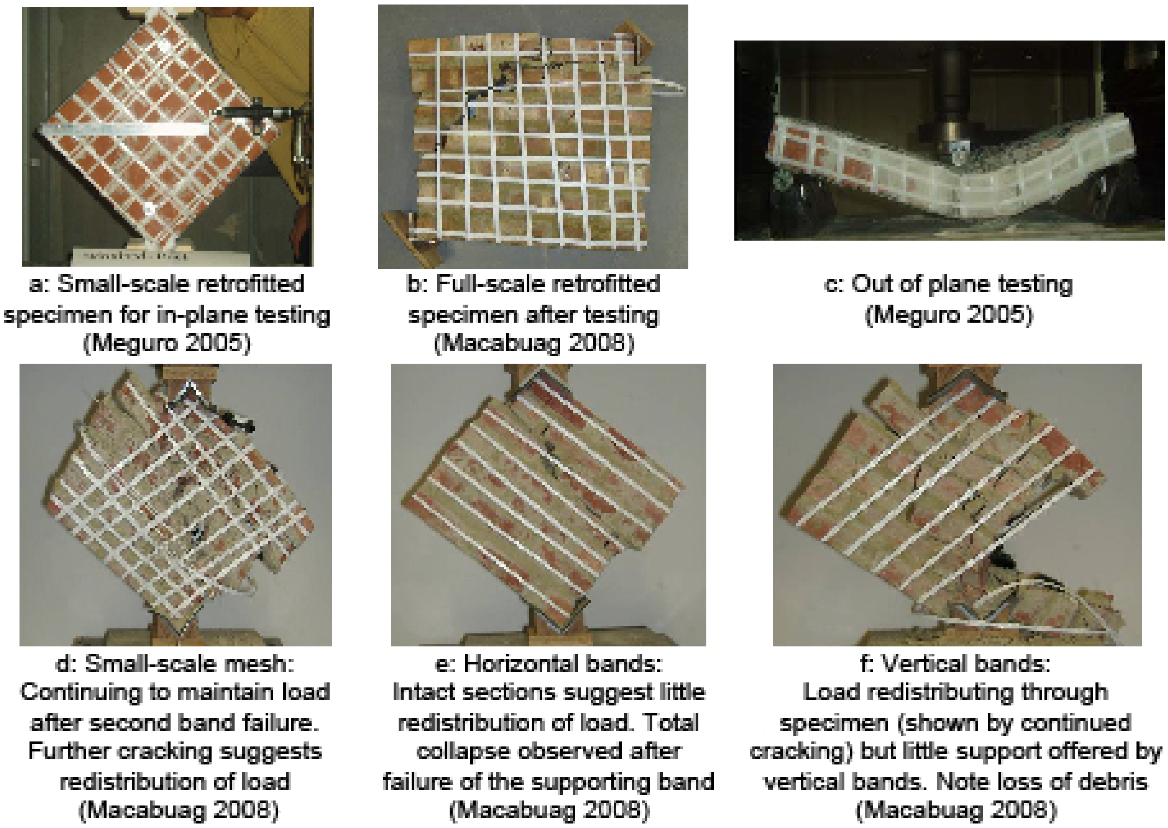


Figure 230
Full and Small Scale Model Testing Failures
Source: http://opus.bath.ac.nz/16170

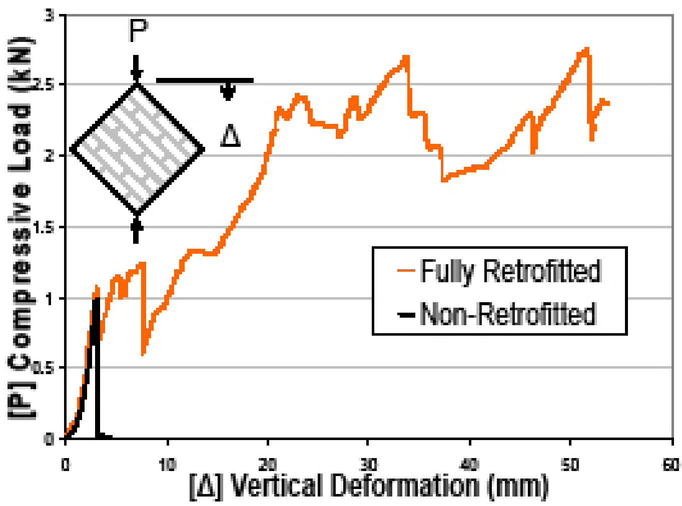


Figure 231
Load vs. Displacement for Retrofitted and Non-Retrofitted Models
Source: http://opus.bath.ac.nz/16170

Full scale shake table tests are also documented and indicate that this retrofit significantly enhances seismic resistance, heavy structural damage resistance and safety of existing masonry buildings.[lllll] This retrofit measure was taught to local, rural masons in a seismically active region of Nepal via a six-day training course. This method of retrofit is economically viable, environmentally sustainable and able to be implemented easily. This may prove relevant in both New Zealand dwellings and in low income communities alike.

http://pci.org/view_file
Iverson, James K and Banchik, Carlos and Brantley, Robert and Sage, John. Precast Segmental Seismic Retrofit for the San Mateo-Hayward Bridge.

The San Mateo-Hayward Bridge in San Francisco Bay, California is a one mile long structure, recently the recipient of a $102million retrofit construction package. The bridge is predominantly concrete construction, with twenty of its rectangular piers being retrofitted (see Figure 232). The construction of the bridge is carefully described in this article. A typical pier/deck section along with the typical retrofit are shown in Figure 233.

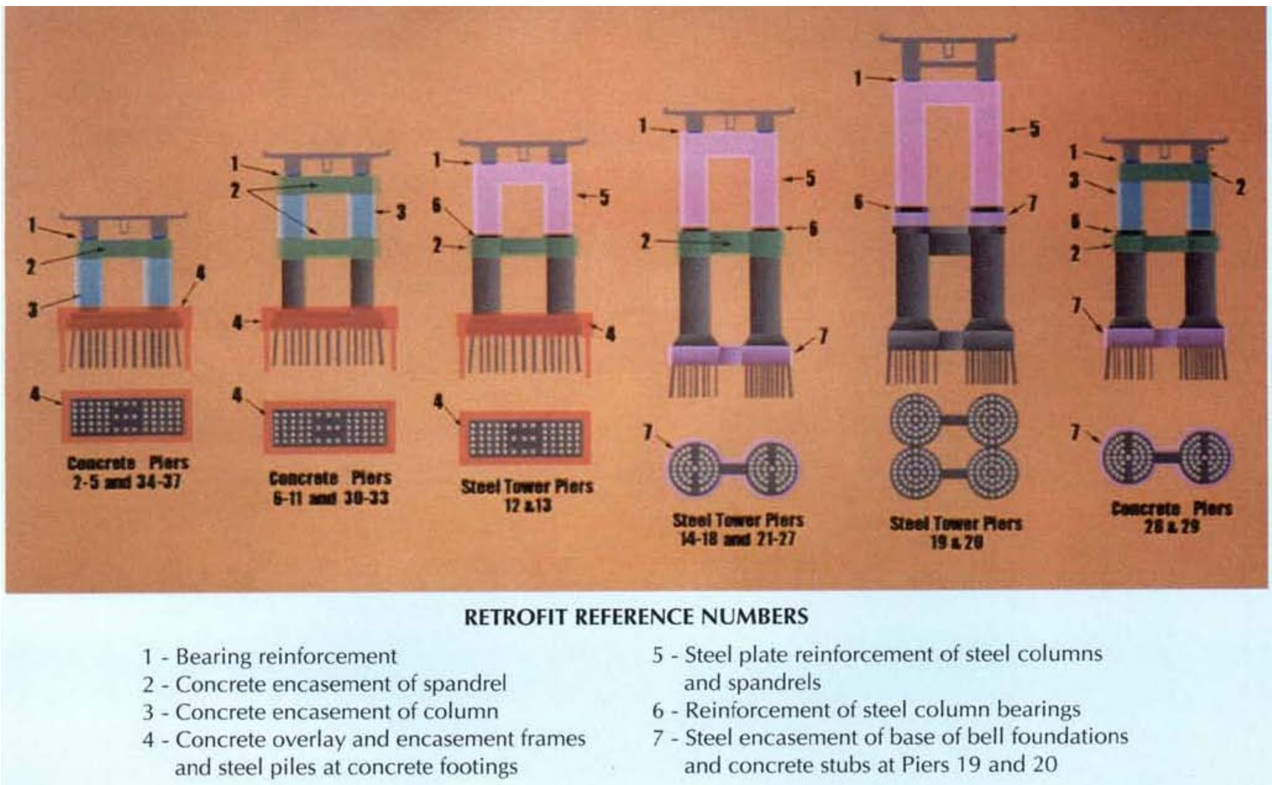


Figure 232
Various Pier Types of Main Span Bridge
Source: http://pci.org/view_file

[lllll] http://opus.bath.ac.nz/16170

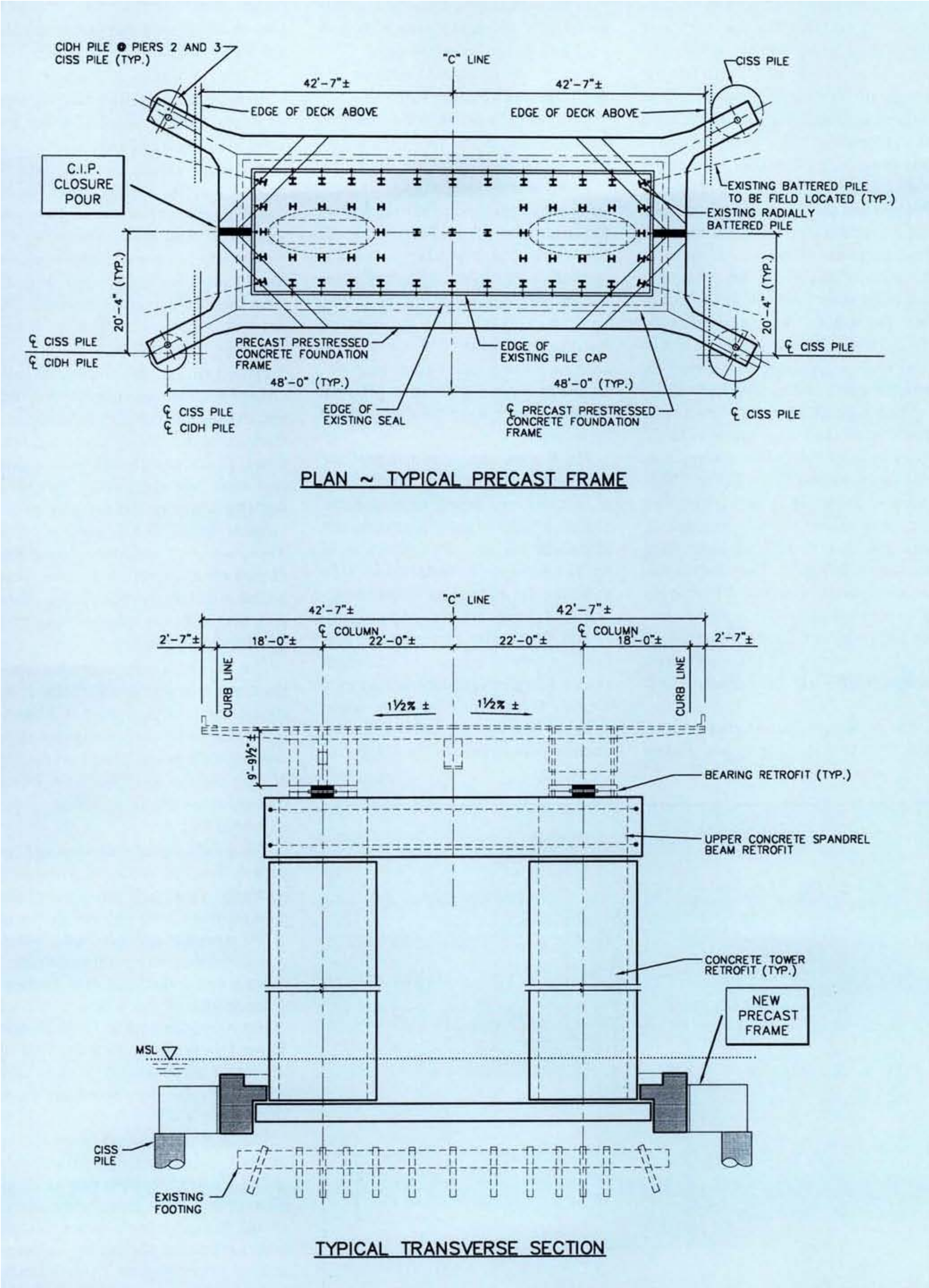


Figure 233
Plan and Elevation of Main Span Bridge
Source: http://pci.org/view_file

In deeper waters, precast bell foundation sub-structure units were used, composed of precast concrete elements. A precast flat plate template was placed on driven timber piles on the bay floor and up to 120 steel H-piles were driven through the template leaving a twelve foot extension above the template. A hollow precast bell-shaped section is then placed onto the template; two of these would span under each pier connected by a precast strut (see Figure 234).

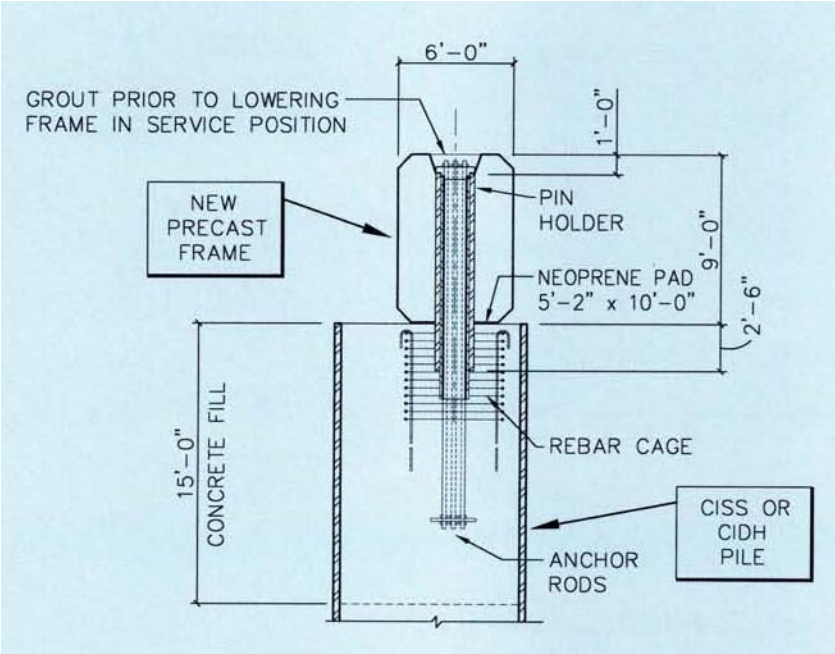


Figure 234
Typical Section Showing Precast Frame to Pile Connection
Source: http://pci.org/view_file

The longitudinal beams used in the retrofit were designed with inner polystyrene box sections through the centre to decrease weight and reduce seismic response. All reinforcing bars were epoxy coated and steel was hot dip galvanised. Submerged steel was sized with an increased thickness to allow for corrosion.
The connection between the existing foundation and the precast frames was detailed with ‘grout bags’ (see Figure 235). The frames were prepared in two halves and lifted into place using erection barges commissioned for the project. Although this retrofit is beyond the scope of New Zealand dwelling retrofit, it does emphasise inventive solutions and thorough considerations. The use of precast concrete encasement frames to retrofit has been very successful and the use of precast and pre-stressed concrete has been ideal.

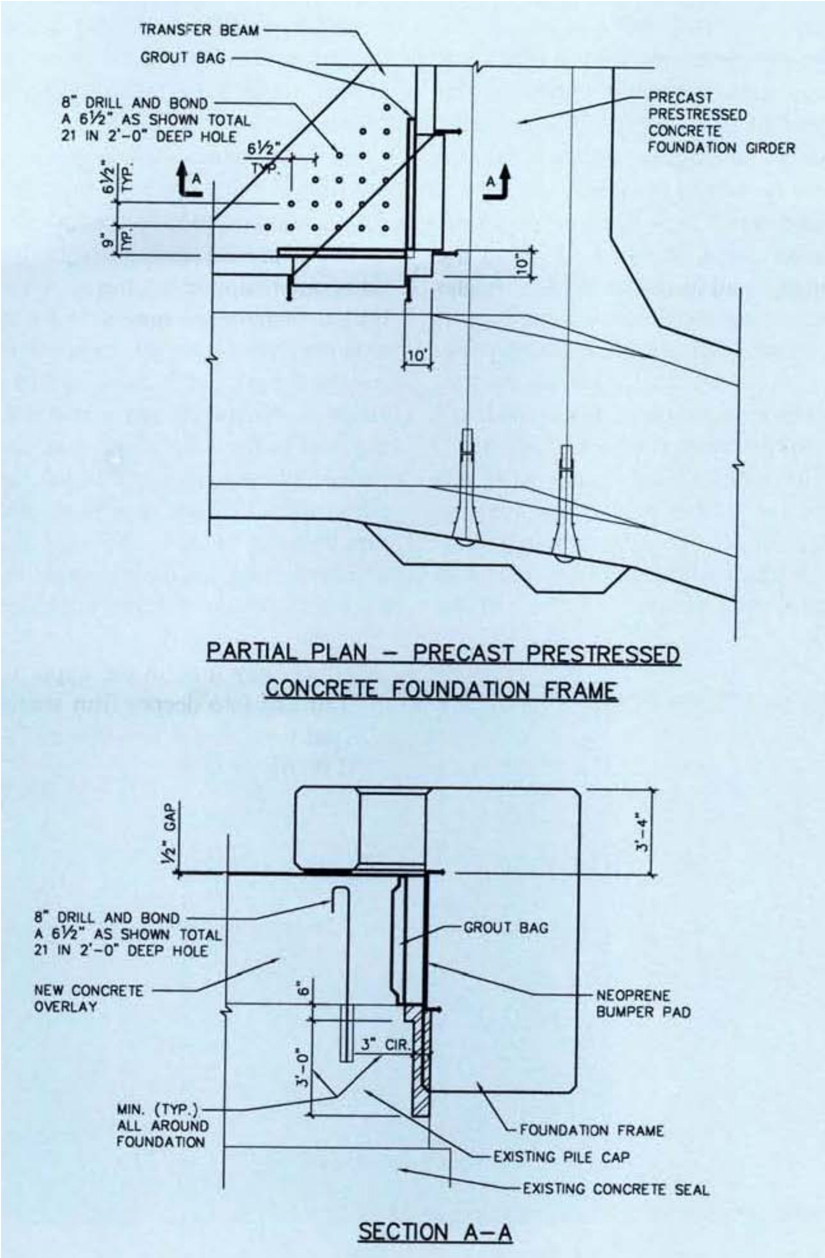


Figure 235
Plan Details for Grout Bag Load Points
Source: http://pci.org/view_file

http://seismicassociation.org

This website was created by the Seismic Retrofit Association, members of which are licensed structural engineers with extensive experience in commercial seismic retrofit. The website gives a definition of seismic retrofit, reasons for retrofitting and the process of a retrofit consultation. The Seismic Retrofit Association specialise in the seismic retrofit of concrete tilt up buildings where reinforcing is needed to stop the roof separating from the perimeter walls. Roof to wall anchors and continuity ties are used, and some figures are given of connections (see Figures 236, 237, 238 and 239). Although this website gives only a brief overview it does emphasise the importance of connections which relates very closely to this report and the retrofit of New Zealand dwellings.

Figure 236
Source: http://seismicassociation.org

Figure 237
Source: http://seismicassociation.org

Figure 238
Source: http://seismicassociation.org

Figure 239
Source: http://seismicassociation.org

http://www.abag.ca.govt/bayarea/eqmaps/fixit

This website has a slideshow with a section detailing the seismic retrofit of cripple wall (jack stud) foundations. The website details recommendations for carrying out the work, which are detailed below:

- "If using the existing girder as the cripple wall top plate is not feasible, and it is cut flush with the end of the new cripple wall, a metal strap connecting the girder to the top plate of the new cripple wall must be provided.
- This connection will be subject to both tension and compression forces
  - It is very important that the girder end be carefully cut so that it will tightly fit against the new cripple wall or foundation.
- Also, to provide enough surface area to make this nailed splice connection and not interfere with the row of nailing along the top edge of the plywood, the new cripple wall top plate must be a minimum 4x4 member instead of using a typical double 2x4 top plate.
- One further consideration at this connection is that the vertical face of the girder and the new top plate must align because the strap should not be kinked or bent.
- A misalignment of 3/4 inch or less can be accommodated by installing plywood of the appropriate thickness on the face of the existing girder to make it flush with the new top plate.
  - If this plywood shim is installed, the length of the 10d nails used in the strap must be increased to provide a minimum of 1-1/2 inches of penetration into the girder.
  - Given the complexity of this connection, the use of the existing girder for the top plate of the new cripple wall is the preferred method.

- Along the walls where the existing floor joists are parallel to the new foundation and cripple wall, the same concept of a continuous member applies.
  - The end joist must be a single piece that extends the full length of the new foundation and continues at least to the next perpendicular girder line beyond the end of the new foundation, where it may be spliced as shown in the Detail G.

- Also along this wall, another strap must be provided to tie together the new double 2x top plates of the cripple wall where they are interrupted by the existing girders framed over new support posts."[mmmmm]

Details of the strap for the joist splice and the strap for the plate splice are given (see Figures 240 and 241).

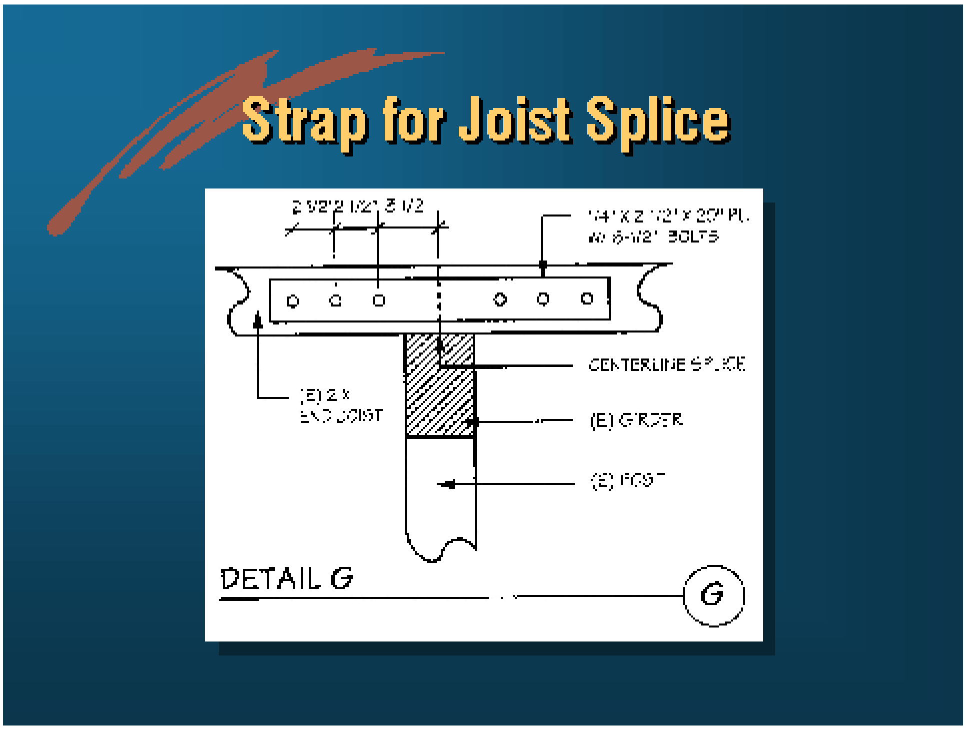


Figure 240
Strap for Joist Splice
Source: http://www.abag.ca.govt/bayarea/eqmaps/fixit

[mmmmm] http://www.abag.ca.govt/bayarea/eqmaps/fixit

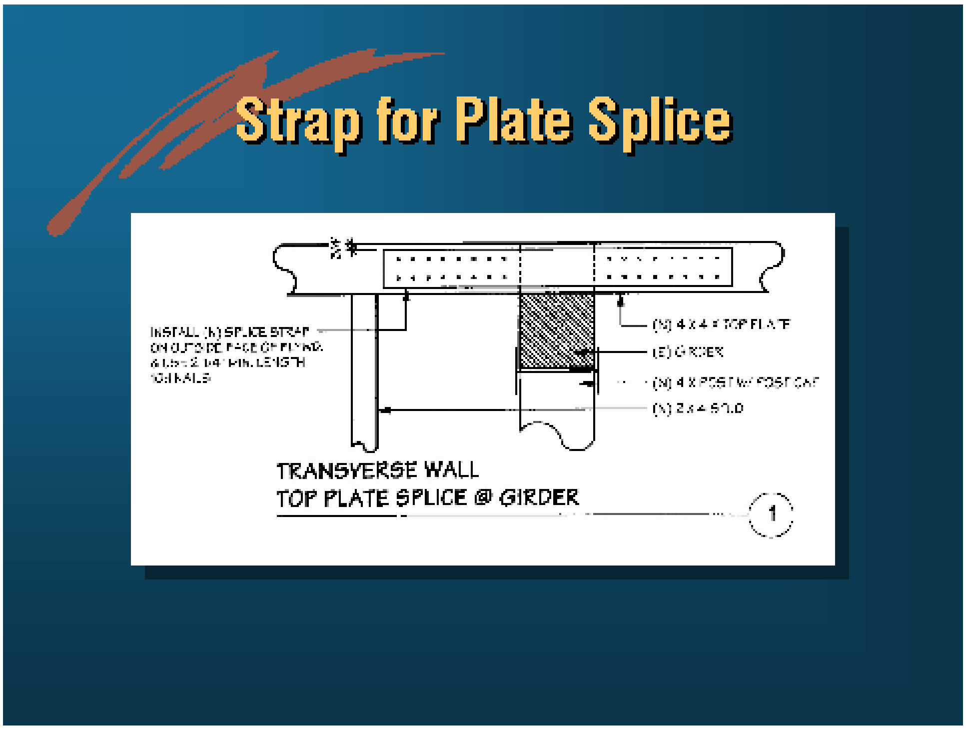


Figure 241
Strap for Plate Splice
Source: http://www.abag.ca.govt/bayarea/eqmaps/fixit

This resource gives a comprehensive analysis on the retrofitting of cripple walls, which may prove relevant for use in jack stud foundations here in New Zealand dwellings.

http://www.bayarearetrofit.com

This website has been set up by Bay Area Retrofit, a company specialising in seismic retrofit in the San Francisco Bay area. The website has several sections including how retrofit works, retrofit design, hazard maps, damage statistics and the services Bay Area Retrofit provide. In the section on Retrofit Design, information is given from the Uniform Code of Building Conservation (see Appendix 3). This covers information on definitions of elements of dwellings, structural weaknesses in elements and how to employ quality control. This resource was compiled by a team of structural engineers specialising in seismic retrofit. Following this there is a section on seismic bolting, the retrofit measure employed by Bay Area Retrofit (see Appendix 4). This is detailed in steps from code requirements to types of bolt, oversized bolt holes and mudsill plates. This information specifies the products used and the size of elements (if applicable). This process is very similar to other foundation bolting processes employed by other companies in the California area, as noted in this report. However, the specification of products and references to seismic codes is relevant. This process may translate to appropriate dwellings in New Zealand in need of seismic retrofit.

http://www.boltusa.com

This website was created by Avalin Seismic Construction Company, Los Angeles, and explains the process of seismic retrofit and how they carry it out. House bolting and foundation bolting is first outlined; “a process of attaching a house to its concrete foundation”[nnnnn] to resist the varied movement of earthquakes (see Figure 242). A combination of expansion wedge anchors and epoxied threaded rods are used, typically spaced 5’ apart for single storey dwellings, and 4’ apart for two storey dwellings (see Figure 243). Side bolting is used if the crawl space does not allow for direct bolting (see Figure 244).

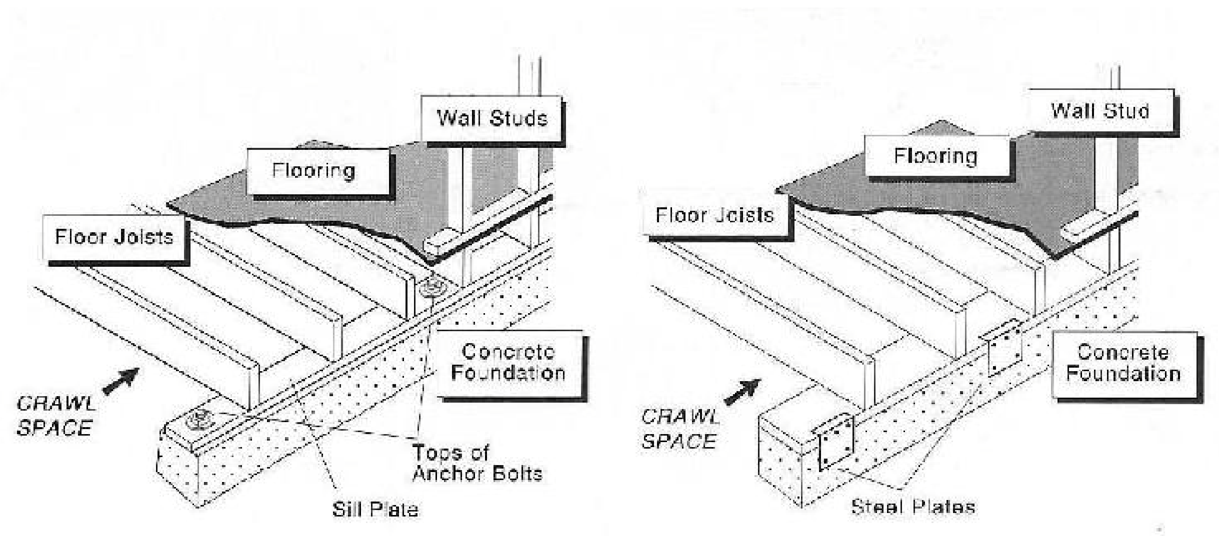


Figure 242
Left: Foundation Bolts installed at the time of Original Construction; Right: Foundation Bolting Plates added as Foundation Bolting Retrofit
Source: http://www.boltusa.com

[nnnnn] http://www.boltusa.com

Figure 243
Expansion Foundation Bolts as Installed
Source: http://www.boltusa.com

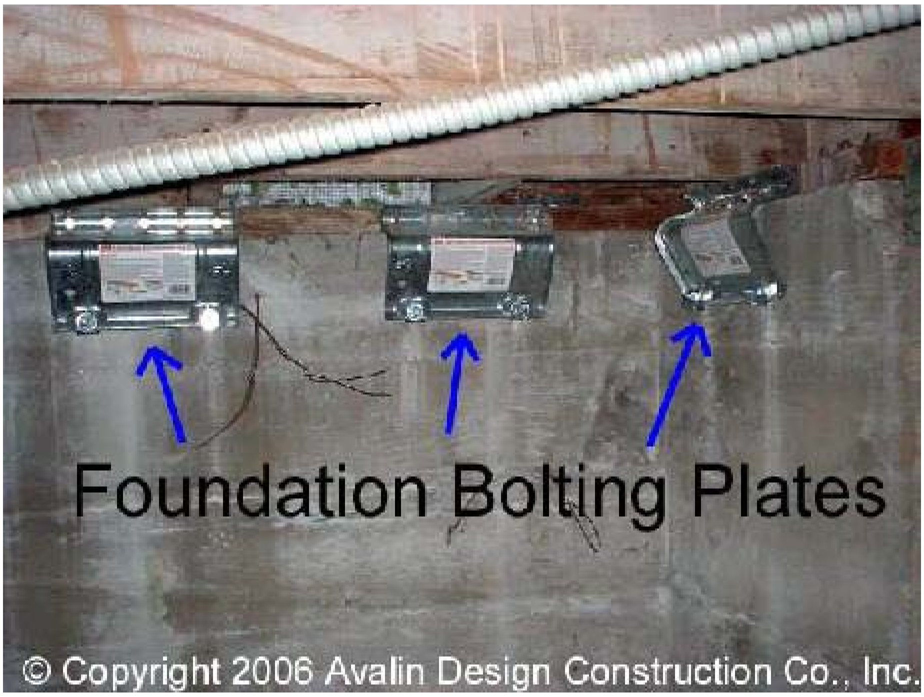


Figure 244
Foundation Bolting Plates as Installed
Source: http://www.boltusa.com

Cripple wall bracing is outlined second, which is commonly carried out through bracing with plywood (see Figure 245). The existing cripple wall (see Figure 246) is braced with new lumber to create solid edges for the new shear wall nailing and new expansion bolts and framing anchors are installed (see Figures 247 and 248).

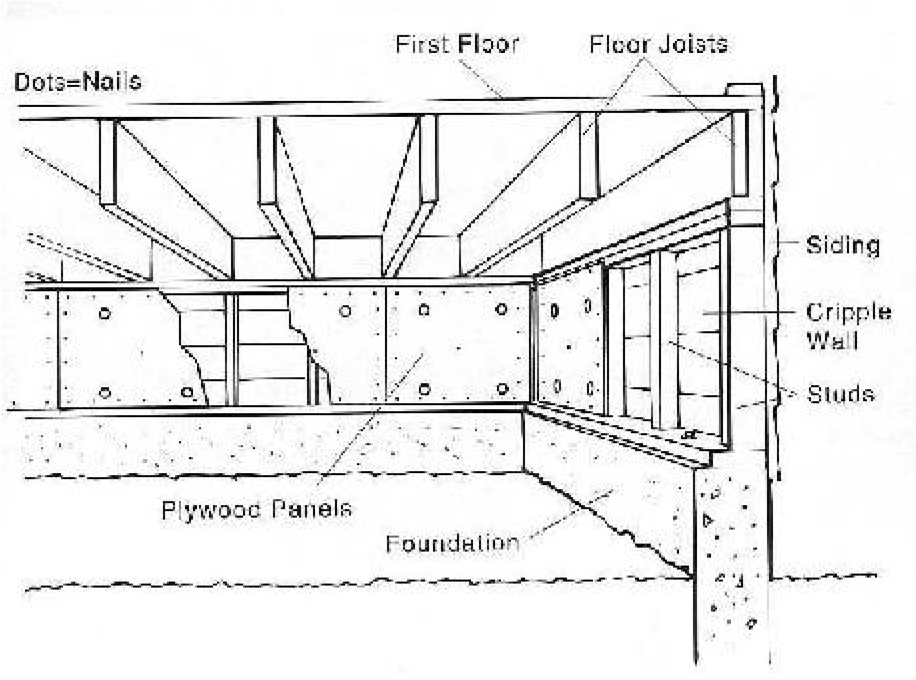


Figure 245
Cripple Wall Retrofit
Source: http://www.boltusa.com

Figure 246
Cripple Wall before Retrofit
Source: http://www.boltusa.com

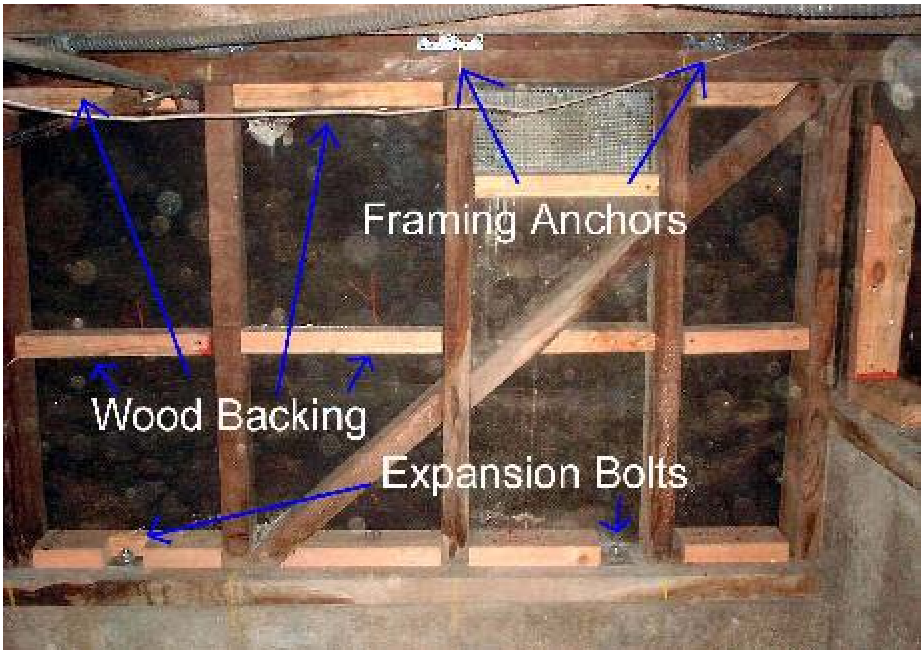


Figure 247
Cripple Wall during Retrofit
Source: http://www.boltusa.com

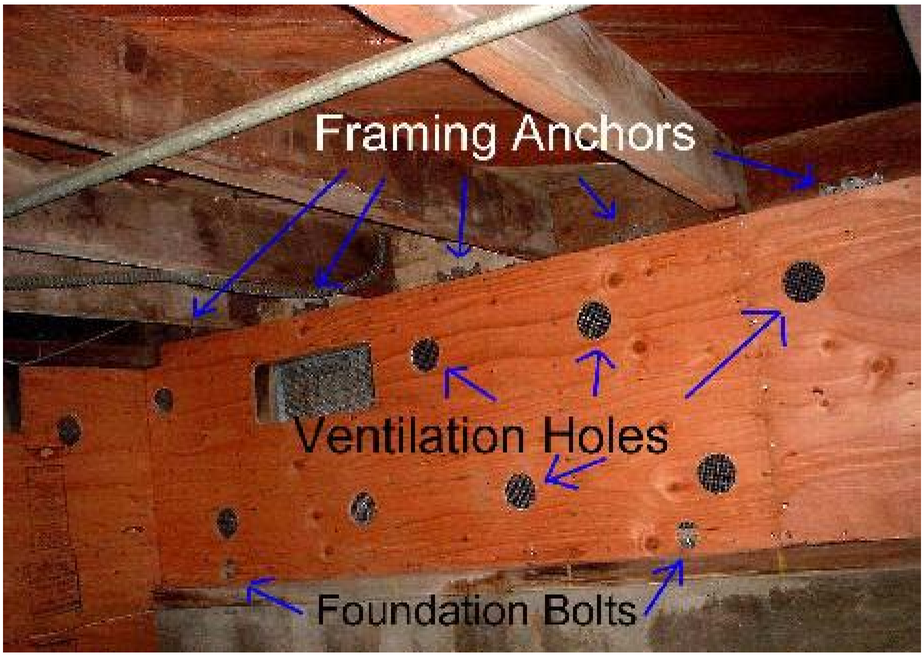


Figure 248
Cripple Wall after Retrofit
Source: http://www.boltusa.com

This resource is very relevant to this report as it outlines a process of retrofitting which may translate well to the New Zealand built environment, particularly the retrofitting of dwellings with jack stud foundations that are not seismically stable.

http://www.ci.san-leandro.ca.us

This website is a homepage for the city of San Leandro, California. It gives information on doing business, living in, and employment in San Leandro as well as emergency information and a drafted local hazard mitigation plan. In a section on earthquakes, a residential seismic strengthening plan has been developed (see Appendix 1). This illustrates cripple wall bracing details (see Figure 249) as well as floor to mud sill connections (see Figure 250), further cripple wall bracing details (see Figure 251) and typical floor to cripple wall connections (see Figure 252). This resource is relevant to this report as it has produced details which may be applicable in New Zealand, and has been developed following research and input from the California Building Officials Seismic Safety Committee, the Earthquake Engineering Institute of Northern California and the Structural Engineers Association of Northern California.

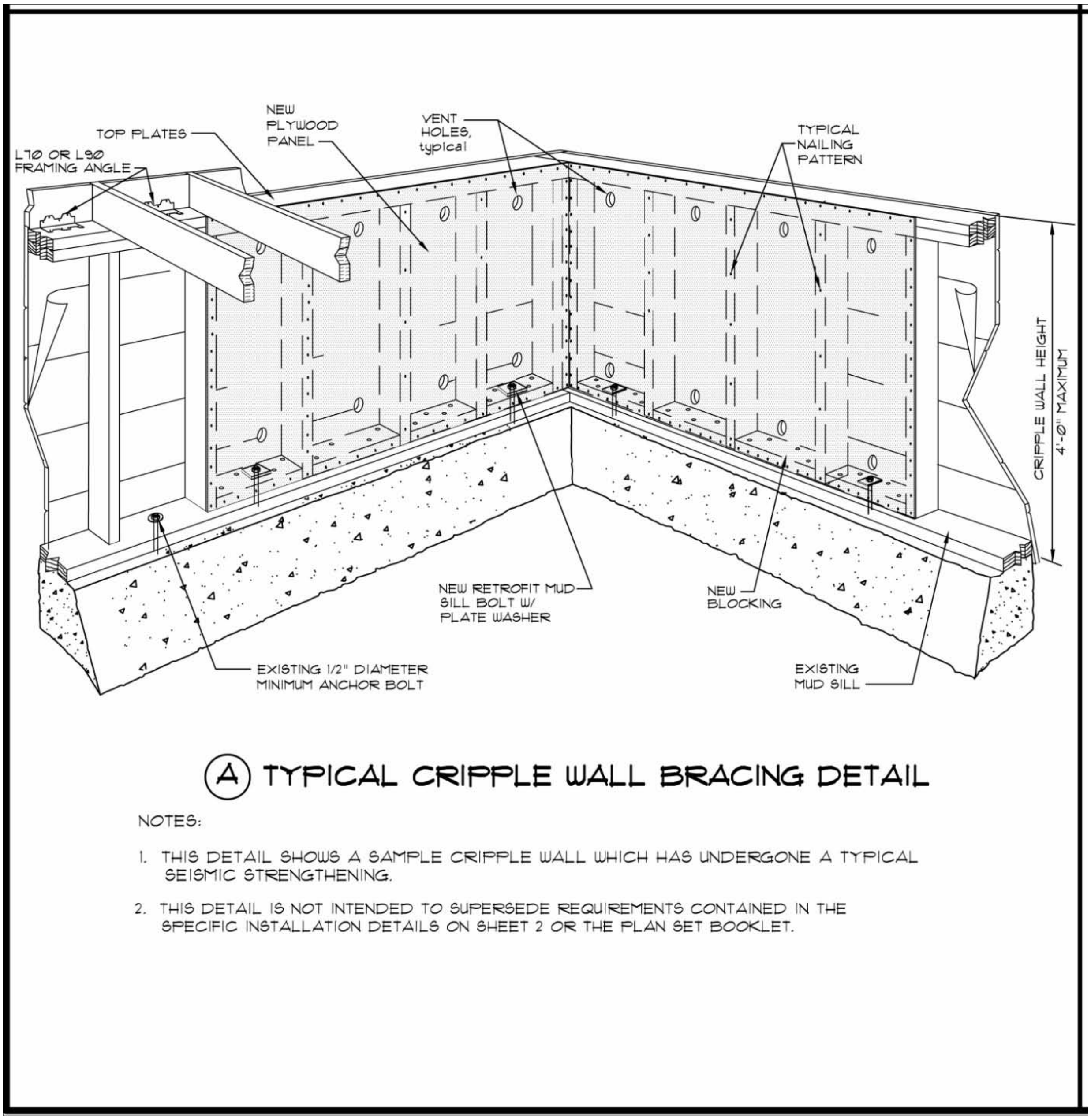


Figure 249
Cripple Wall Bracing Detail
Source: http://www.ci.san-leandro.ca.us

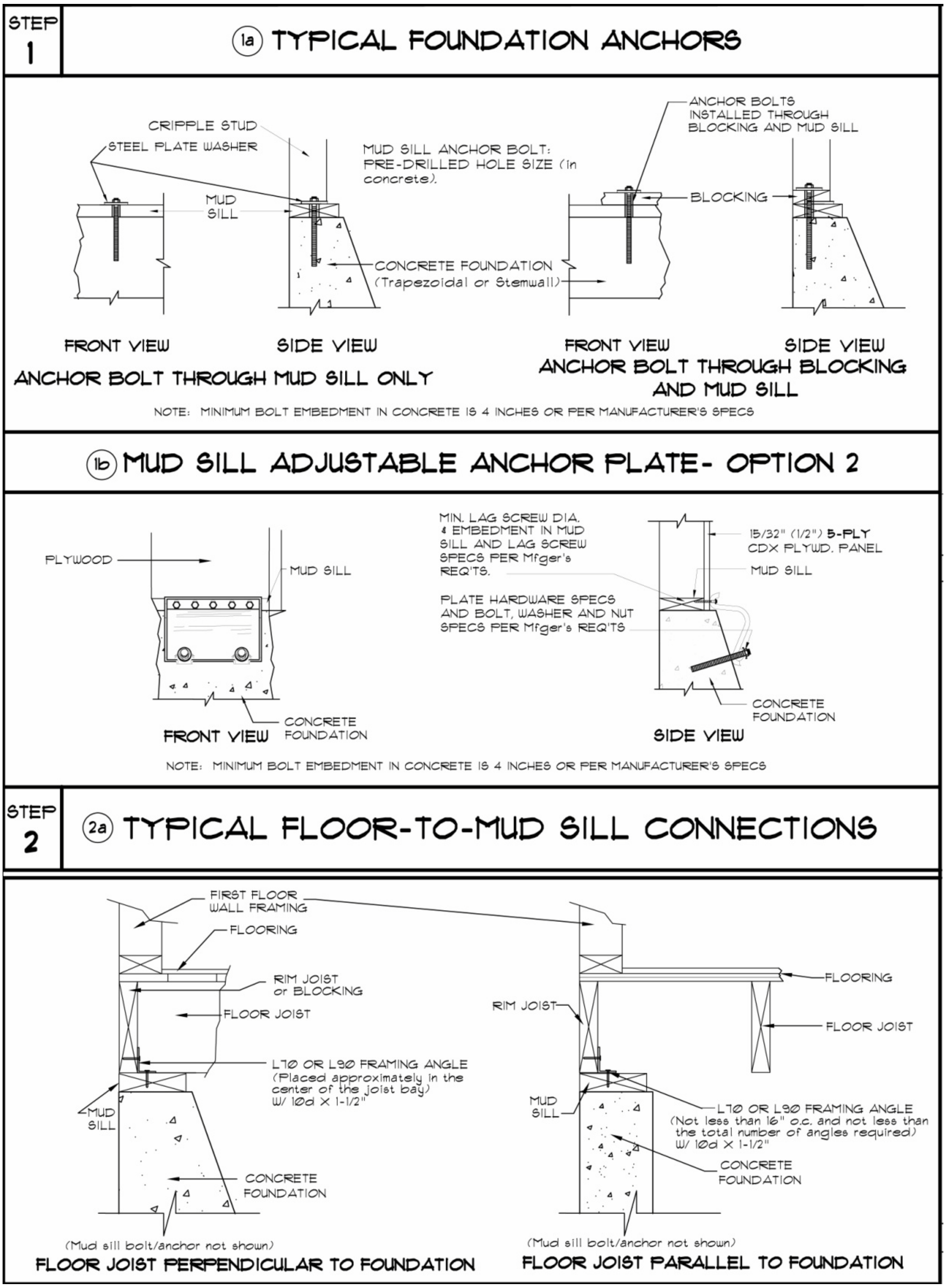


Figure 250
Floor to Mud Sill Connections
Source: http://www.ci.san-leandro.ca.us

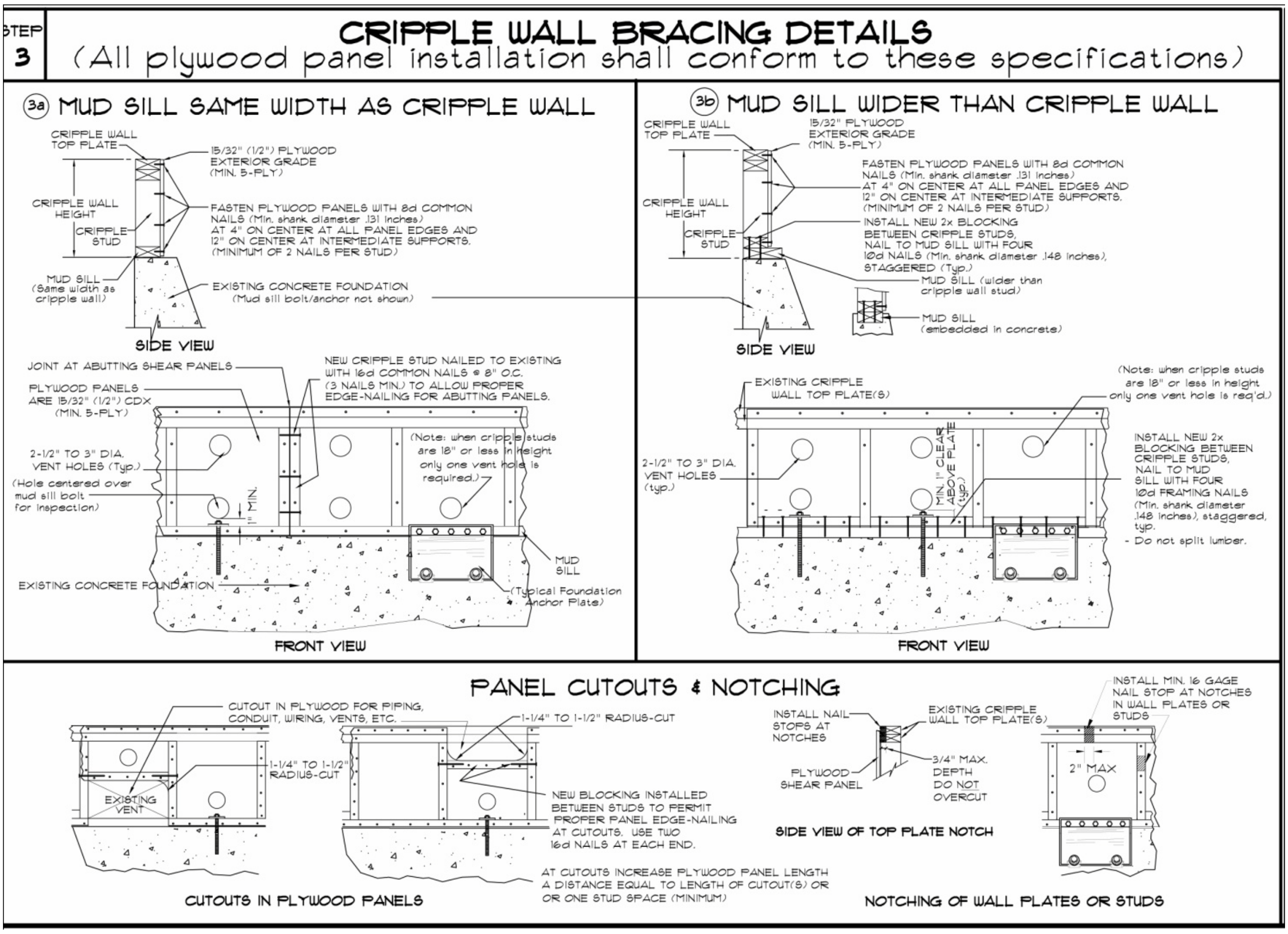


Figure 251
Cripple Wall Bracing Details
Source: http://www.ci.san-leandro.ca.us

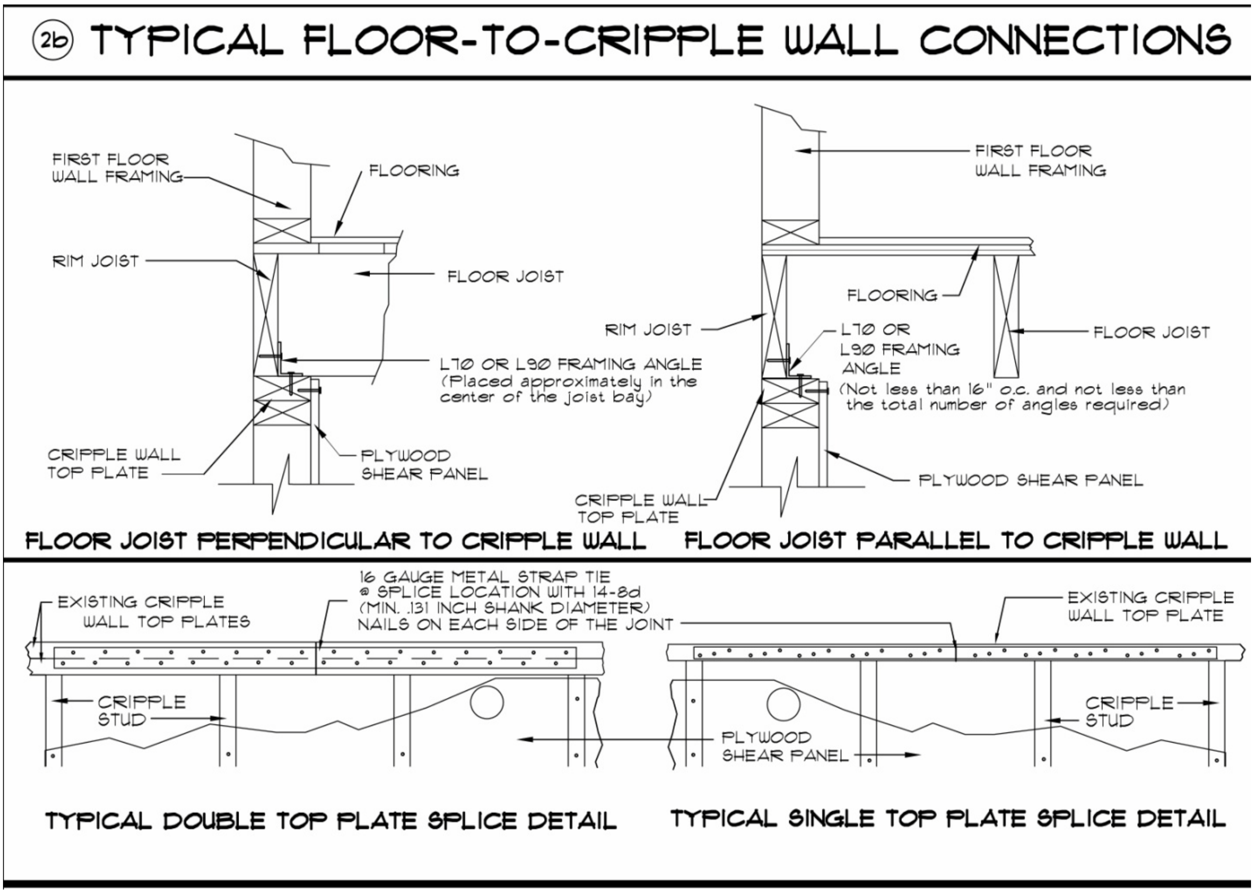


Figure 252
Floor to Cripple Wall Connections
Source: http://www.ci.san-leandro.ca.us

http://www.empa.ch/Plugins
Stieger, Rene. Improved efficiency of timber structures: A review of activities at the EMPA Wood Laboratory.
Presented as part of the EMPA-Symposium, Switzerland, 2003, Jan.

This article examines timber construction and the sustainable activities of the EMPA Wood Laboratory in field and timber engineering. This includes safety and reliability, combination of wood with other materials, and air permeability of timber building envelopes. The article also examines the present situation, looking at the new Swiss structural timber design code SIA265, quality in timber housebuilding, safety and reliability of timber structures, use of fibre reinforced plastics in timber engineering and moisture dependent vapour-control layers.
The EMPA Wood Laboratory has been closely involved in the research and development of codes and standards for the timber industry. Timber grading is explained and timber quality emphasised and discussed. Timber possesses some weaknesses, such as “anisotropy and inhomogenity, compounded by wide variations in material property values and a relatively high susceptibility to transverse tensile and shear failure at joints.”[ooooo] These weaknesses can be offset by combining timber with materials such as concrete, fibre-reinforced plastics or steel. Each of these combinations is explained, covering the history of its development. Testing methods are also documented.
The new Swiss structural timber design code is analysed and compared and contrasted to its predecessor, and it is noted that timber is gaining in popularity as the chosen material for residential buildings.

[ooooo] http://www.empa.ch/Plugins

The article concludes that greater attention will be devoted in future to the reinforcement of wood and wood based products using post strengthening technologies and composite materials. Research is also being conducted into vapour-control layers and their addition to modern buildings. The reliability and quality of load bearing timber structures is again emphasised. Although this article does not give seismic retrofit details it does discuss the varied possibilities of timber application and the need for quality construction, which is very relevant in the retrofit of New Zealand dwellings, the majority of which are timber construction.

http://www.facweb.iitkgp.ernet.in/SE202-21
Battacharyya, SK. Retrofitting of Building Structures Damaged Due to Earthquake.

This article begins by introducing the need for properly detailed structures for earthquake performance. Unreinforced masonry buildings are in particular need of seismic upgrade. The article covers non destructive and destructive testing methods for concrete, structural steel and masonry.
Renovating steel frames buildings is covered first, where the welding of steel angles, channels or bars is quite common to increase the load carrying capacity of the existing framing (see Figure 253). Columns can also be reinforced by welding cover plates or similar onto both of the flanges. To fix deteriorated column bases the approach is to shore the column, remove deteriorated material and weld or bolt reinforcing to the column.

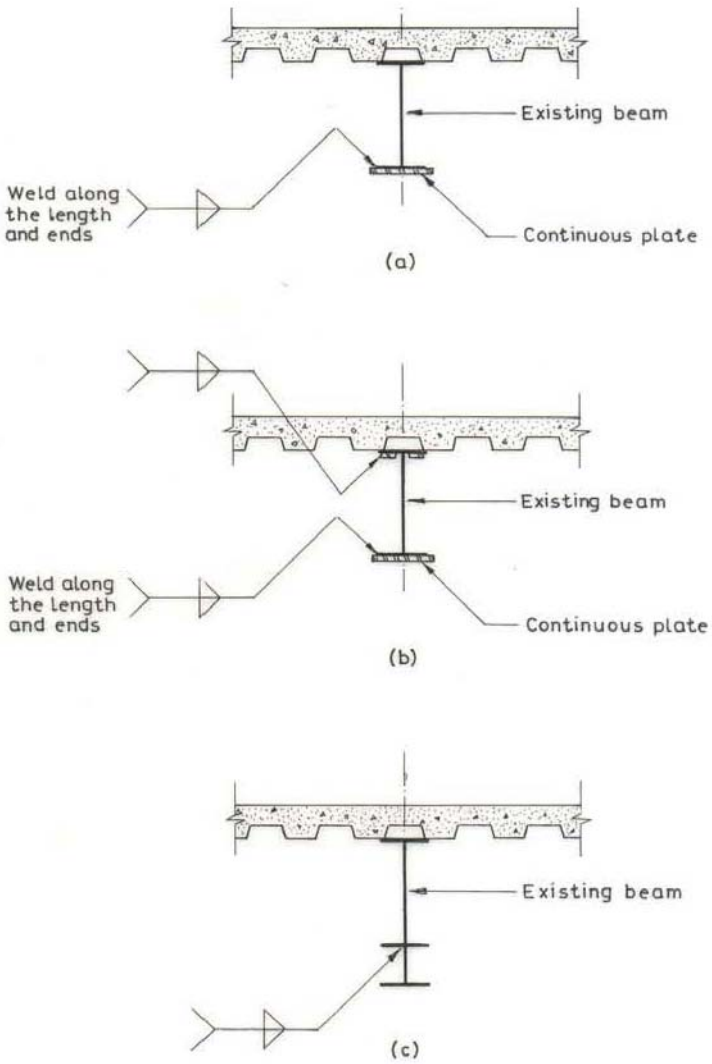


Figure 253
Reinforcing Existing Steel Beams
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

Renovating concrete structural elements is covered second. Adding a steel channel on each side of an existing concrete beam is a solution which allows the channels to be connected to the concrete columns. The three beams are interconnected with bolting (see Figure 254). Flexible steel channels could also be used, fastened to the existing concrete at the ends. The intention is to induce an upward force by deflecting the beams downward through jacking or wedging the space between the underside of the slab and the beams (see Figure 255).

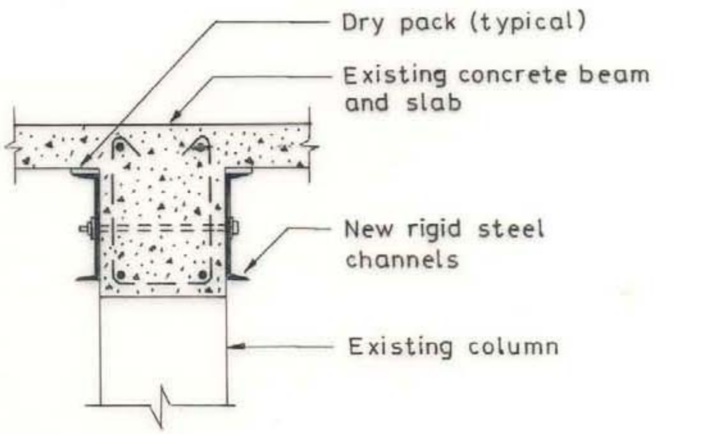


Figure 254
Adding Steel Beams on each side of an Existing Concrete Beam
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

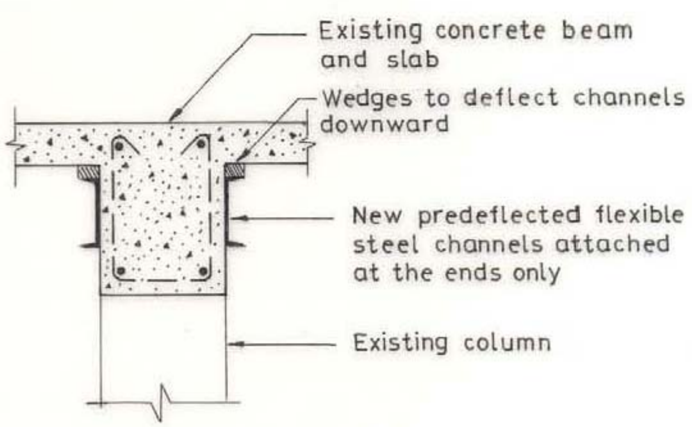


Figure 255
Adding Steel Beams on each side of an Existing Concrete Beam
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

The concrete section may be enlarged to strengthen it. New reinforced concrete is placed around the existing beam; proper interconnection is critical for the functioning of the whole. The sections can be tied together with stirrups (see Figure 256), by short dowels (see Figure 257), or by enveloping the beam with a new floor overlay (see Figure 258).

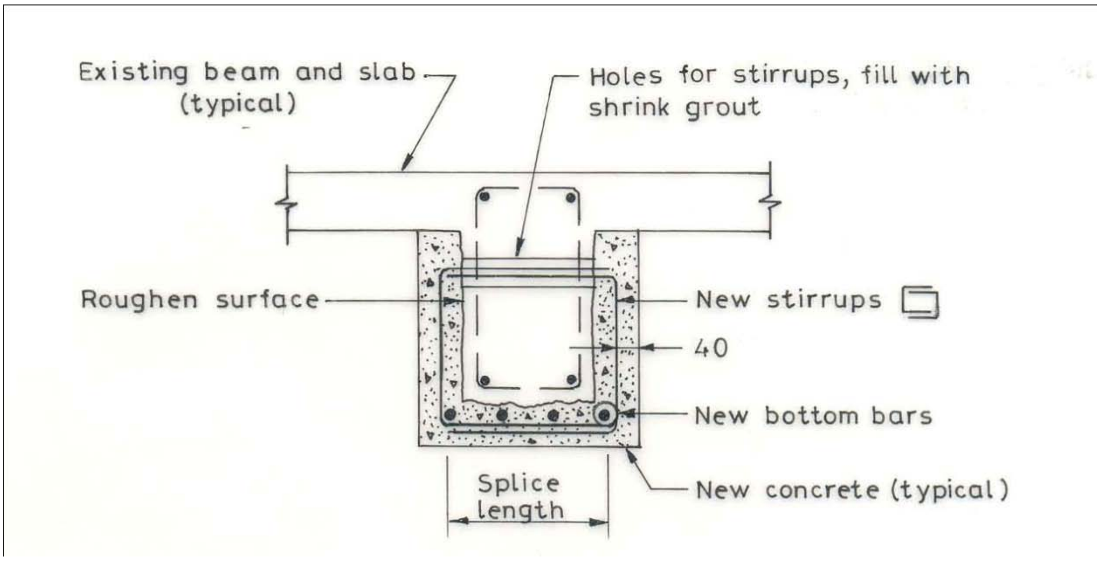


Figure 256
Enlarging a Section of an Existing Concrete Beam
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

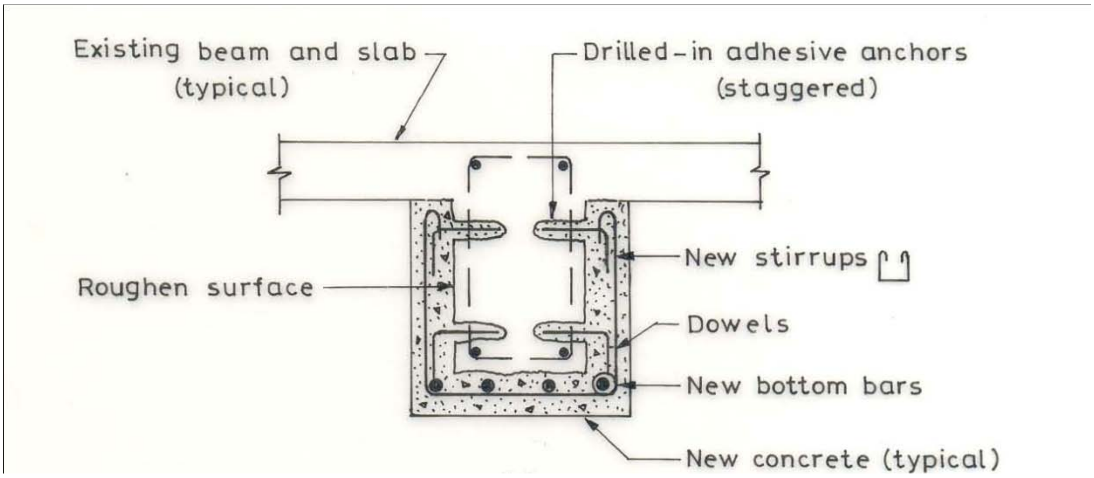


Figure 257
Enlarging a Section of an Existing Concrete Beam
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

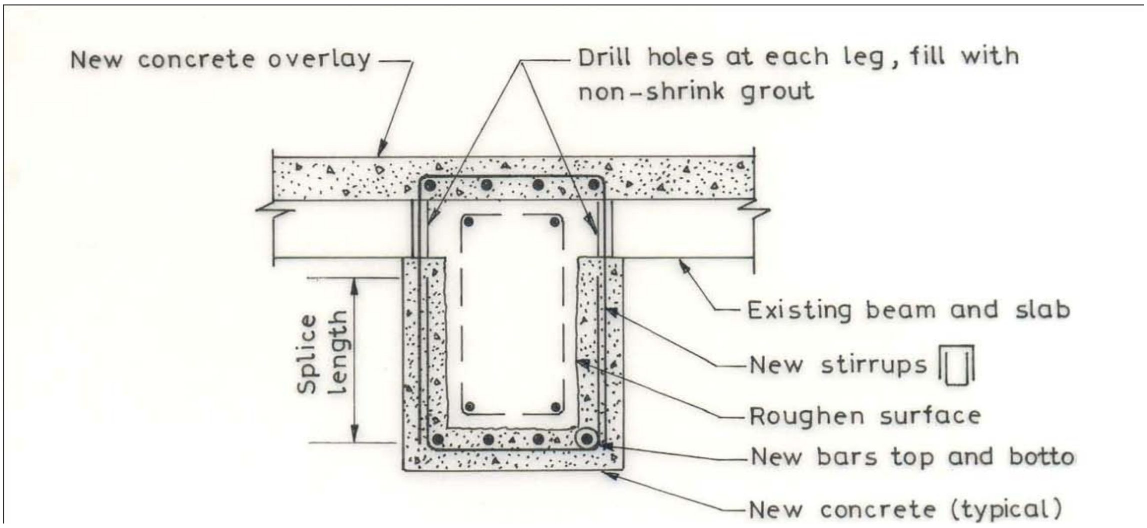


Figure 258
Enlarging a Section of an Existing Concrete Beam
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

When the beam lacks moment capacity it can be reinforced with structural steel tension plates bolted to the beam (see Figure 259). A welded U-bracket can be used if substantial additional steel is required. Differing damages can also be mitigated as shown in Figures 260, 261, and 262.

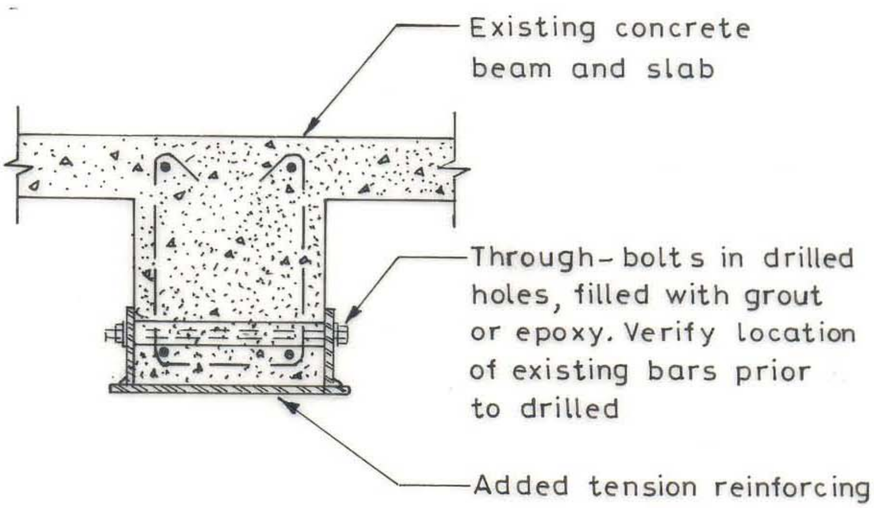


Figure 259
Addition of Steel Member to Improve Moment Capacity
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

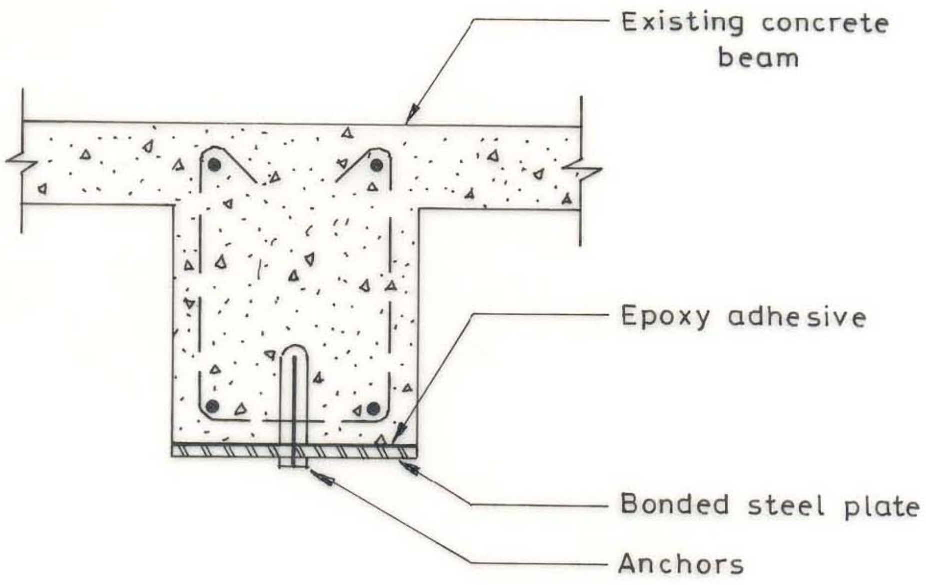


Figure 260
Concrete Damage Repair
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

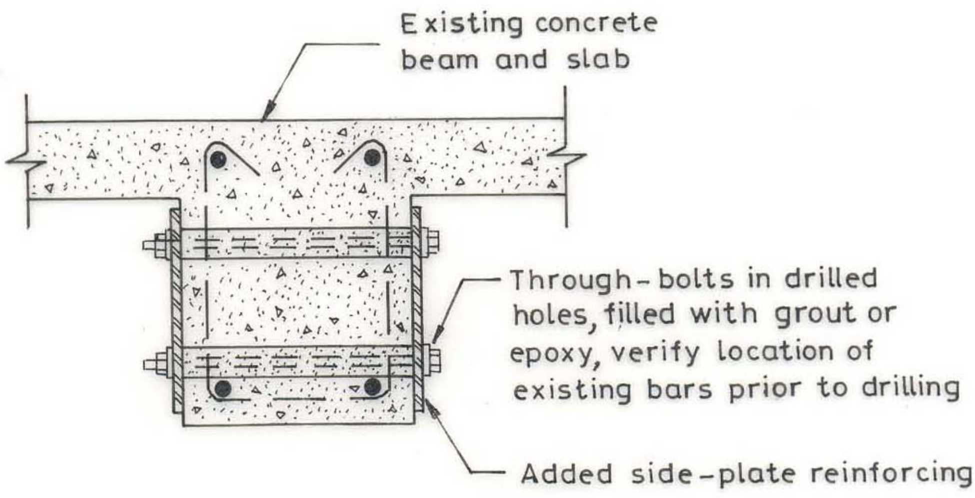


Figure 261
Concrete Damage Repair
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

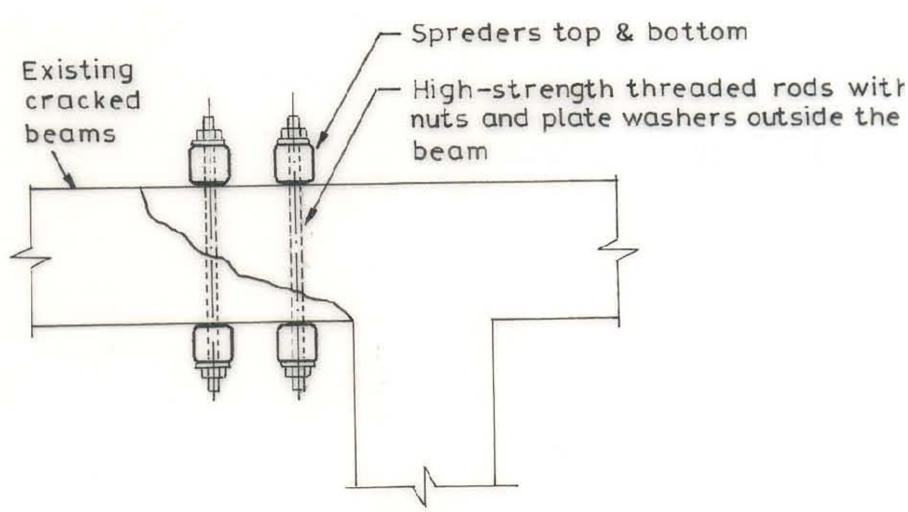


Figure 262
Concrete Damage Repair
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

Cracks can be generated in concrete due to earthquakes. This can be 'stitched' with dowels (see Figure 263 and 264). Epoxy injection or grouting can 'glue' the concrete together, or sealant can be applied to mitigate cracking also.

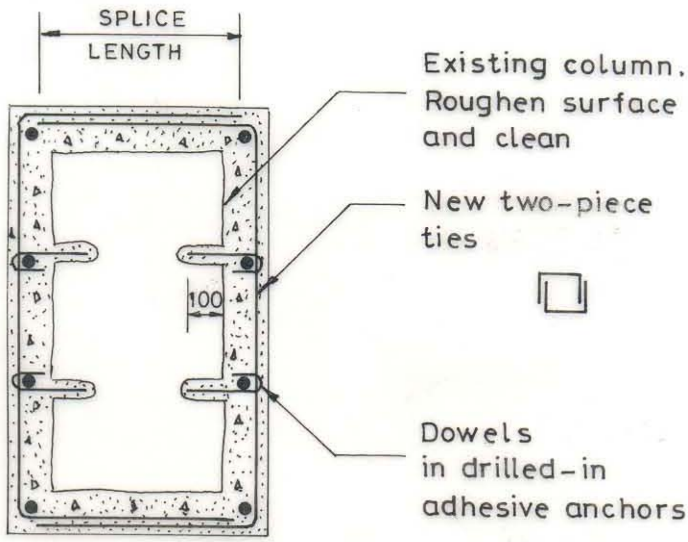


Figure 263
Retrofitting Concrete Columns
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

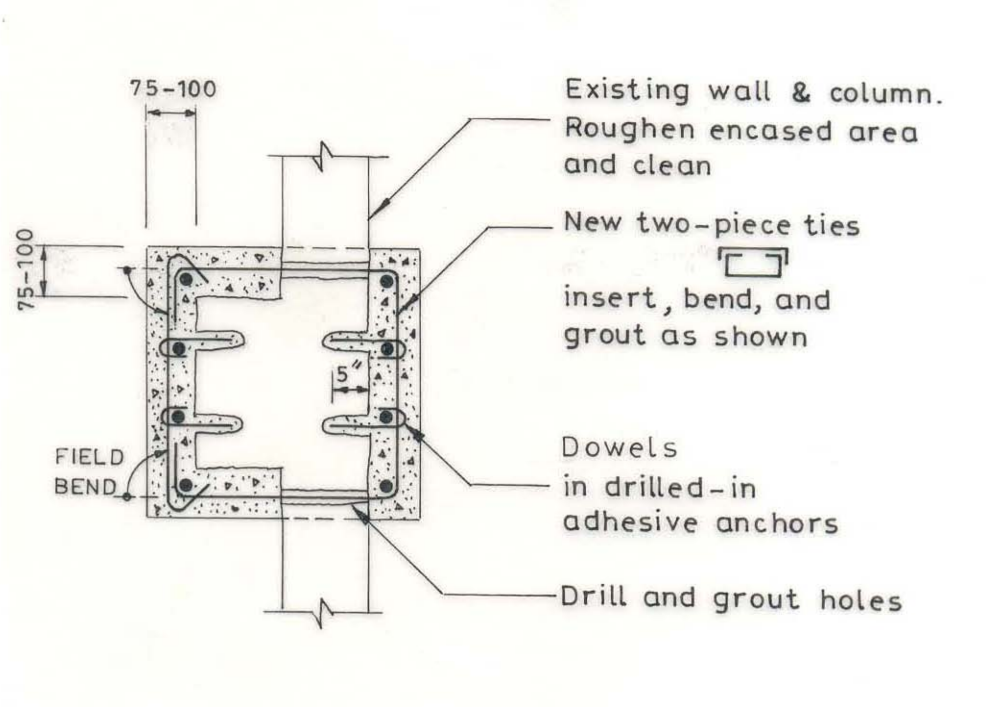


Figure 264
Retrofitting Concrete Columns
Source: http://www.facweb.iitkgp.ernet.in/SE202-21

Although this article does not specifically relate to subfloor and foundation detailing, some retrofit solutions presented may be relevant in the retrofit of concrete piled foundations or where concrete is damages or cracked and in need of repair and attention.

http://www.foundationbolting.com

This website was created by Stern's Construction, Inc., a firm that specialises in seismic retrofit services in the Los Angeles area. Seismic retrofit, the need for retrofit and retrofit construction are explained. There is also a section on this website devoted to the Los Angeles Department of Building and Safety retrofit diagrams which illustrate how retrofit details are to be carried out. This is a series of 14 figures, covering from replacement of concrete footing and stem wall, to cripple wall details and anchorage for joists supported on concrete (see Figures 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277 and 278). The details for the cripple wall would work well in New Zealand in jack stud foundations, and the fixings to concrete foundation walls may also translate well to the New Zealand building environment. Thus, this resource is very relevant to the seismic retrofit of dwelling subfloors and foundations in New Zealand.

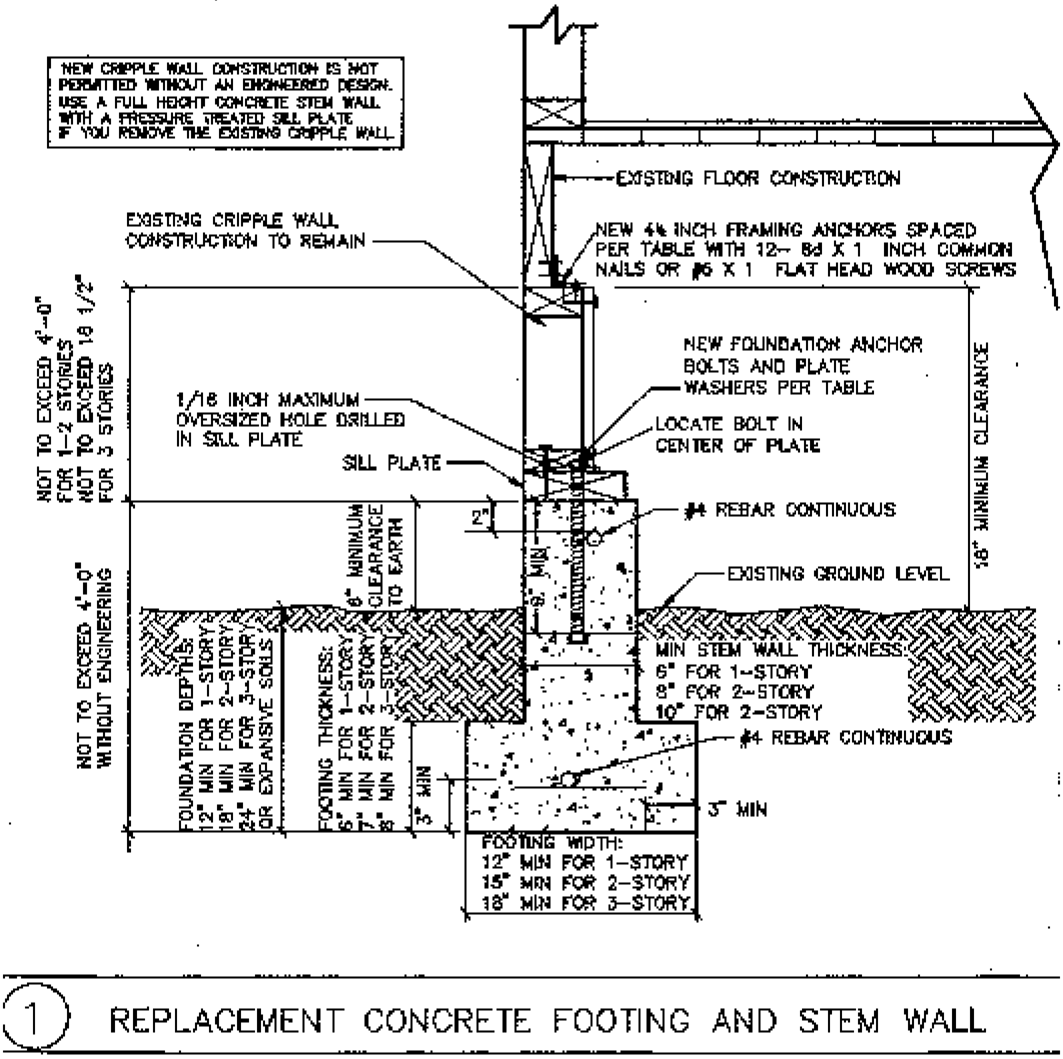


Figure 265
Replacement Concrete Footing and Stem Wall
Source: http://www.foundationbolting.com

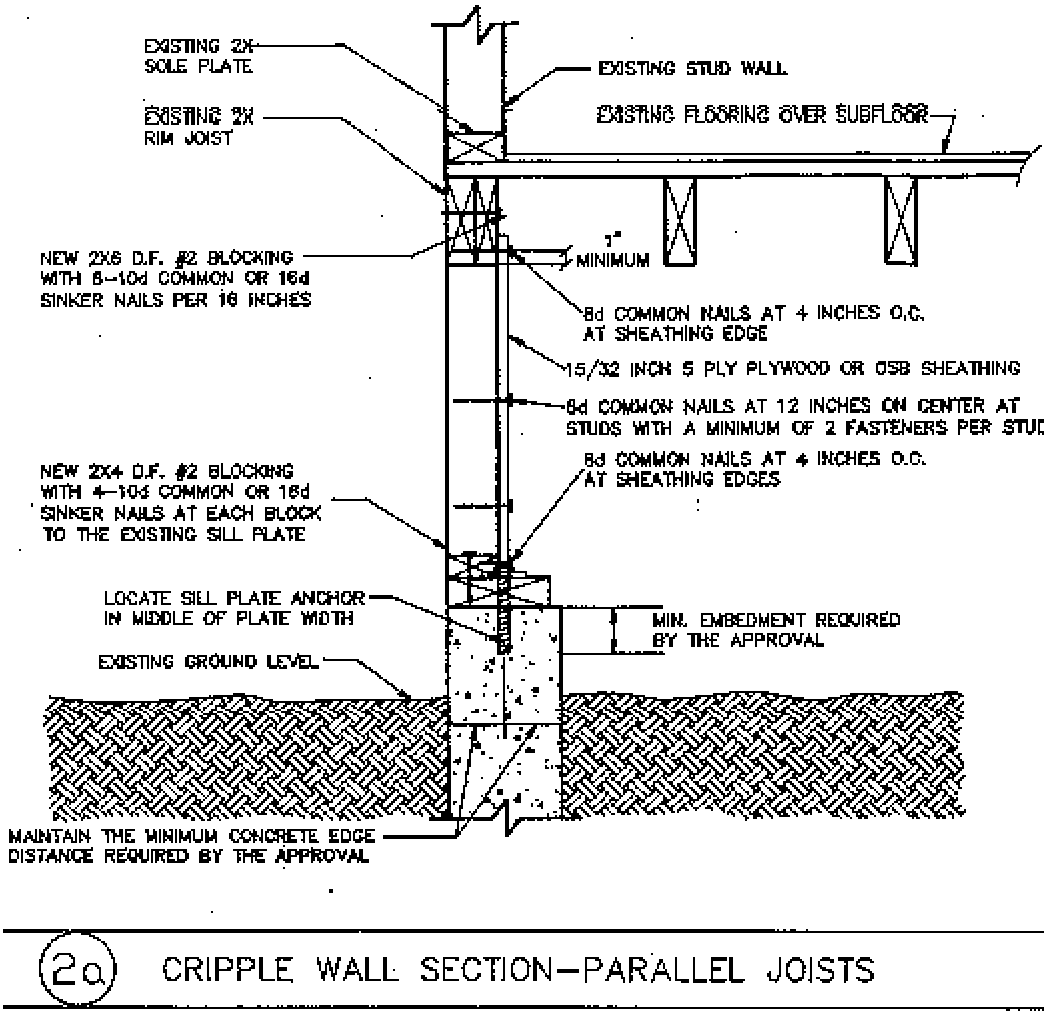


Figure 266
Cripple Wall Section – Parallel Joists
Source: http://www.foundationbolting.com

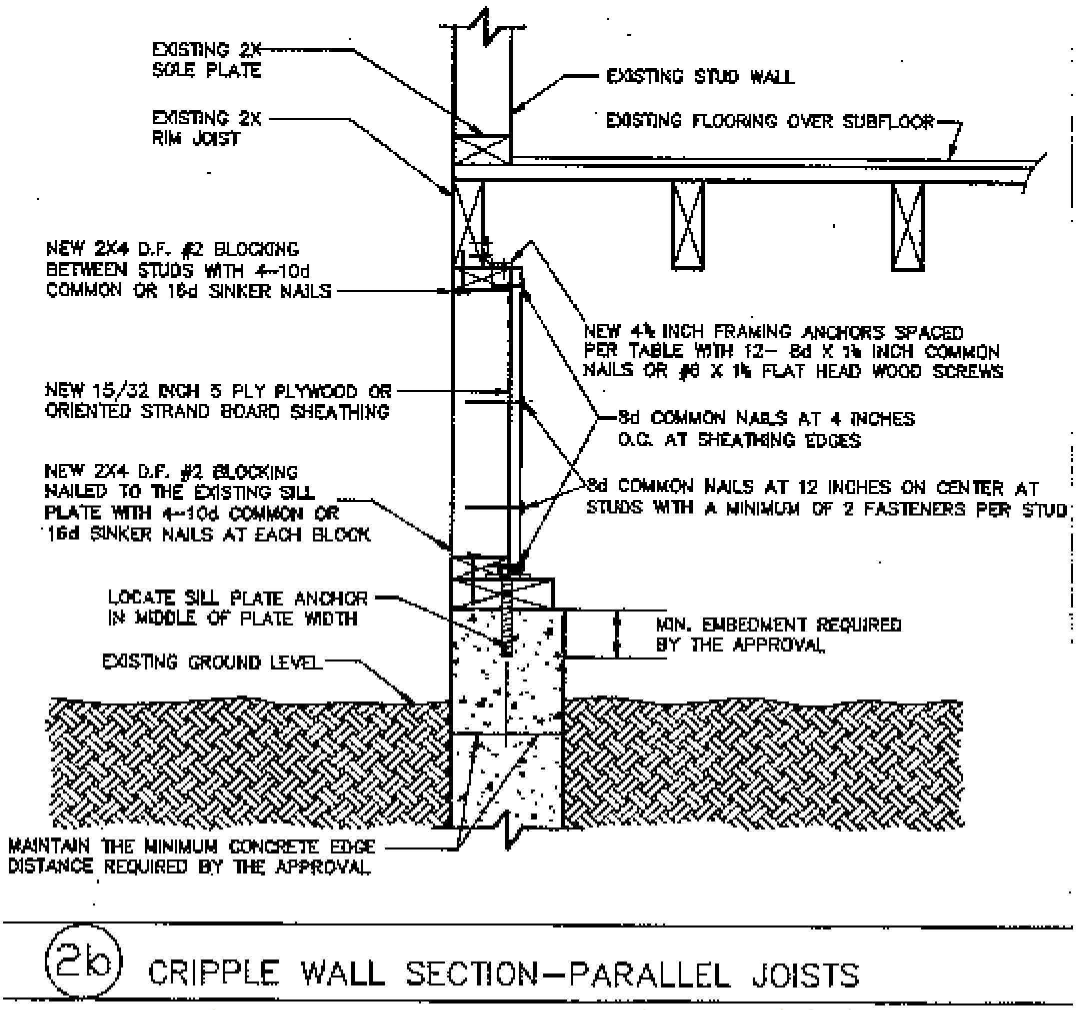


Figure 267
Cripple Wall Section – Parallel Joists
Source: http://www.foundationbolting.com

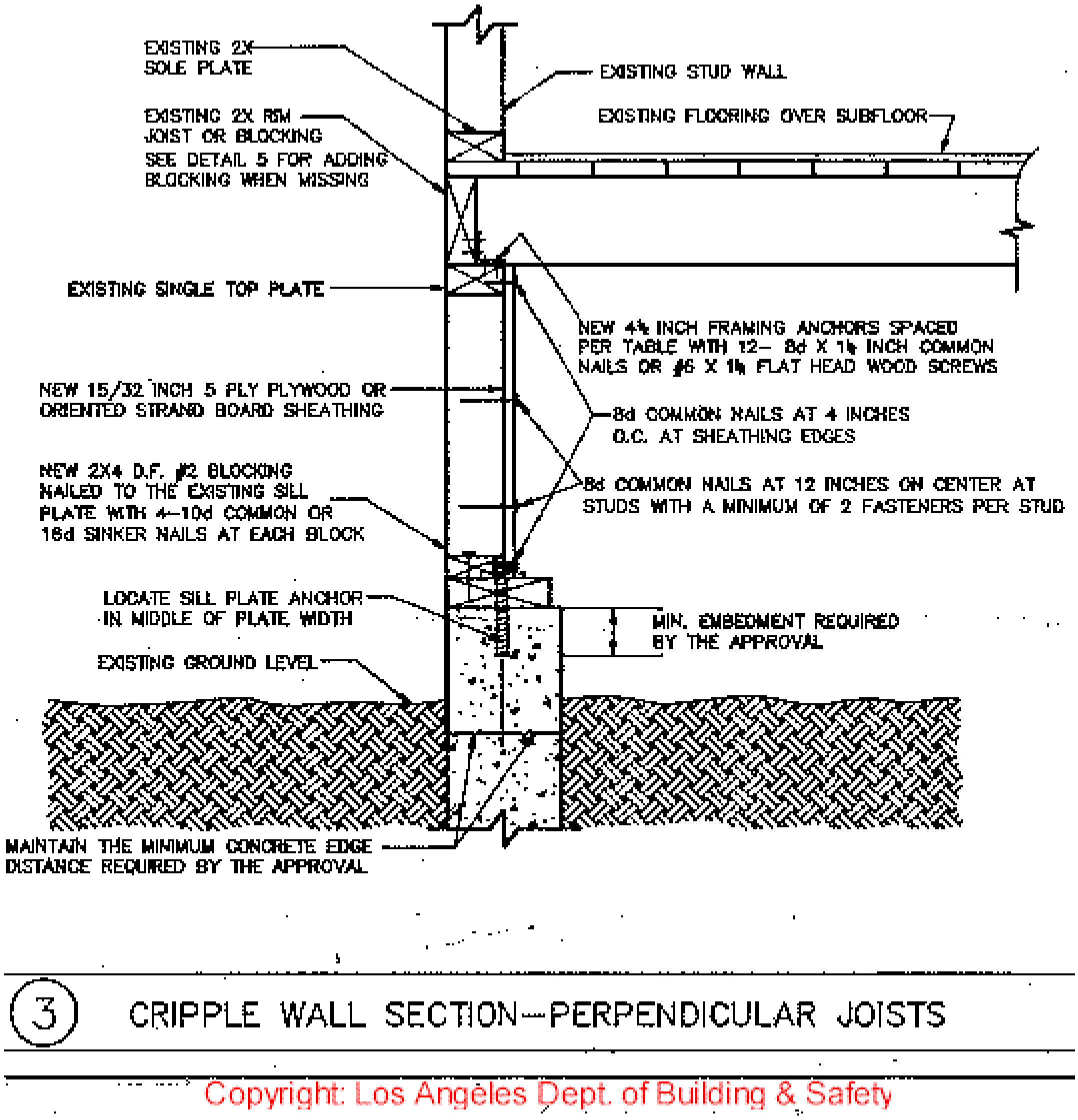


Figure 268
Cripple Wall Section – Perpendicular Joists
Source: http://www.foundationbolting.com

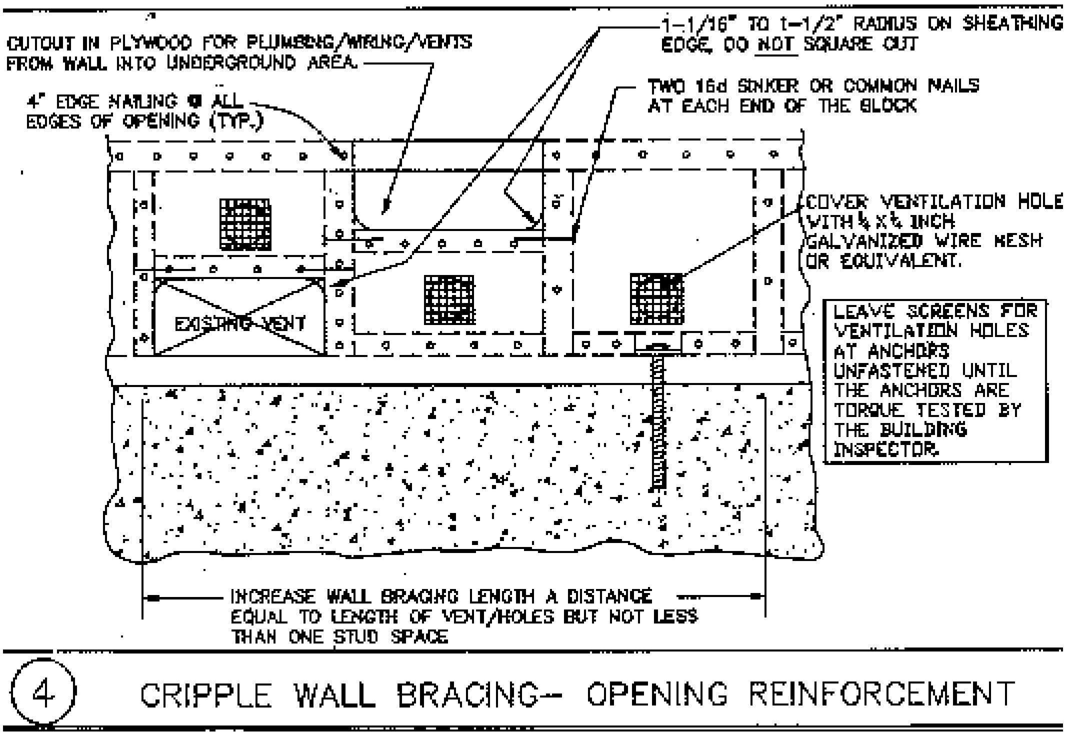


Figure 269
Cripple Wall Bracing – Opening Reinforcement
Source: http://www.foundationbolting.com

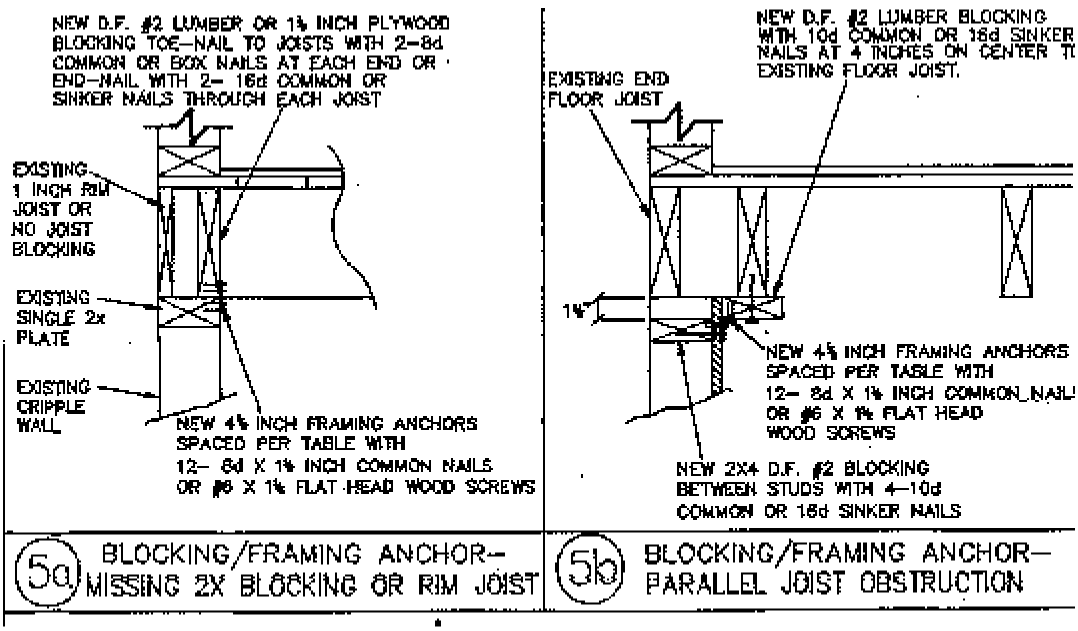


Figure 270
Blocking/Framing Anchor
Source: http://www.foundationbolting.com

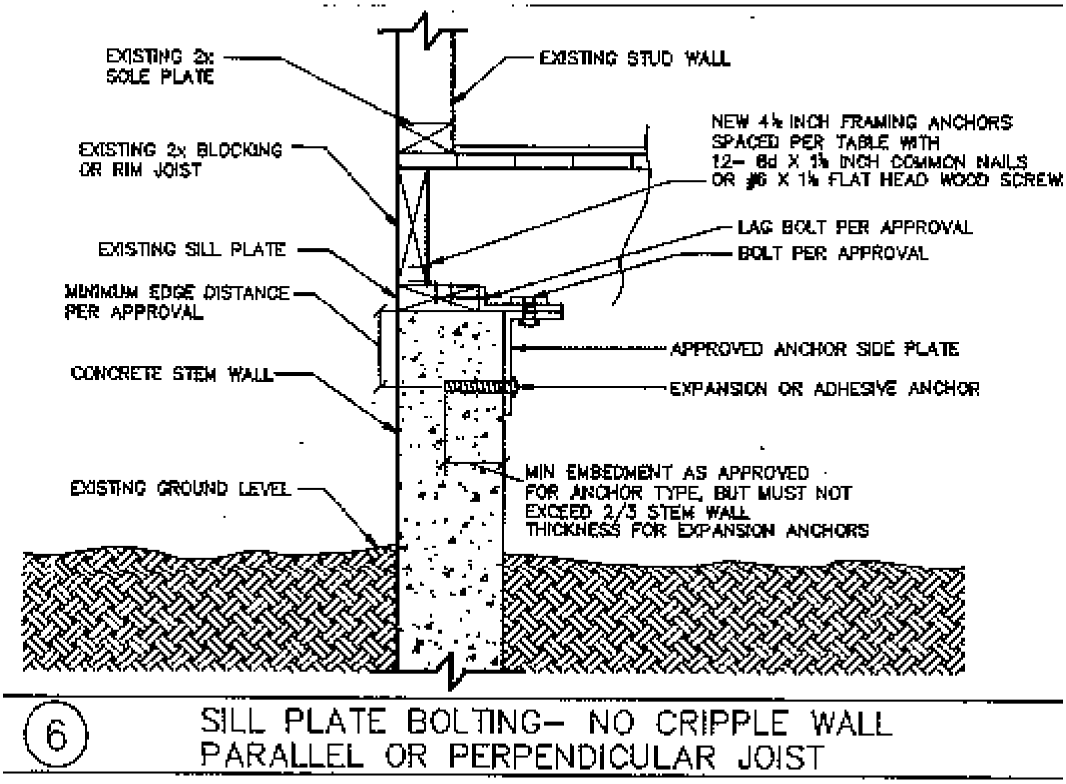


Figure 271
Sill Plate Bolting
Source: http://www.foundationbolting.com

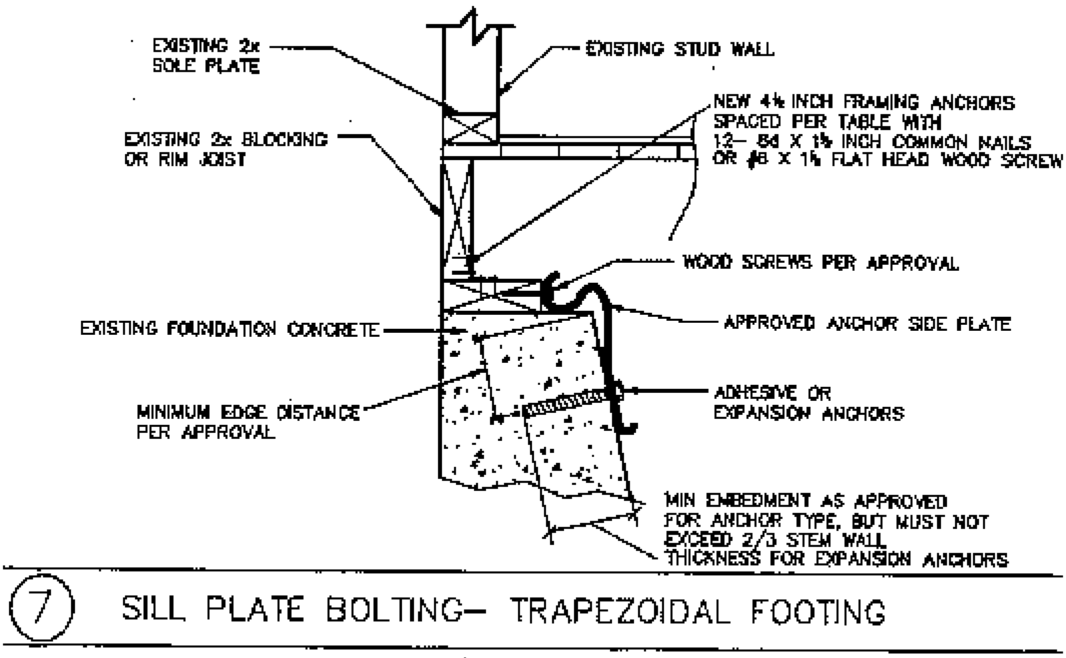


Figure 272
Sill Plate Bolting
Source: http://www.foundationbolting.com

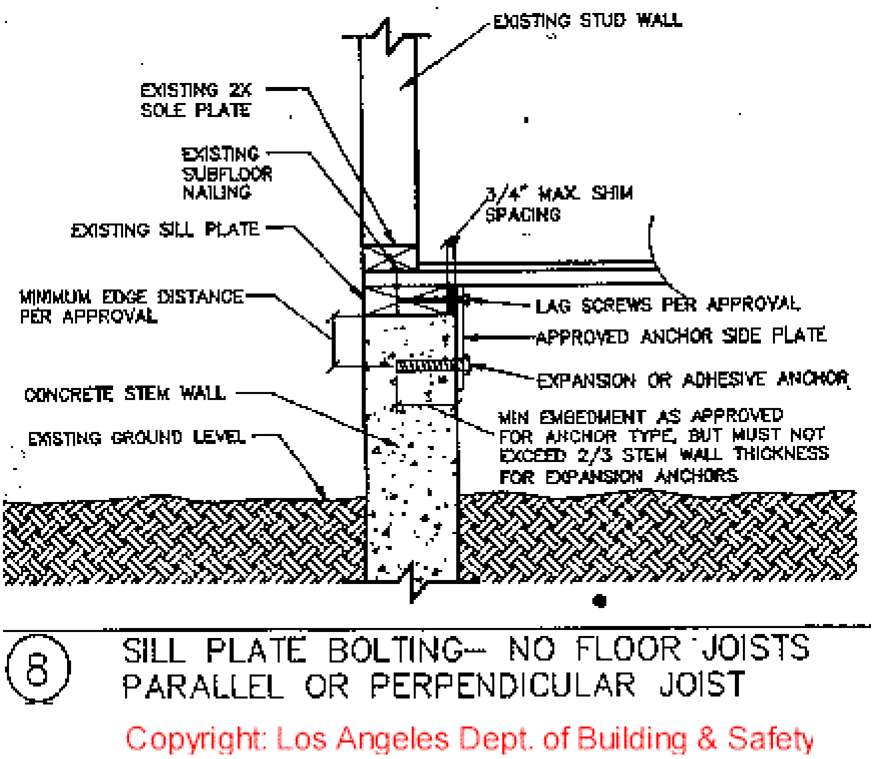


Figure 273
Sill Plate Bolting
Source: http://www.foundationbolting.com

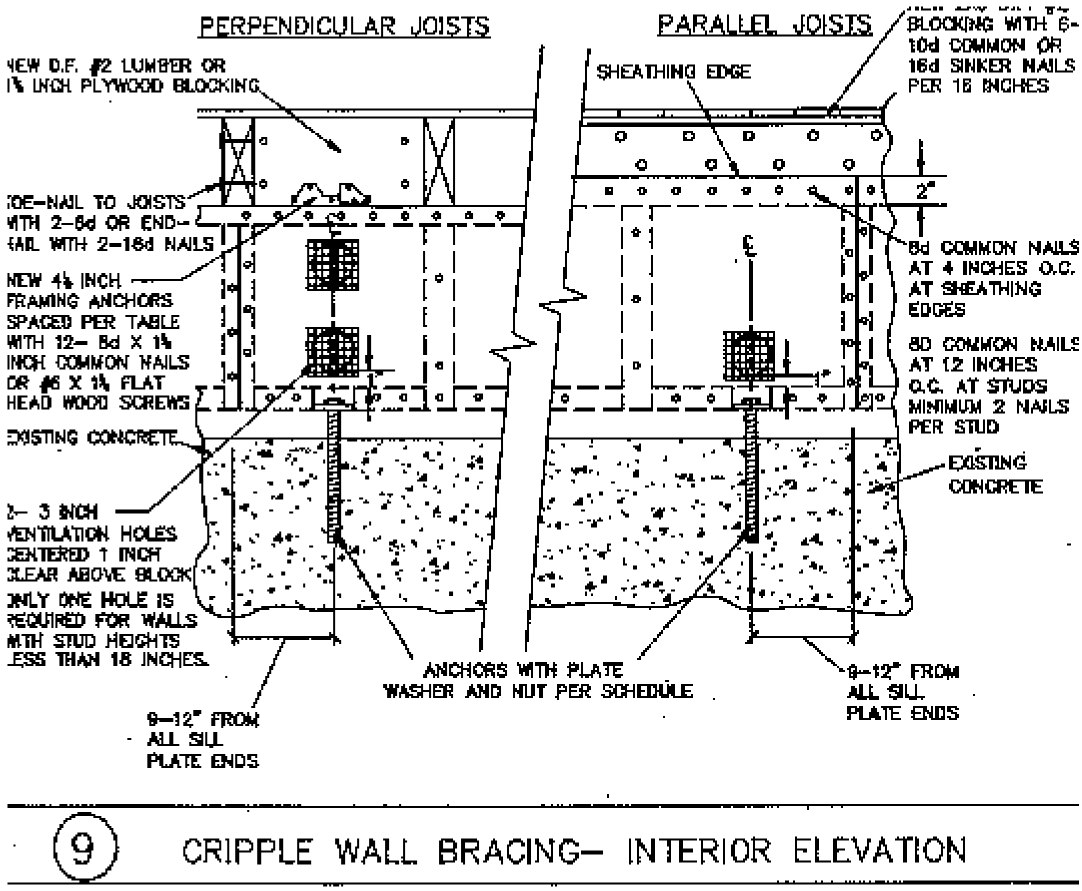


Figure 274
Cripple Wall Bracing
Source: http://www.foundationbolting.com

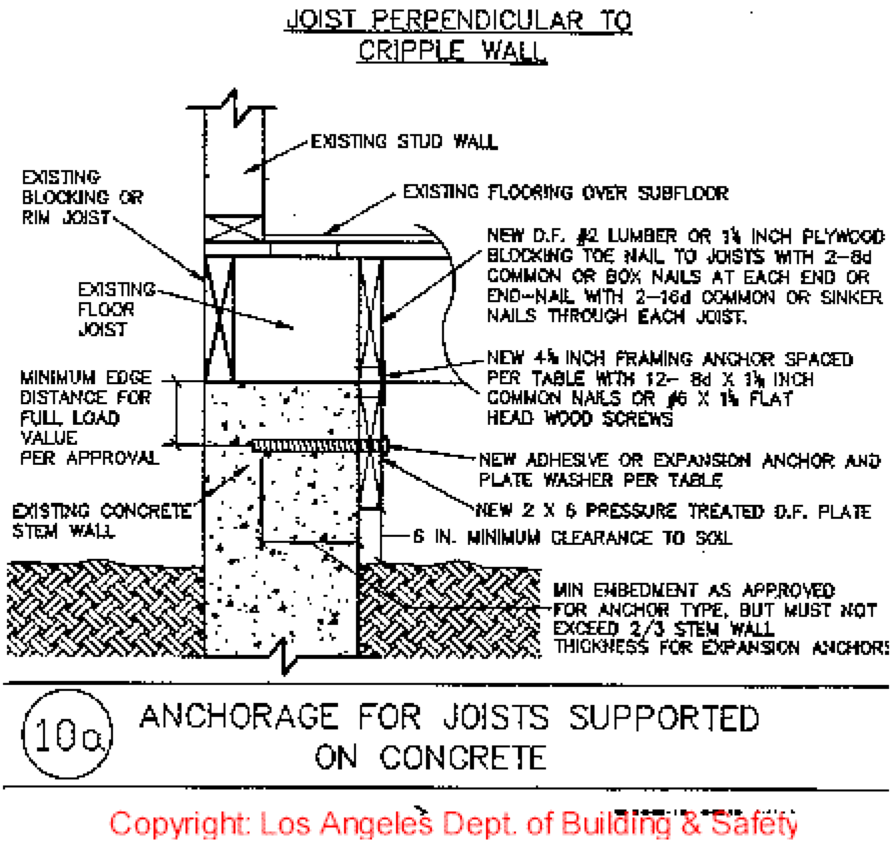


Figure 275
Anchorage for Joists Supported on Concrete
Source: http://www.foundationbolting.com

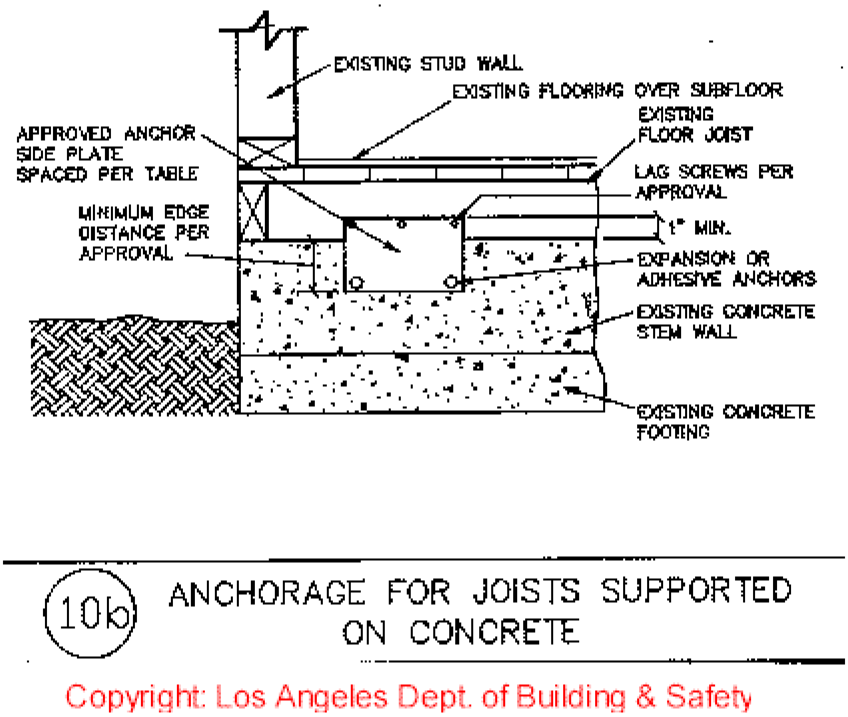


Figure 276
Anchorage for Joists Supported on Concrete
Source: http://www.foundationbolting.com

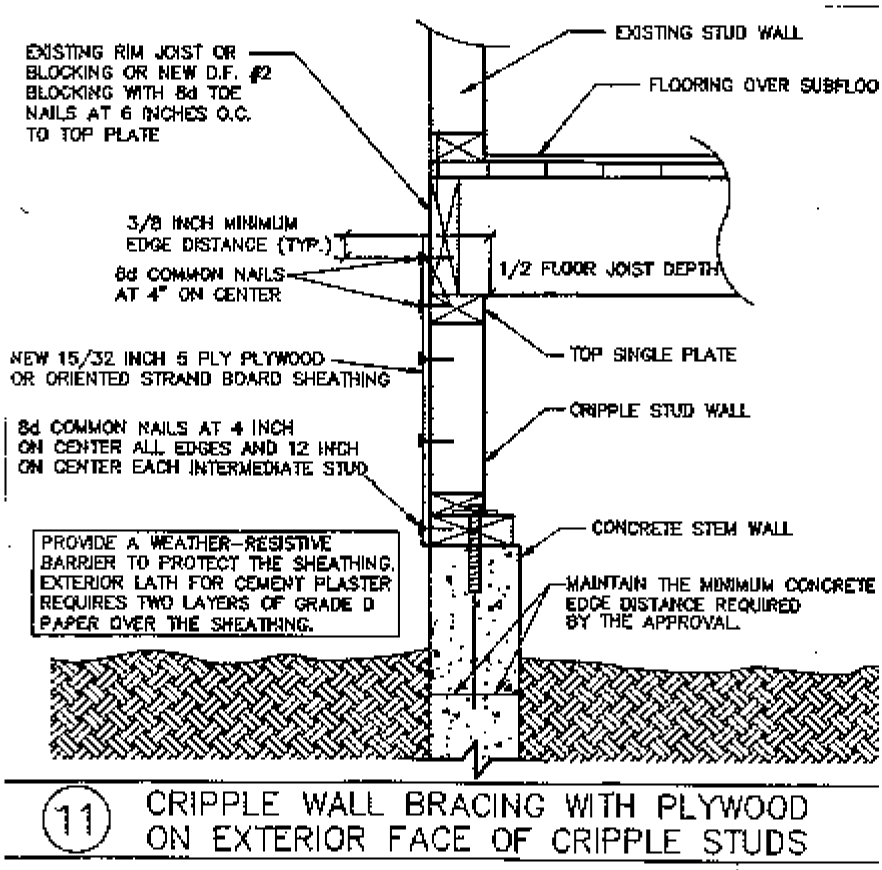


Figure 277
Cripple Wall Bracing with Plywood
Source: http://www.foundationbolting.com

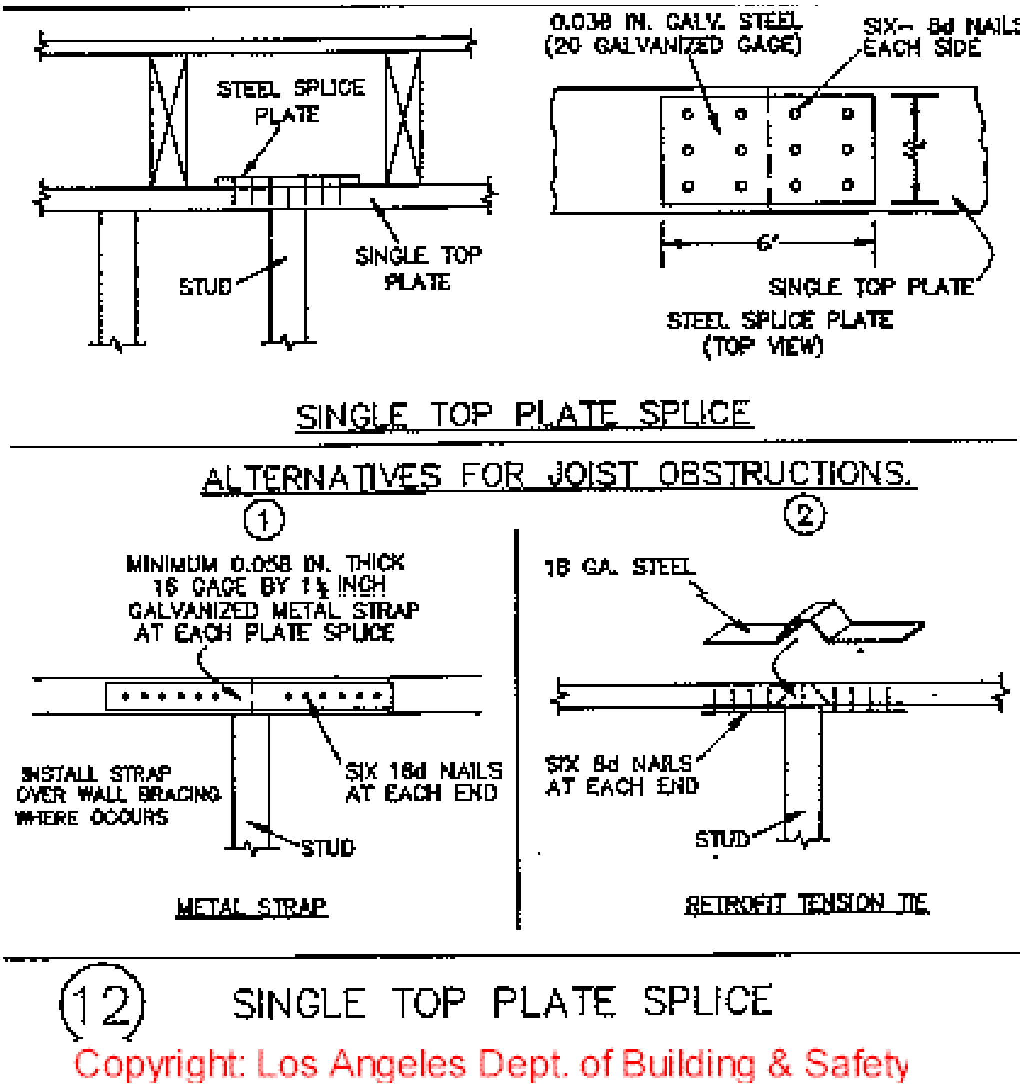


Figure 278
Single Top Plate Splice
Source: http://www.foundationbolting.com

http://www.grif.umontreal.ca/pages/CELEBIOGLU_Banu
Celebioglu, Banu and Limoncu, Sevgul. Strengthening of Historic Buildings in Post Disaster Cases.

Timber construction makes up a large majority of Turkey's historic buildings, and although considered very earthquake resistant, these historic timber buildings continue to be seriously damaged in earthquakes.[ppppp] Residents of these dwellings are then relocated to 'post disaster houses' or obtain government financial support for repairs. Relocation results in culture shock, and interventions have often destroyed supporting systems of the dwelling and decreased its earthquake resistance. As this article emphasises, these buildings are important as they affect the economic, social and cultural life in Turkey.

[ppppp] http://www.grif.umontreal.ca/pages/CELEBIOGLU_Banu

Two or three storied traditional timber constructions are typically formed consisting of a timber framework on a basement wall or masonry ground floor, very similar to New Zealand's own full or partial foundation wall foundation types. Strengthening of these structures is considered in terms of maintenance and technique. Continuous maintenance is emphasised in this article to ensure the longevity of the structure. Strengthening techniques are then outlined. Strapping of a building involves bolting the structure to the foundation, or strapping the timber frame together with cable and protecting the elements with wooden angle plates. Walls must be connected to each other using braces of timber, steel or synthetic fibre and plywood stiffeners between building and strapping cables may give increased strength. This system can be applied to masonry buildings also and allows the building to perform structurally as a whole. Infill openings may be used to provide structural continuity. Bracing can be used to repair weakened wooden structural systems; it should be added to have minimum impact and not overload the existing structural system. Reinforcing joints and connections in the timber is ideal, by using anchor ties or bolts, or metal or glass fibre reinforced plastic. Missing areas in the timber members may be filled with epoxy resins.

These methods have been suggested in this article as low cost, practical approaches to retrofit timber structures without compromising their character or integrity. This relates very closely to the retrofitting of timber dwellings in New Zealand.

http://www.helifix.com.au/masonry_repair_details.html

Helifix is a company producing high performance stainless steel helical wall ties, fixings and masonry repair and reinforcement systems.[qqqqq] Established in 1984, Helifix specializes in the research and development of building products and techniques including a focus on several areas of remedial construction. Their website has a specialist area devoted to masonry repair, which relates closely to the retrofit of partial or full foundation wall foundation types in New Zealand dwellings. The following set of figures detail methods of masonry repair using Helifix products (the figures are also printed in full size in Appendix 2). The first figure details crack stitching a cavity wall using HeliBars, a reinforcing bar set into place with grout (see Figure 279). Concrete patching can be carried out using patchpins (see Figure 280), a stainless steel pin for concrete patching. This is driven into the concrete and mortar applied over to conceal the remedial work, which is ideal. Crack stitching a rendered cavity wall can be done using HeliBars (see Figure 281). The stainless steel reinforcement bar is set into place with grout. Grout is applied over the bar to conceal it. HeliBars can be used to repair a crack near a corner in a cavity wall (see Figure 282). Here the bar is cut to the required length and bent to fit in the slots and grouted into place. The repair of a crack near the corner of a cavity wall can also be carried out using CemTies (see Figure 283). Here a stainless steel structural pin is inserted into the wall at the required spacing and set with grout. DryFix may also be used for this repair (see Figure 284). This is where a dry stainless steel pining system is used. Cross stitching of a cracked solid wall may be done using CemTies (see Figure 285). This uses stainless steel structural pins, grouted into a wall, and CemTies wound into the grout filled hole.

The repair of a crack near a corner in a solid wall may be done using HeliBars (see Figure 286). Again this utilizes a stainless steel reinforcement bar, grouted into place. CemTies can also be used (see Figure 287). The repair of a crack near a corner in a stone wall cane be done with HeliBars (see Figure 288) or the bars may be used to crack stitch a solid wall (see Figure 289). Repair of a crack near a corner in a stone wall may also be carried out using CemTies (see Figure 290).

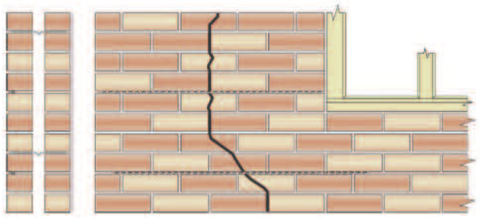
[qqqqq] http://www.helifix.com.au

REPAIR DETAIL BCS01 HELIFIX

BCS01

Crack stitching a cavity wall using HeliBars

Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB



METHOD STATEMENT

1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing.* Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
6. Push the HeliBar into the grout to obtain good coverage.
7. Inject a second bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for new pointing.
8. Point up the remaining slot with a suitable matching mortar and make good the crack using an appropriate Helifix bonding agent or filler, depending on the width of the crack.
9. Clean tools with clean, fresh water.

***NOTE** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.

RECOMMENDED TOOLING

For cutting slots up to 40mm deep ....Wall chaser, mortar saw or angle grinder with vacuum attachment
For mixing HeliBond...Drill with mixing paddle
For injection of HeliBond into slots ....Helifix Pointing Gun with mortar nozzle
For smoothing pointing ....Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

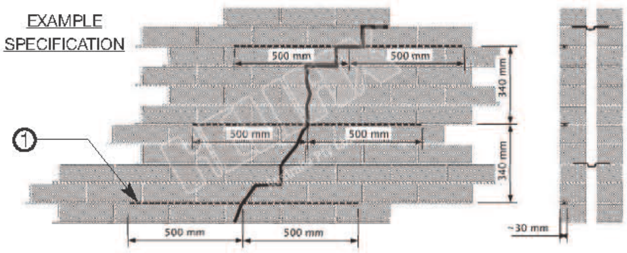
A. Depth of slot into the masonry to be 25mm to 35mm.
B. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
C. HeliBar to be long enough to extend a minimum of 500mm either side of the crack or 500mm beyond the outer cracks if two or more adjacent cracks are being stitched using one rod.
D. Normal vertical spacing is 340mm (4 brick courses).
E. Where a crack is less than 500mm from the end of a wall or an opening the HeliBar is to be continued for at least 100mm around the corner and bonded into the adjoining wall or bent back and fixed into the reveal, avoiding any DPC.
F. Install Helifix remedial wall ties if existing ties are defective in any way. Refer to Repair Details BRT01–03 for details on Helifix remedial wall tie installation.
G. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

EXAMPLE SPECIFICATION



CRACK STITCHING A CRACKED BRICK WALL

Material: HELIBAR 6 X 1000
Product code: HBR6x1000

CRACK TO BE STITCHED BY BONDING 1M LENGTHS OF 6MM DIA. HELIBAR (HBR6) INTO CUT SLOTS USING HELIBOND GROUT (HLB). HELIBARS TO EXTEND 500MM PAST EITHER SIDE OF THE CRACK AND TO BE INSTALLED AT A VERTICAL SPACING OF NOT MORE THAN 4 BRICK COURSES APART. SLOTS TO BE CUT INTO THE HORIZONTAL MORTAR JOINTS TO A DEPTH OF 25-35MM AND TO A HEIGHT EQUAL TO THE MORTAR JOINT HEIGHT.

1	HBR	HELIBAR	HELIFIX	HELIFIX (AUSTRALIA) PTY LTD		
				TYPICAL WALL TYPE AND HELIBAR APPLICATION		
ITEM	CODE	DESCRIPTION		SCALE 1:20	DWG No. BCS01-EXS	SHEET 1 of 1

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Figure 279
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCR01

HELIFIX

BCR01

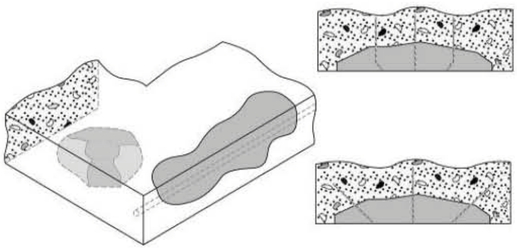
Concrete patching using PatchPins

Product	Description	Code
PatchPin	Stainless steel pin for concrete patching	HPP

METHOD STATEMENT

1. Clean the area to be patched. Remove all loose material and leave the surface ready to accept the patching material in accordance with the manufacturer's instructions.
2. Clean and treat any exposed, embedded steel.
3. Drill 6.5mm diameter holes into the concrete to the specified depth and at the specified spacing.
4. Attach the PatchPin support tool to an SDS hammer drill set to a slow speed and light hammer only.
5. Load the PatchPin into the support tool.
6. Drive the PatchPin into the pre-drilled pilot hole. Check that the exposed end of the pin finishes below the intended face of the finished concrete. The pin end may be bent if the straight length is too long.
7. Apply the patching mortar in accordance with the manufacturer's instructions.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling..SDS rotary hammer drill 650/800w
For installation of StarTie...............................SDS rotary hammer drill and PatchPin support tool

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Depth of hole to be 30-50mm depending on the hardness of the material, with harder materials requiring less embedment.

B. Pin spacing and position may be varied at the discretion of the specifier to suit site conditions. Typically, placing pins 50mm in from the edge with intermediate pins to keep centres within 150-200mm will prove adequate.

C. Generally, pins should be applied at not less than two pins per patch.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on **1300 66 70 71**.

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Figure 280

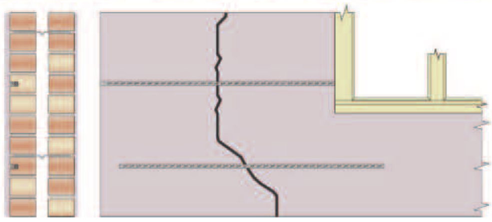
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS02 HELIFIX

BCS02

Crack stitching a rendered cavity wall using HeliBars

Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB



METHOD STATEMENT

1. Using an appropriate power cutting tool with vacuum attachment, cut slots through the render and into the masonry to the specified depth and at the required vertical spacing.* Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
6. Push the HeliBar into the grout to obtain good coverage.
7. Inject a second bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for making good the render.
8. The crack within the wall should be waterproofed using an appropriate Helifix bonding agent or filler, e.g. HeliBond or CrackBond, depending on the width of the crack, and the crack and remaining slots at the surface made good with a suitable matching render or mortar.
9. Clean tools with clean, fresh water.

NOTE. ***Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.***

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***

RECOMMENDED TOOLING

For cutting slots up to 40mm deep .... Wall chaser, mortar saw or angle grinder with vacuum attachment

To achieve final depth of slot beyond 40mm .... Hand or Helifix Power Chisel

For mixing HeliBond .... Drill with mixing paddle

For injection of HeliBond into slots .... Helifix Pointing Gun with mortar nozzle

For smoothing pointing .... Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Depth of slot into the masonry to be 25mm to 35mm + the thickness of the render.

B. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.

C. HeliBar to be long enough to extend a minimum of 500mm either side of the crack or 500mm beyond the outer cracks if two or more adjacent cracks are being stitched using one rod.

D. Normal vertical spacing is 340mm (4 brick courses).

E. Where a crack is less than 500mm from the end of a wall or an opening the HeliBar is to be continued for at least 100mm around the corner and bonded into the adjoining wall or bent back and fixed into the reveal, avoiding any DPC.

F. Install Helifix remedial wall ties if existing ties are defective in any way. Refer to Repair Details BRT01–03 for details on Helifix remedial wall tie installation.

G. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 281

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS03 HELIFIX

BCS03

Repair of a crack near a corner in a cavity wall using HeliBars

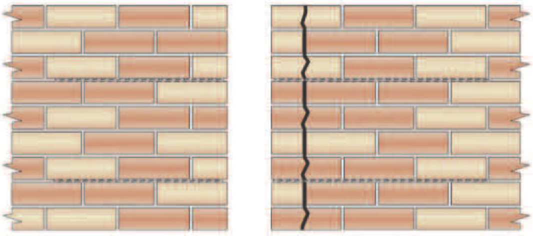
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing.* Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond. If the wall is rendered and the mortar joints are not visible, cut the horizontal slots through the render and into the masonry.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 6.
3. Cut the 6mm HeliBar to the required length and bend to fit in the slots.
4. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
5. Fit the mortar nozzle to the gun.
6. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
7. Push the 6mm HeliBar into the grout to obtain good coverage.
8. Inject a second bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for new pointing.
9. Point up the remaining slot with a suitable matching mortar and make good the crack using an appropriate Helifix bonding agent or filler, depending on the width of the crack.
10. Clean tools with clean, fresh water.

***NOTE** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

⚠ Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.



RECOMMENDED TOOLING

For cutting slots up to 40mm deep..................Wall chaser, mortar saw or angle grinder with vacuum attachment
To achieve final depth of slot beyond 40mm......................Hand or Helifix Power Chisel
For mixing HeliBond ....Drill with mixing paddle
For injection of HeliBond into slots............................Helifix Pointing Gun with mortar nozzle
For smoothing pointing...Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Depth of slot into the masonry to be 25mm to 35mm + thickness of any render.
B. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
C. HeliBar to be long enough to extend a minimum of 500mm either side of the crack or 500mm beyond the outer cracks if two or more adjacent cracks are being stitched using one rod.
D. Normal vertical spacing is 340mm (4 brick courses).
E. Where a crack is less than 500mm from the end of a wall or an opening the HeliBar is to be continued for at least 100mm around the corner and bonded into the adjoining wall or bent back and fixed into the reveal, avoiding any DPC.
F. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 282
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS04

HELIFIX

BCS04

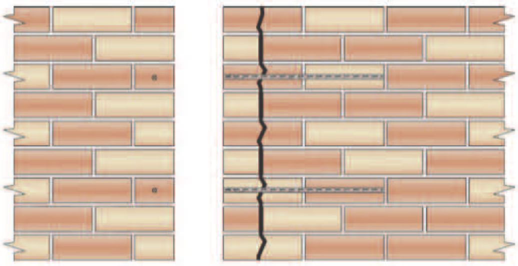
Repair of a crack near a corner in a cavity wall using CemTies

Product	Description	Code
CemTie	Grade 316 stainless steel structural pin	HCT
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Mark the locations for the CemTie pins onto the face of the wall at the required spacing.*
2. Drill a 16mm Ø clearance hole through the outer wall to the required depth.*
3. Clean out all dust from the hole and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the hole is damp or primed prior to commencing step 8.
4. Attach the required length of CemTie pinning nozzle to the Helifix Pointing Gun.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the gun.
6. Pump grout to fill the nozzle.
7. Wind the CemTie into the nozzle and ensure that it is fully covered in grout. (Alternatively, fill the hole with grout and wind the CemTie into the grout-filled hole.)
8. Insert the nozzle to the full depth of the drilled hole and pump the grout. Slowly withdraw the nozzle while pumping. The CemTie will be carried out with the HeliBond grout as it is forced through the nozzle. Back pressure will help to push the nozzle back out of the hole.
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings. Make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.
10. Clean tools with clean, fresh water.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



ELEVATION　　　SECTION A

RECOMMENDED TOOLING

For drilling............SDS rotary hammer drill 650/700w
For mixing HeliBond............Drill with mixing paddle
For insertion of the CemTies............Helifix Pointing Gun with CemTie Pinning Nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. CemTies are to be installed at a vertical spacing of 425mm.
B. CemTies are to extend at least 250mm past the crack.
C. Depth of hole to be CemTie length + 25mm.
D. Ensure the CemTies are installed into solid brick and not the mortar joints or loose rubble within the wall.
E. If cracking occurs on both elevations consider using HeliBar crack stitching around the corner (see Repair Detail BCS03). If CemTies are to be used, they should be staggered between each elevation.
F. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the hole, or priming with HeliPrimer WB, should be carried out just prior to inserting the CemTie.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 283

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS05 HELIFIX

BCS05

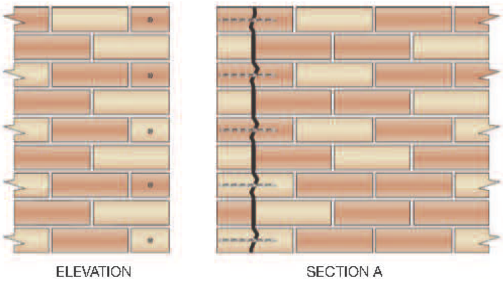
Repair of a crack near a corner in a cavity wall using DryFix

Product	Description	Code
DryFix	Stainless steel dry pinning system	HDF

METHOD STATEMENT

1. Mark the locations for the DryFix ties onto the face of the wall at the required spacing. (Refer to the Specification Notes for typical spacing requirements.)
2. Drill a 5mm Ø pilot hole through the near skin and into the remote skin to the specified depth using a light-weight SDS hammer drill set to a slow speed and light hammer only. A rotary percussion 3-jaw chuck drill may be preferred if the masonry is particularly soft. A 6mm or 6.5mm Ø pilot hole size may be preferred if the masonry is particularly hard. (Refer to the Specification Notes for typical depth requirements.)
3. Attach the Helifix Power Driver attachment to an SDS hammer drill set to a slow speed and light hammer only. (DryFix ties are self-tapping and will work themselves into the wall following the hammer action of the drill.)
4. Load the DryFix tie into the power driver attachment.
5. Support the power driver attachment with one hand, while using the other to work the drill, and drive the DryFix tie into the pre-drilled pilot hole to approximately 10mm beyond the surface of the near skin.
6. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings. Make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling ....Rotary percussion or SDS rotary hammer drill 650/700w

For installation of DryFix ....SDS rotary hammer drill and DryFix Power Driver attachment

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. DryFix ties are to be installed at a vertical spacing of 170mm (every 2 brick courses).

B. DryFix ties are to extend at least 70mm past the crack.

C. Depth of pilot hole to be DryFix tie length + 10mm.

D. DryFix ties are to be installed at least 25mm in from the brick edge.

E. If cracking occurs on both elevations consider using HeliBar crack stitching around the corner (see Repair Detail BCS03). If DryFix ties are to be used, they should be staggered between each elevation.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 284

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS08 HELIFIX

BCS08

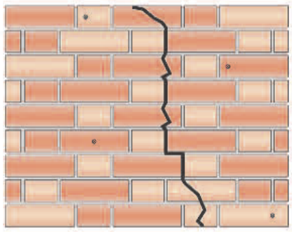
Cross stitching a cracked solid wall using CemTies

Product	Description	Code
CemTie	Grade 316 stainless steel structural pin	HCT
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Mark the locations for the CemTie pins onto the face of the wall at the required spacing. (Refer to the Specification Notes for typical spacing requirements.)
2. Drill a 12–14mm Ø clearance hole, or 16mm Ø if the CemTie is longer than 450mm, at the required location and angle, and to the specified depth.*
3. Clean out all dust from the hole and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the hole is damp or primed prior to commencing step 8.
4. Attach the required length of CemTie pinning nozzle to the Helifix Pointing Gun.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the gun.
6. Pump grout to fill the nozzle.
7. Wind the CemTie into the nozzle and ensure that it is fully covered in grout. (Alternatively, fill the hole with grout and wind the CemTie into the grout-filled hole.)
8. Insert the nozzle to the full depth of the drilled hole and pump the grout. Slowly withdraw the nozzle while pumping. The CemTie will be carried out with the HeliBond grout as it is forced through the nozzle. Back pressure will help to push the nozzle back out of the hole.
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings. Make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.
10. Clean tools with clean, fresh water.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling ....SDS Rotary hammer drill 650/700w
For mixing HeliBond ....Drill with mixing paddle
For insertion of the CemTies...............................Helifix Pointing Gun with CemTie Pinning Nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. CemTies are to be installed perpendicular to the direction of the plane of the crack (e.g. in the horizontal plane for vertical cracks and in the vertical plane for horizontal cracks).
B. CemTies are to start a minimum of 225mm away from the crack.
C. Depth of hole to be CemTie length + 25mm.
D. Angle of drilling to be such that the CemTies will pass through the crack within the centre third of the wall.
E. CemTies are to start from alternate sides of the crack and to be at 225mm spacing measured along the length of the crack.
F. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the hole, or priming with HeliPrimer WB, should be carried out just prior to inserting the CemTie.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 285
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS09 HELIFIX

BCS09

Repair of a crack near a corner in a solid wall using HeliBars

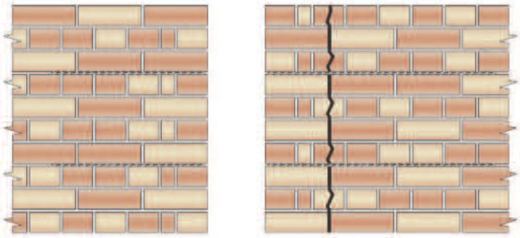
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing. (Refer to the Specification Notes for typical depth and spacing requirements.) Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond. If the wall is rendered and the mortar joints are not visible, cut the horizontal slots through the render and into the masonry.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
6. Push the 6mm HeliBar into the grout to obtain good coverage.
7. Repeat steps 5 and 6 as required to install all specified HeliBar into the slot.
8. Inject a final bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond grout as necessary, leaving 10-15mm for new pointing.
9. Point up the remaining slot with a suitable matching mortar and make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.
10. Clean tools with clean, fresh water.

***NOTE.** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For cutting slots up to 40mm deep .... Wall chaser, mortar saw or angle grinder with vacuum attachment
To achieve final depth of slot beyond 40mm Hand or Helifix Power Chisel
For mixing HeliBond .... Drill with mixing paddle
For injection of HeliBond into slots .... Helifix Pointing Gun with mortar nozzle
For smoothing pointing .... Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Allow for the installation of one HeliBar for each skin of brickwork into each cut slot. By example, a common 230mm solid wall construction (equivalent to two skins of tied brickwork) will require the installation of two HeliBars per slot. A solid wall equivalent in depth to three skins of bonded masonry will require three HeliBars per slot.
B. Depth of slot into the masonry to be 35mm to 40mm + thickness of any render, assuming a 230mm solid wall. Add 10mm for each additional skin of brickwork.
C. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
D. HeliBar to be long enough to extend a minimum of 500mm either side of the crack or 500mm beyond the outer cracks if two or more adjacent cracks are being stitched using one rod.
E. Normal vertical spacing is 340mm (4 brick courses).
F. Where a crack is less than 300mm from the end of a wall or an opening the HeliBar is to be continued for at least 100mm around the corner and bonded into the adjoining wall or bent back and fixed into the reveal, avoiding any DPC.
G. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 286
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS10 HELIFIX

BCS10

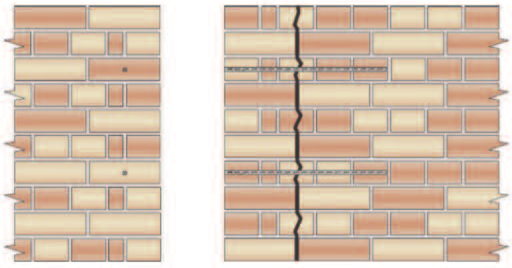
Repair of a crack near a corner in a solid wall using CemTies

Product	Description	Code
CemTie	Grade 316 stainless steel structural pin	HCT
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Mark the locations for the CemTie pins onto the face of the wall at the required spacing.*
2. Drill a 16mm Ø clearance hole through the outer wall to the required depth.*
3. Clean out all dust from the hole and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the hole is damp or primed prior to commencing step 8.
4. Attach the required length of CemTie pinning nozzle to the Helifix Pointing Gun.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the gun.
6. Pump grout to fill the nozzle.
7. Wind the CemTie into the nozzle and ensure that it is fully covered in grout. (Alternatively, fill the hole with grout and wind the CemTie into the grout-filled hole.)
8. Insert the nozzle to the full depth of the drilled hole and pump the grout. Slowly withdraw the nozzle while pumping. The CemTie will be carried out with the HeliBond grout as it is forced through the nozzle. Back pressure will help to push the nozzle back out of the hole.
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings. Make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.
10. Clean tools with clean, fresh water.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling .... SDS rotary hammer drill 650/700w
For mixing HeliBond .... Drill with mixing paddle
For insertion of the CemTies .... Helifix Pointing Gun with CemTie Pinning Nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. CemTies are to be installed at a maximum vertical spacing of 425mm.
B. CemTies are to extend an equal distance, and typically to not more than 500mm, either side of the crack.
C. Depth of hole to be CemTie length + 25mm.
D. Ensure the CemTies are installed into solid brick and not the mortar joints or loose rubble within the wall.
E. If cracking occurs on both elevations consider using HeliBar crack stitching around the corner. If CemTies have to be used, they should be staggered between each elevation.
F. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the hole, or priming with HeliPrimer WB, should be carried out just prior to inserting the CemTie.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 287

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS11 HELIFIX

BCS11

Repair of a crack near a corner in a stone wall using HeliBars

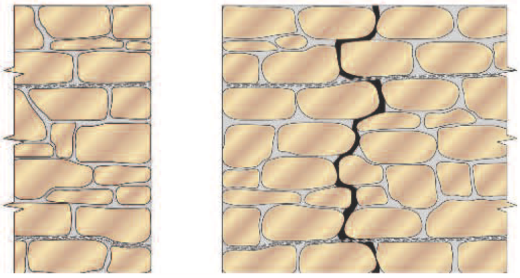
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing. (Refer to the Specification Notes for typical depth and spacing requirements.) Ensure that as much mortar is removed as possible from the exposed surfaces in order to provide a good masonry/grout bond. This operation may require the use of hand tools to remove the mortar due to the random nature of the stone.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
6. Push the 6mm HeliBar into the grout to obtain good coverage.
7. Repeat steps 5 and 6 as required to install all specified HeliBars into the slot.
8. Inject a final bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond grout as necessary, leaving 10-15mm for new pointing.
9. Point up the remaining slot with a suitable matching mortar and make good the crack using an appropriate Helifix bonding agent or filler, depending on the width of the crack.
10. Clean tools with clean, fresh water.

***NOTE:** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For cutting slots up to 40mm deep......................Wall chaser, mortar saw or angle grinder with vacuum attachment

To achieve final depth of slot beyond 40mm Hand or Helifix Power Chisel

For mixing HeliBond ....Drill with mixing paddle

For injection of HeliBond into slots............................Helifix Pointing Gun with mortar nozzle

For smoothing pointing..Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Allow for the installation of one HeliBar for each 100mm of wall thickness into each cut slot. By example, a common 200mm solid stone wall construction will require the installation of two HeliBars per slot. A 300mm solid wall construction will require three Helibars per slot.

B. Depth of slot into a common 200mm stone wall to be 35mm to 40mm. Add 10mm for each additional 100mm of wall thickness.

C. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.

D. HeliBar to be long enough to extend a minimum of 500mm either side of the crack or 500mm beyond the outer cracks if two or more adjacent cracks are being stitched using one rod.

E. Normal vertical spacing is 425mm.

F. Where a crack is less than 300mm from the end of a wall or an opening the HeliBar is to be continued for at least 100mm around the corner and bonded into the adjoining wall or bent back and fixed into the reveal, avoiding any DPC.

G. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 288

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS06 /BCS07 HELIFIX

BCS06 BCS07

Crack stitching a solid wall using HeliBars

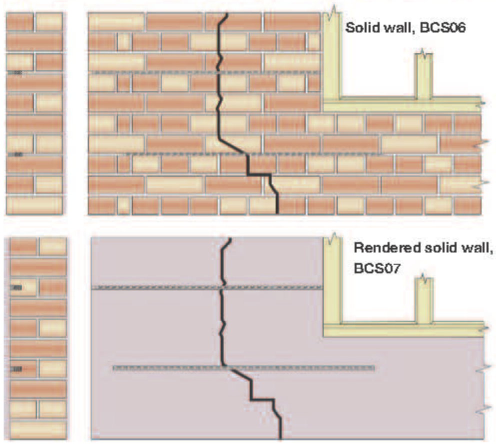
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the brick or horizontal mortar joints, to the specified depth and at the required vertical spacing. (Refer to the Specification Notes for typical depth and spacing requirements.) Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond. If the wall is rendered and the mortar joints are not visible, cut the horizontal slots through the render and into the masonry.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use a suitable primer. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
6. Push the 6mm HeliBar into the grout to obtain good coverage.
7. Repeat steps 5 and 6 as required to install all specified HeliBar into the slot.
8. Inject a final bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for new pointing.
9. Point up the remaining slot with a suitable matching mortar and make good the crack using an appropriate Helifix bonding agent or filler, depending on the width of the crack.
10. Clean tools with clean, fresh water.

***NOTE**: Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For cutting slots up to 40mm deep .... Wall chaser, mortar saw or angle grinder with vacuum attachment
To achieve final depth of slot beyond 40mm Hand or Helifix Power Chisel
For mixing HeliBond .... Drill with mixing paddle
For injection of HeliBond into slots .... Helifix Pointing Gun with mortar nozzle
For smoothing pointing .... Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Allow for the installation of one HeliBar for each skin of brickwork into each cut slot. By example, a common 230mm solid wall construction (equivalent to two skins of tied brickwork) will require the installation of two HeliBars per slot. A solid wall equivalent in depth to three skins of bonded masonry will require three HeliBars per slot.
B. Depth of slot into the masonry to be 35mm to 40mm + thickness of any render, assuming a 230mm solid wall. Add 10mm for each additional skin of brickwork.
C. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
D. HeliBar to be long enough to extend a minimum of 500mm either side of the crack or 500mm beyond the outer cracks if two or more adjacent cracks are being stitched using one rod.
E. Normal vertical spacing is 340mm (4 brick courses).
F. Where a crack is less than 500mm from the end of a wall or an opening the HeliBar is to be continued for at least 100mm around the corner and bonded into the adjoining wall or bent back and fixed into the reveal, avoiding any DPC.
G. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 289
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BCS12/BCS13 HELIFIX

BCS12 BCS13

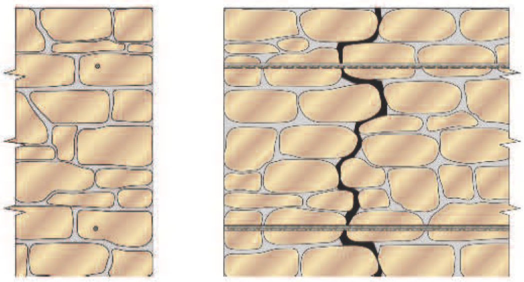
Repair of a crack near a corner in a stone wall using CemTies

Product	Description	Code
CemTie	Grade 316 stainless steel structural pin	HCT
HeliBond	Injectable cementitious grout	HLB

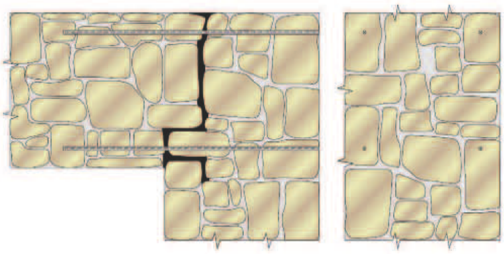
METHOD STATEMENT

1. Mark the locations for the CemTie pins onto the face of the wall at the required spacing. (Refer to the Specification Notes for typical spacing requirements.)
2. Drill a 16mm Ø clearance hole through the outer wall to the required depth. (Refer to the Specification Notes for typical depth requirements.)
3. Clean out all dust from the hole and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the hole is damp or primed prior to commencing step 8.
4. Attach the required length of CemTie Pinning Nozzle to the Helifix Pointing Gun.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the gun.
6. Pump grout to fill the nozzle.
7. Wind the CemTie into the nozzle and ensure that it is fully covered in grout. (Alternatively, fill the hole with grout and wind the CemTie into the grout-filled hole.)
8. Insert the nozzle to the full depth of the drilled hole and pump the grout. Slowly withdraw the nozzle while pumping. The CemTie will be carried out with the HeliBond grout as it is forced through the nozzle. Back pressure will help to push the nozzle back out of the hole.
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings. Make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.
10. Clean tools with clean, fresh water.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



Repair of a crack near a corner, BCS12



Repair of internal and external cracks near a corner, BCS13

RECOMMENDED TOOLING

For drilling ....SDS rotary hammer drill 650/700w
For mixing HeliBond..Drill with mixing paddle
For insertion of the CemTies ....Helifix Pointing Gun with CemTie Pinning Nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. CemTies are to be installed at a vertical spacing of 425mm.
B. CemTies are to extend an equal distance, and typically to not more than 500mm, either side of the crack.
C. Depth of hole to be CemTie length + 25mm.
D. Ensure the CemTies are installed into solid stone and not the mortar joints or loose rubble within the wall.
E. If cracking occurs on both elevations consider using HeliBar crack stitching around the corner (see Repair Detail BCS11). If CemTies have to be used, they should be staggered between each elevation.
F. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the hole, or priming with HeliPrimer WB, should be carried out just prior to inserting the CemTie.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 290

Source: http://www.helifix.com.au/masonry_repair_details.html

Helifix have also developed procedures for creating load bearing beams in cavity or solid walls using HeliBars (see Figures 291 and 292). This is where two of the stainless steel reinforcement bars are grouted into a wall, one on top of another and concealed with a matching mortar. Helibars may also be used for lintel stabilisation. Slots are cut into the horizontal mortar joints and HeliBars grouted into place until all slots have been filled (see Figure 293).

REPAIR DETAILS BLB01/02/04 HELIFIX

BLB01 BLB02 BLB04

Creating load-bearing beams in cavity or solid walls using HeliBars, external and/or internal Beaming

Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

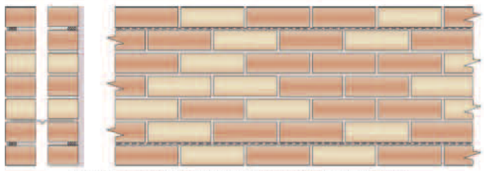
1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing. (Refer to the Specification Notes for typical depth and spacing requirements.) If the wall is plastered/rendered and the mortar joints are not visible, cut the horizontal slots through any plaster/render and into the masonry. Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond cementitious grout, 10-15mm deep, into the back of the slot.
6. Push the first 6mm HeliBar into the grout to obtain good coverage.
7. Inject a second bead of HeliBond grout over the exposed HeliBar.
8. Push the second 6mm HeliBar into the grout to obtain good coverage.
9. Inject a third bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for new pointing.
10. Point up the remaining slot with a suitable matching mortar.
11. Clean tools with clean, fresh water.

***NOTE:** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

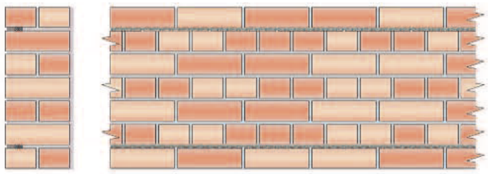
⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.



Cavity wall, BLB01 (external) and BLB02 (internal)



Solid wall, BLB04

RECOMMENDED TOOLING

For cutting slots up to 40mm deep........................Wall chaser, mortar saw or angle grinder with vacuum attachment
To achieve final depth of slot beyond 40mm Hand or Helifix Power Chisel
For mixing HeliBond ....Drill with mixing paddle
For injection of HeliBond into slots...........................Helifix Pointing Gun with mortar nozzle
For smoothing pointing...Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. A minimum of two HeliBars should be installed into each cut slot. Allow for the installation of one additional HeliBar per slot for each additional skin of brickwork over the standard two when creating beams in deep solid walls.

B. Depth of slot into the masonry of a CAVITY WALL to be 40mm to 55mm + the thickness of any plaster (internal) or render (external). Depth of slot into the masonry of a SOLID WALL (230mm) to be 55mm to 70mm + the thickness of any plaster or render. Add 10mm for each additional skin of brickwork.

C. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.

D. If HeliBars are to be joined in a straight run, overlap the bars by a minimum of 500mm.

E. Top and bottom reinforcements should be positioned as far apart as practicable, up to a maximum distance equivalent to 10 brick courses (approx. 850mm).

F. Any fractures in the masonry within the 'beam zone' MUST be stabilised by crack stitching (see Repair Detail BCS01), CrackBond TE or replacement of the masonry.

G. Any missing or very poor quality masonry MUST be replaced.

H. Install Helifix remedial wall ties if existing ties are defective in any way. Refer to Repair Details BRT01-03 for details on Helifix remedial tie installation.

I. Multiple Helibeams should be installed starting at the top and working down to the bottom.

J. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

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Figure 291

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAILS BLB01/02/04 HELIFIX

BLB01 BLB02 BLB04 Creating load-bearing beams in cavity or solid walls using HeliBars, external and/or internal Beaming

Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

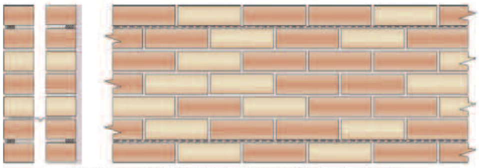
1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing. (Refer to the Specification Notes for typical depth and spacing requirements.) If the wall is plastered/rendered and the mortar joints are not visible, cut the horizontal slots through any plaster/render and into the masonry. Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond cementitious grout, 10-15mm deep, into the back of the slot.
6. Push the first 6mm HeliBar into the grout to obtain good coverage.
7. Inject a second bead of HeliBond grout over the exposed HeliBar.
8. Push the second 6mm HeliBar into the grout to obtain good coverage.
9. Inject a third bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for new pointing.
10. Point up the remaining slot with a suitable matching mortar.
11. Clean tools with clean, fresh water.

***NOTE**: Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

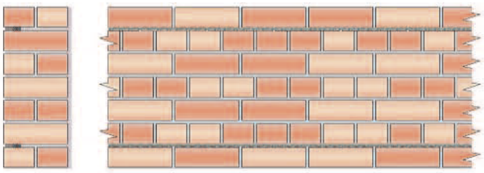
⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.



Cavity wall, BLB01 (external) and BLB02 (internal)



Solid wall, BLB04

RECOMMENDED TOOLING

For cutting slots up to 40mm deep....................Wall chaser, mortar saw or angle grinder with vacuum attachment
To achieve final depth of slot beyond 40mm Hand or Helifix Power Chisel
For mixing HeliBond ....Drill with mixing paddle
For injection of HeliBond into slots...........................Helifix Pointing Gun with mortar nozzle
For smoothing pointing..Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. A minimum of two HeliBars should be installed into each cut slot. Allow for the installation of one additional HeliBar per slot for each additional skin of brickwork over the standard two when creating beams in deep solid walls.
B. Depth of slot into the masonry of a CAVITY WALL to be 40mm to 55mm + the thickness of any plaster (internal) or render (external). Depth of slot into the masonry of a SOLID WALL (230mm) to be 55mm to 70mm + the thickness of any plaster or render. Add 10mm for each additional skin of brickwork.
C. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
D. If HeliBars are to be joined in a straight run, overlap the bars by a minimum of 500mm.
E. Top and bottom reinforcements should be positioned as far apart as practicable, up to a maximum distance equivalent to 10 brick courses (approx. 850mm).
F. Any fractures in the masonry within the 'beam zone' MUST be stabilised by crack stitching (see Repair Detail BCS01), CrackBond TE or replacement of the masonry.
G. Any missing or very poor quality masonry MUST be replaced.
H. Install Helifix remedial wall ties if existing ties are defective in any way. Refer to Repair Details BRT01–03 for details on Helifix remedial tie installation.
I. Multiple Helibeams should be installed starting at the top and working down to the bottom.
J. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slot, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond grout.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

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Figure 292
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BLRD1

HELIFIX

BLRD1

Stabilising failed lintels in cavity walls using HeliBars

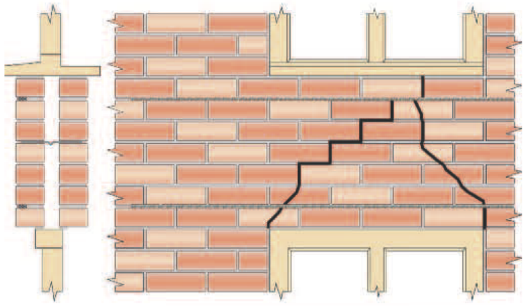
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints, to the specified depth and at the required vertical spacing.* If the wall is plastered/rendered and the mortar joints are not visible, cut the horizontal slots through any plaster/render and into the masonry. Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond.
2. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot are damp or primed prior to commencing step 5.
3. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
4. Fit the mortar nozzle to the pointing gun.
5. Inject a bead of HeliBond cementitious grout, 10-15mm deep, into the back of the slot.
6. Push the first 6mm HeliBar into the grout to obtain good coverage.
7. Inject a second bead of HeliBond grout over the exposed HeliBar.
8. Push the second 6mm HeliBar into the grout to obtain good coverage.
9. Inject a third bead of HeliBond grout over the exposed HeliBar and iron it into the slot using a finger trowel. Inject additional HeliBond as necessary, leaving 10-15mm for new pointing.
10. Repeat steps 5 to 9 for remaining slots.
11. Point up the remaining slots with a suitable matching mortar. Make good the cracks with an appropriate Helifix bonding agent depending on the width of the crack.
12. Clean tools with clean, fresh water.

***NOTE:** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

*⚠ **Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For cutting slots up to 40mm deep .... Wall chaser, mortar saw or angle grinder with vacuum attachment
For drilling .... SDS rotary hammer drill 650/700w
For mixing HeliBond .... Drill with mixing paddle
For injection of HeliBond into slots .... Helifix Pointing Gun with mortar nozzle
For insertion of the CemTies .... Helifix Pointing Gun with CemTie Pinning Nozzle
For smoothing pointing .... Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

- **A.** Depth of slot into masonry to 40mm to 55mm.
- **B.** Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
- **C.** Top and bottom reinforcements should be positioned as far apart as practicable, up to a maximum distance equivalent to 10 brick courses (approx. 850mm).
- **D.** HeliBar to be long enough to extend a minimum of 500mm beyond each side of the opening.
- **E.** Any fractures in the masonry within the 'beam zone' MUST be stabilised by Crack Stitching, CrackBond or masonry replacement.
- **G.** Any missing or very poor quality masonry MUST be replaced.
- **H.** In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the slots and holes, or priming with HeliPrimer WB, should be carried out just prior to injecting the HeliBond.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

TEL. 1300 66 70 71

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Figure 293

Source: http://www.helifix.com.au/masonry_repair_details.html

HeliBars can be used to create movement joints in masonry walls. A movement sleeve is placed over one half of the HeliBar and grouted into place, ensuring no grout comes into contact with the area of bar encased by the sleeve to protect its movement capability (see Figures 294 and 295). BowTies, stainless steel remedial wall ties, can be used to restrain a bowed wall by driving the tie into joist ends. Resin is injected to secure the tie (see Figures 296 and 297).

REPAIR DETAIL BMJ01 HELIFIX

BMJ01

Creating movement joints in cavity walls using HeliBars

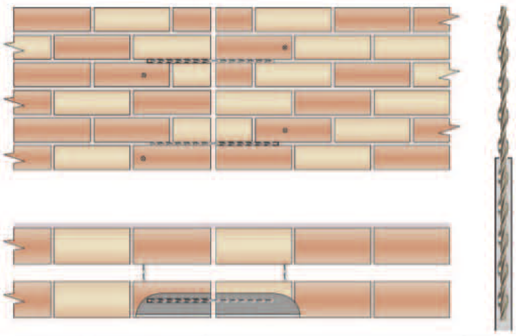
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Mark the position on the wall for the movement joint.
2. Install the specified number of appropriate Helifix wall ties adjacent to the location of the movement joint.*
3. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints either side of the movement joint, to the specified depth and at the required vertical spacing.* Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond. If the wall is rendered and the mortar joints are not visible, cut the horizontal slots through the render and into the masonry.
4. Cut the movement joint to the specified width and at the required location.
5. Clean out all dust and mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 8.
6. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
7. Fit the mortar nozzle to the pointing gun.
8. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
9. Fit the movement sleeve over one half of the 6mm HeliBar and push the complete assembly into the grout ensuring a good bond between the HeliBar and the sleeve in the slot. Ensure that no grout comes into contact with the end of the HeliBar covered by the sleeve, as this end must be free to move.
10. Inject a second bead of HeliBond grout up against the HeliBar and sleeve assembly to obtain good coverage of both.
11. Point up the remaining slot with a suitable matching mortar.
12. Seal the joint with a suitable flexible mastic type material.
13. Clean tools with clean, fresh water.

***NOTE:** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For cutting slots up to 40mm deep......................Wall chaser, mortar saw or angle grinder with vacuum attachment

To achieve final depth of slot beyond 40mm ....Hand or Helifix Power Chisel

For drilling wall tie pilot holes ....Light-weight SDS rotary hammer drill or rotary percussion drill 650/700w

For installation of DryFix wall ties........SDS rotary hammer drill 650/700w and SDS power driver attachment

For mixing HeliBond ....Drill with mixing paddle

For injection of HeliBond into slots............................Helifix Pointing Gun with mortar nozzle

For smoothing pointing...Standard finger trowel

* Specification Notes

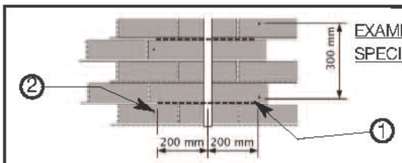
The following criteria are to be used unless specified otherwise:

- **A.** Depth of slot to accommodate the HeliBar and sleeve assembly to be 40mm + the thickness of any render.
- **B.** Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
- **C.** HeliBar should extend a minimum of 200mm either side of the expansion joint.
- **D.** Alternate the position of the sleeve on adjacent HeliBars.
- **E.** HeliBars to be installed at a maximum 300mm vertical spacing.
- **F.** Suitable Helifix wall ties to be installed on each side of the newly formed movement joint not more than 225mm back from the joint and at a maximum of 300mm vertical spacing. Refer to Repair Details BRT01–03 for details on Helifix remedial tie installation.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.



EXPANSION JOINT CUT INTO NEAR LEAF OF 270mm CAVITY BRICK WALL

Material: DRYFIX 8 x 220 and HELIBAR 6

Product code: **HDF8x220** and **HBR 6mm**

INSTALL DRYFIX 8MM DIA. X 220MM L. (HDF8x220) TIES EITHER SIDE OF THE LOCATION OF THE MOVEMENT JOINT AT 300MM VERTICAL CTS AND AT NOT MORE THAN 225MM BACK FROM THE JOINT (SEE HELIFIX REPAIR DETAIL BRT01). CUT THE JOINT AND BOND SLEEVED HELIBARS 6MM DIA. X 400MM L. INTO HORIZONTAL SLOTS CUT ACROSS THE JOINT AT 300MM VERTICAL CTS. USING HELIBOND GROUT. HELIBAR MOVEMENT TIES SHOULD EXTEND A MINIMUM OF 200MM EITHER SIDE OF THE JOINT.

ITEM	CODE	DESCRIPTION		
1	HBR	HELIBAR	HELIFIX	HELIFIX (AUSTRALIA) PTY LTD
2	HDF	DRYFIX		TYPICAL WALL TYPE AND HELIBAR MOVEMENT TIE APPLICATION
				SCALE 1:20 / DWG No. BMJ01-EXS / SHEET 1 of 1

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Figure 294

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BMJ02 HELIFIX

BMJ02

Creating movement joints in solid walls using HeliBars

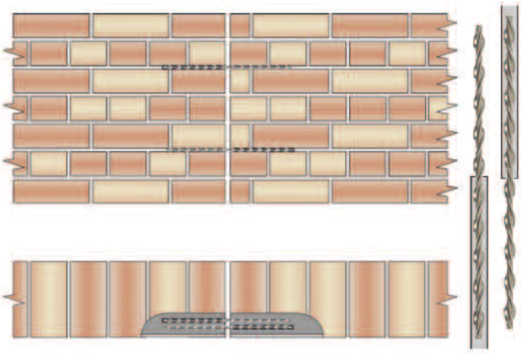
Product	Description	Code
HeliBar	Grade 316 stainless steel reinforcement bar	HBR
HeliBond	Injectable cementitious grout	HLB

METHOD STATEMENT

1. Mark the position on the wall for the movement joint.
2. Using an appropriate power cutting tool with vacuum attachment, cut slots into the horizontal mortar joints either side of the movement joint, to the specified depth and at the required vertical spacing. (Refer to the Specification Notes for typical depth and spacing requirements.) Ensure that as much mortar is removed as possible from the exposed brick surfaces in order to provide a good masonry/grout bond. If the wall is rendered and the mortar joints are not visible, cut the horizontal slots through the render and into the masonry.
3. Cut the movement joint to the specified width and at the required location.
4. Clean out all dust and loose mortar from the slots and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the slot is damp or primed prior to commencing step 7.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the Helifix Pointing Gun.
6. Fit the mortar nozzle to the gun.
7. Inject a bead of HeliBond grout, 10-15mm deep, into the back of the slot.
8. Fit the movement sleeve over one half of the first 6mm HeliBar and push the complete assembly into the grout ensuring a good bond between the HeliBar and the sleeve in the slot. Ensure that no grout comes into contact with the end of the HeliBar covered by the sleeve, as this end must be free to move.
9. Inject a second bead of grout over the HeliBar and tube assembly. Again, ensure that no grout comes into contact with the end of the HeliBar covered by the sleeve.
10. Push a second 6mm HeliBar and sleeve assembly into the grout.
11. Inject a third bead of HeliBond grout up against the HeliBar and sleeve assembly to obtain good coverage of both.
12. Point up the remaining slot with a suitable matching mortar.
13. Seal the joint with a suitable flexible mastic type material.
14. Clean tools with clean, fresh water.

***NOTE.** Pointing may be carried out as soon as is convenient after the HeliBond has started to gel. Ensure that pointing does not disturb the masonry/HeliBond connection.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For cutting slots up to 40mm deep........................Wall chaser, mortar saw or angle grinder with vacuum attachment
To achieve final depth of slot beyond 40mm ....Hand or Helifix Power Chisel
For mixing HeliBond ....Drill with mixing paddle
For injection of HeliBond into slots ....Helifix Pointing Gun with mortar nozzle
For smoothing pointing...Standard finger trowel

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. Allow for the installation of one HeliBar/sleeve assembly for each skin of brickwork into each cut slot. By example, a common 230mm solid wall construction (equivalent to two skins of tied brickwork) will require the installation of two HeliBar/sleeve assemblies per slot. A solid wall equivalent in depth to three skins of bonded masonry will require three Helibar/sleeve assemblies per slot.
B. Depth of slot to accommodate the HeliBar and sleeve assembly to be 70mm + the thickness of any render.
C. Height of slot to be equal to full mortar joint height, with a minimum of 8mm.
D. HeliBar should extend a minimum of 200mm either side of the movement joint.
E. Alternate the position of the sleeve on adjacent HeliBars.
F. HeliBar/sleeve assemblies to be installed at a maximum 300mm vertical spacing.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 295
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAILS BRB01/03/04 HELIFIX

BRB01 BRB03 BRB04

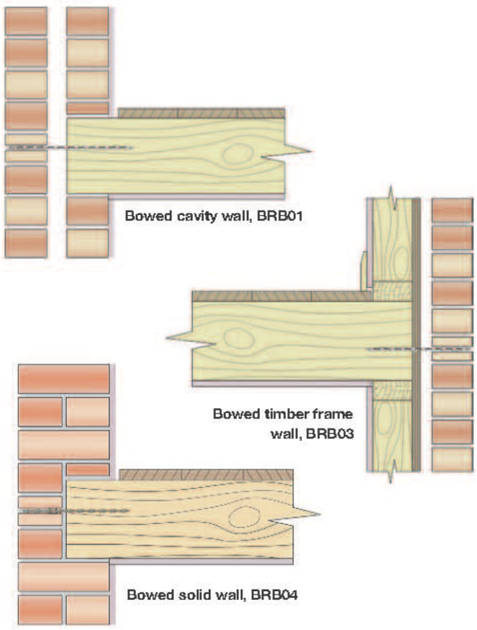
Restraining a bowed cavity, timber frame or solid wall using BowTies into joist ends

Product	Description	Code
BowTie	Grade 316 stainless steel remedial wall tie	HBT
EpoxyPlus	High performance pure epoxy resin	HTE

METHOD STATEMENT

1. Mark the positions of the joists on the external wall.
2. Drill the clearance holes for the BowTies (normally 12mm Ø) through the masonry only and in line with the centre of the joists.
3. Clean out the hole to clear any dust or debris.
4. Insert the BowTie power support tool into an SDS rotary hammer drill and place the BowTie into the support tool.
5. Drive the BowTie into the timber to the required depth. (Refer to the Specification Notes for typical depth requirements.)
6. Place the end of the nozzle of the resin applicator over the exposed end of the BowTie. Masking tape may be placed around the hole to protect the surface of the wall from resin spillage. Cloth may also be wrapped around the nozzle to help seal the opening during installation and protect the wall face from resin spillage.
7. Pump the resin applicator to inject Helifix EpoxyPlus resin into the hole. The resin will track down the tie, following its helical profile. Inject resin until the hole in the near skin is filled completely.
8. Allow the resin to gel (normally 15 to 20 minutes).
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling and insertion of BowTies...SDS rotary hammer drill 650/700w
For installation of BowTies ....BowTie support tool
For injection of Helifix EpoxyPlus resin............Applicator gun with nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. BowTie penetration into the end grain of the timber joist must be a minimum of 70mm.

B. Each joist in the area of concern is to be secured with a BowTie (i.e. spacing of BowTies is to correspond with the original joist spacing).

C. Ensure that all joists into which BowTies are to be installed are both sound and secure.

D. Install Helifix remedial wall ties if existing ties are defective in any way. Refer to Repair Details BRT01–03 for details on Helifix remedial tie installation.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 296
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAILS BRB01/03/04 HELIFIX

BRB01 BRB03 BRB04

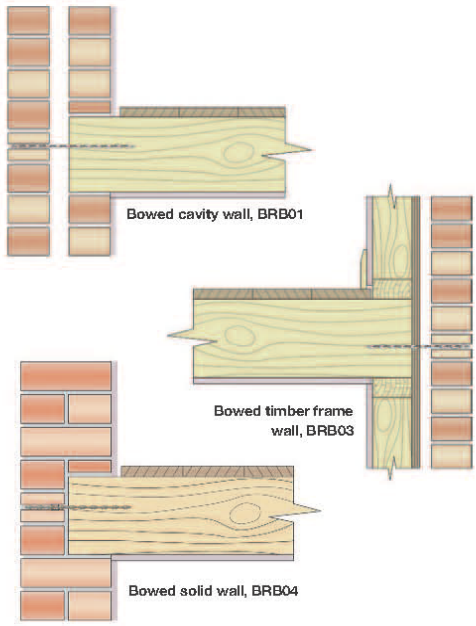
Restraining a bowed cavity, timber frame or solid wall using BowTies into joist ends

Product	Description	Code
BowTie	Grade 316 stainless steel remedial wall tie	HBT
EpoxyPlus	High performance pure epoxy resin	HTE

METHOD STATEMENT

1. Mark the positions of the joists on the external wall.
2. Drill the clearance holes for the BowTies (normally 12mm Ø) through the masonry only and in line with the centre of the joists.
3. Clean out the hole to clear any dust or debris.
4. Insert the BowTie power support tool into an SDS rotary hammer drill and place the BowTie into the support tool.
5. Drive the BowTie into the timber to the required depth. (Refer to the Specification Notes for typical depth requirements.)
6. Place the end of the nozzle of the resin applicator over the exposed end of the BowTie. Masking tape may be placed around the hole to protect the surface of the wall from resin spillage. Cloth may also be wrapped around the nozzle to help seal the opening during installation and protect the wall face from resin spillage.
7. Pump the resin applicator to inject Helifix EpoxyPlus resin into the hole. The resin will track down the tie, following its helical profile. Inject resin until the hole in the near skin is filled completely.
8. Allow the resin to gel (normally 15 to 20 minutes).
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling and insertion of BowTies...SDS rotary hammer drill 650/700w
For installation of BowTies ....BowTie support tool
For injection of Helifix EpoxyPlus resin............Applicator gun with nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. BowTie penetration into the end grain of the timber joist must be a minimum of 70mm.
B. Each joist in the area of concern is to be secured with a BowTie (i.e. spacing of BowTies is to correspond with the original joist spacing).
C. Ensure that all joists into which BowTies are to be installed are both sound and secure.
D. Install Helifix remedial wall ties if existing ties are defective in any way. Refer to Repair Details BRT01–03 for details on Helifix remedial tie installation.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 297
Source: http://www.helifix.com.au/masonry_repair_details.html

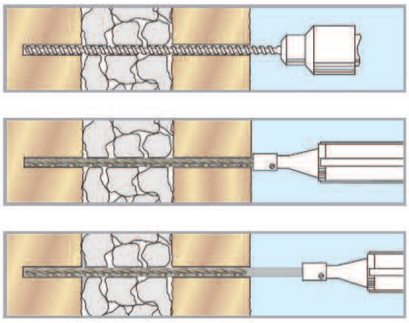
Repair of delaminated or separating masonry is a rubble-filled or solid wall may also be carried out using CemTies (see Figure 298). These can also be used to repair brick faced random stone walls through the brick faces or mortar joints (see Figure 299).
DryFix, a stainless steel dry pinning system, can be used to replace worn or absent wall ties (see Figure 300). These can be hidden from view with sand, cement and oxide mix or with silicone sealant. Retroties may also be used to do this, where a stainless steel remedial wall tie is set into the wall with high performance pure epoxy resin (see Figure 301).

REPAIR DETAIL BRF01 HELIFIX

BRF01

Repair of delaminated or separating masonry in a rubble-filled or solid wall using CemTies

Product	Description	Code
CemTie	Grade 316 stainless steel structural pin	HCT
HeliBond	Injectable cementitious grout	HLB



METHOD STATEMENT

1. Mark the locations for the CemTie pins onto the face of the wall at the required spacing.*
2. Drill a 12–14mm Ø clearance hole, or a 14-16mm Ø hole if the CemTie is longer than 450mm, at the required location and to the specified depth.*
3. Clean out all dust from the hole and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the hole is damp or primed prior to commencing step 8.
4. Attach the required length of CemTie Pinning Nozzle to the Helifix Pointing Gun.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the gun.
6. Pump grout to fill the nozzle.
7. Wind the CemTie into the nozzle and ensure that it is fully covered in grout. (Alternatively, fill the hole with grout and wind the CemTie into the grout-filled hole.)
8. Insert the nozzle to the full depth of the drilled hole and pump the grout. Slowly withdraw the nozzle while pumping. The CemTie will be carried out with the HeliBond grout as it is forced through the nozzle. Back pressure will help to push the nozzle back out of the hole.
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings.
10. Clean tools with clean, fresh water.

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***

RECOMMENDED TOOLING

For drilling ....SDS rotary hammer drill 650/700w
For mixing HeliBond..Drill with mixing paddle
For insertion of the CemTies ....Helifix Pointing Gun with CemTie Pinning Nozzle

* Specification Notes

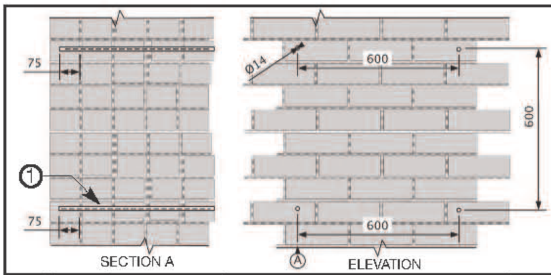
The following criteria are to be used unless specified otherwise:

A. CemTies are to be installed at a minimum density of approx. 2.8 ties/m² (approx. 600mm horizontal and 600mm vertical spacing).
B. The density is to be increased around openings with ties placed at a maximum 300mm vertical spacing and 225mm back from the opening.
C. Depth of hole to be CemTie length + 25mm. CemTies should be embedded to a minimum depth of 75mm into the far leaf.
D. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the hole should be carried out just prior to inserting the CemTie.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.



EXAMPLE SPECIFICATION

STABILISING A SOLID WALL
Material: CEMTIE 8
Product code: HCT8

8MM DIA. CEMTIES (HCT8) TO BE INSTALLED INTO CLEARANCE HOLES USING HELIBOND INJECTABLE CEMENTITIOUS GROUT (HLB). CEMTIES TO BE SUFFICIENTLY LONG TO EXTEND 75MM INTO THE FAR LEAF. CEMTIES TO BE INSTALLED AT A VERTICAL AND HORIZONTAL SPACING OF NOT MORE 600MM CTS. CLEARANCE HOLES TO MEASURE 12-14MM IN DIAMETER.

ITEM	CODE	DESCRIPTION		
1	HCT	CEMTIE	HELIFIX	HELIFIX (AUSTRALIA) PTY LTD — TYPICAL SOLID WALL TYPE AND CEMTIE APPLICATION — SCALE 1:20 — DWG No. BRF01-EXS — SHEET 1 of 1

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Figure 298
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BRFO2/BRFO3 HELIFIX

BRFO2 BRFO3

Repair of brick-faced random stone walls using CemTies through brick faces or mortar joints

Product	Description	Code
CemTie	Grade 316 stainless steel structural pin	HCT
HeliBond	Injectable cementitious grout	HLB

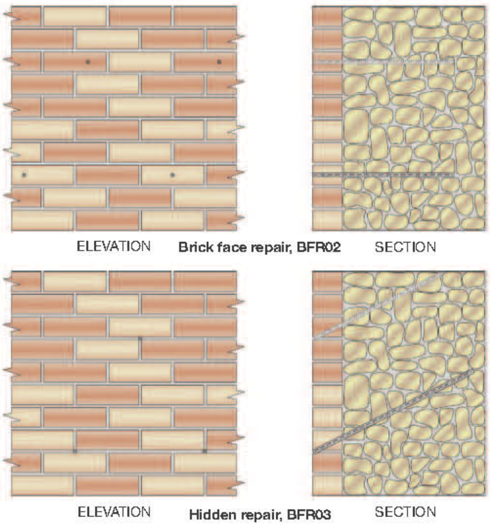
METHOD STATEMENT

1. Mark the positions for the holes on the outer face of the wall. (Refer to the Specification Notes for typical spacing requirements.)
2. Drill a 12–14mm Ø clearance hole, or 16mm Ø if the CemTie is longer than 450mm, at the required location, through the brick face of the wall and into the back-up material to the specified depth. (Refer to the Specification Notes for typical depth requirements.)

   Alternatively, to avoid marking the brick faces, the hole should be drilled through the perpendicular mortar joint between two adjacent bricks. The hole should be angled either upwards (as shown) or downwards to pass through the brick and then continue into the back-up material.
3. Clean out all dust from the hole and thoroughly flush with water. Where the substrate is very porous or flushing with water is inappropriate, use HeliPrimer WB. Ensure the hole is damp or primed prior to commencing step 8.
4. Attach the required length of CemTie Pinning Nozzle to the Helifix Pointing Gun.
5. Mix HeliBond cementitious grout thoroughly using a drill and mixing paddle and load into the gun.
6. Pump grout to fill the nozzle.
7. Wind the CemTie into the nozzle and ensure that it is fully covered in grout. (Alternatively, fill the hole with grout and wind the CemTie into the grout-filled hole.)
8. Insert the nozzle to the full depth of the drilled hole and pump the grout. Slowly withdraw the nozzle while pumping. The CemTie will be carried out with the HeliBond grout as it is forced through the nozzle. Back pressure will help to push the nozzle back out of the hole.
9. Make good all holes at the surface using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings. Make good the crack using an appropriate Helifix bonding agent or filler depending on the width of the crack.
10. Clean tools with clean, fresh water.

***NOTE** If diamond core drilling is used, the internal surface of the hole must be roughened to ensure a good bond.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling .... SDS rotary hammer drill 650/700w
For mixing HeliBond .... Drill with mixing paddle
For insertion of the CemTies .... Helifix Pointing Gun with CemTie Pinning Nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. The density of the ties will depend upon the condition of the masonry and the loading that it is expected to withstand. Typically, CemTies should be installed at a minimum density of 2.8 ties/m2 (approx. 600mm horizontal and 600mm vertical spacing).

B. The depth of fixing into the back-up material must be sufficient to provide a secure connection (prior testing may be required).

C. Depth of hole to be CemTie length + 25mm.

D. CemTies are to be installed at an angle of 30° to 40° when following the hidden repair detail to allow sufficient fixing in the brick facing.

E. In hot conditions ensure the masonry is well wetted or primed to prevent premature drying of the HeliBond due to rapid de-watering. Ideally additional wetting of the hole should be carried out just prior to inserting the CemTie.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

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Figure 299

Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BRT01 HELIFIX

BRT01

Replacing wall ties using DryFix

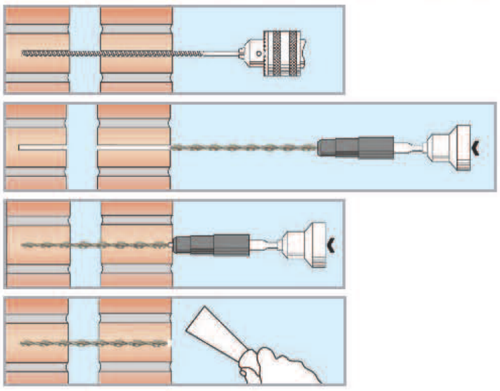
Product	Description	Code
DryFix	Stainless steel dry pinning system	HDF

METHOD STATEMENT

1. Mark the locations for the DryFix ties onto the face of the wall at the required spacing.* Wherever possible, the holes should be drilled directly into the masonry, but they may also be driven into the existing mortar provided that this is strong and in good condition.
2. Drill a 5mm Ø pilot hole through the near leaf and into the remote leaf to the specified depth using a light-weight SDS hammer drill set to a slow speed and light hammer only.* A rotary percussion 3-jaw chuck drill may be preferred if the masonry is particularly soft or thin and prone to excessive spalling. A 6mm or 6.5mm Ø pilot hole size may be preferred if the masonry is particularly hard.
3. Attach the Helifix Power Driver attachment to an SDS hammer drill set to a slow speed and light hammer only. (DryFix ties are self-tapping and will work themselves into the wall following the hammer action of the drill.)
4. Load the DryFix tie into the power driver attachment.
5. Support the power driver attachment with one hand, while using the other to work the drill, and drive the DryFix tie into the pre-drilled pilot hole to approximately 10mm beyond the surface of the near leaf.
6. Make good the hole using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust or drillings.

***NOTE.** Avoid leaning or pushing heavily on the drill during operation to ensure the accuracy of the hole's diameter and to limit spalling of the near leaf as the drill breaks into the cavity.*

Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.



RECOMMENDED TOOLING

For drilling ....Rotary percussion or SDS rotary hammer drill 650/700w

For installation of DryFix ....SDS rotary hammer drill and DryFix Power Driver attachment

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. DryFix ties are to be installed at 600mm vertical and horizontal centres into continuous brickwork. Ties are to be installed at 300mm centres around openings (e.g. around windows).

B. Depth of pilot hole to be DryFix tie length + 10mm.

C. DryFix length to equal near brick width less 10mm + cavity width + far leaf embedment depth. Typically, ties should be sufficiently long to embed 35-70mm into the remote leaf depending on its hardness, with harder materials requiring less embedment. Typically, an embedment of 60-70mm isto be achieved when installing into common, dry-pressed or extruded brickwork.

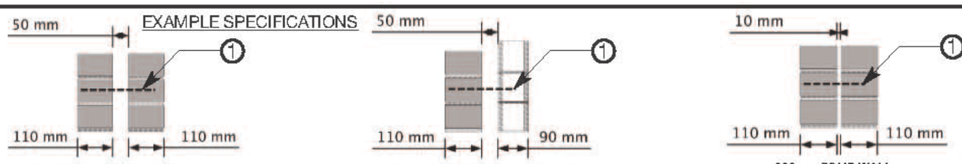
D. Ties may be installed from either side of the wall.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on **1300 66 70 71**.

EXAMPLE SPECIFICATIONS



270mm CAVITY BRICK WALL
Material: DRYFIX 8 X 220
Product code: **HDF8x220**

DryFix 8mm dia. x 220mm l. (HDF8x220) ties to be installed at 600mm vertical and horizontal cts on open brick faces, and 300mm cts around openings. Ties to be driven 60-70mm into the remote leaf and recessed 10mm below the face of the near leaf.

250mm CAVITY BRICK/BLOCK WALL
Material: DRYFIX 8 x 195
Product code: **HDF8x195**

DryFix 8mm dia. x 195mm l. (HDF8x195) ties to be installed at 600mm vertical and horizontal cts on open brick faces, and 300mm cts around openings. Ties to connect with the near web of the block and to be recessed 10mm below the face of the brick leaf.

230mm SOLID WALL
Material: DRYFIX 8 x 170
Product code: **HDF8x170**

DryFix 8mm dia. x 170mm l. (HDF8x170) ties to be installed at 600mm vertical and horizontal cts on open brick faces, and 300mm cts around openings. Ties to be driven 60-70mm into the remote leaf and recessed 10mm below the face of the near leaf.

ITEM	CODE	DESCRIPTION		
1	HDF	DRYFIX	HELIFIX	HELIFIX (AUSTRALIA) PTY LTD
				TYPICAL WALL TYPES AND DRYFIX APPLICATIONS
				SCALE 1:20 / DWG No. BRT01-EXS / SHEET 1 of 1

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Figure 300
Source: http://www.helifix.com.au/masonry_repair_details.html

REPAIR DETAIL BRT02 HELIFIX

BRT02

Replacing wall ties using RetroTies

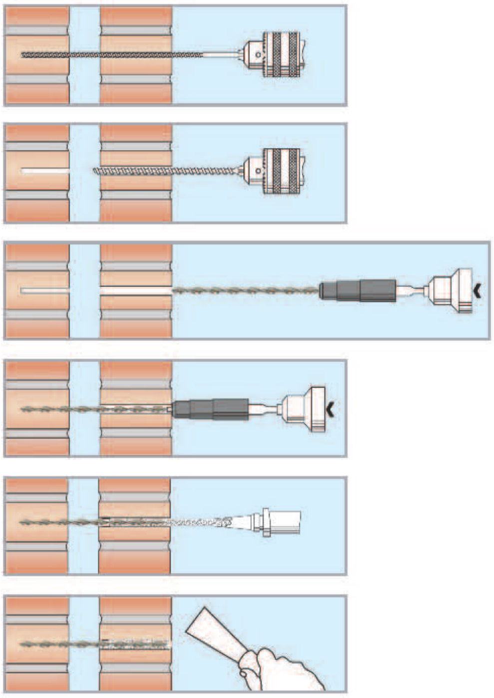
Product	Description	Code
RetroTie	Grade 316 stainless steel remedial wall tie	HRT
EpoxyPlus	High performance pure epoxy resin	HTE

METHOD STATEMENT

1. Mark the positions for the RetroTie pilot/clearance holes on the outer face of the wall.* Wherever possible, the holes should be drilled directly into the masonry, but they may also be driven into the exisitng mortar provided that this is strong and in good condition.
2. Drill a 5mm Ø pilot hole through the near leaf and into the remote leaf to the specified depth using a light-weight SDS hammer drill set to a slow speed and light hammer only.* A rotary percussion 3-jaw chuck drill may be preferred if the masonry is particularly soft or thin and prone to excessive spalling. A 6mm or 6.5mm Ø pilot hole size may be preferred if the inner leaf is particularly hard.
3. Following the same path as the pilot hole, drill a 10mm Ø clearance hole through the near skin only.
4. Attach the Helifix Power Driver attachment or RetroTie support tool to an SDS hammer drill set to a slow speed and light hammer only. (RetroTies are self-tapping and will work themselves into the remote wall following the hammer action of the drill.)
5. Load the RetroTie into the power driver or support tool.
6. Push the RetroTie through the near skin to align the end of the tie with the opening to the pilot hole on the face of the remote leaf.
7. If using a power driver attachment, support the attachment with one hand, while using the other to work the drill, and drive the RetroTie into the pre-drilled pilot hole in the remote leaf to the specified depth. If using the RetroTie support tool, simply drive the tie into the pilot hole to the specified depth. (The RetroTie support tool does not require hand-held support during operation.)
8. Place the end of the nozzle of the resin applicator over the exposed end of the RetroTie in the near leaf. Masking tape may be placed around the hole to protect the surface of the wall from resin spillage. Cloth may also be wrapped around the nozzle to help seal the opening during injection and protect the wall face from spillage.
9. Pump the resin applicator to inject Helifix EpoxyPlus resin into the hole. The resin will track down the tie, following its helical profile. Inject resin until the hole in the near leaf is filled completely.
10. Allow the resin to gel (normally 15 to 20 minutes).
11. Make good the hole using either a mixture of sand, cement and oxide colouring to match the original surrounding brick surfaces or a silicone sealant coated with brick dust/drillings.

***NOTE:** Avoid leaning or pushing heavily on the drill during operation to ensure the accuracy of the hole's diameter and to limit spalling of the near leaf as the drill breaks into the cavity.*

⚠ ***Always locate, identify and isolate any electrical, water or gas services which may be present in the wall or the wall cavities and can pose a safety risk before drilling or cutting. Always take the necessary safety precautions. Use electrical safety gloves and wear appropriate footwear and eyewear.***



RECOMMENDED TOOLING

For drilling.....................Rotary percussion or SDS rotary hammer drill 650/700w

For installation of RetroTie.....................SDS rotary hammer drill and DryFix Power Driver attachment or RetroTie support tool

For injection of Helifix EpoxyPlus resin...........Applicator gun with nozzle

* Specification Notes

The following criteria are to be used unless specified otherwise:

A. RetroTies are to be installed at 600mm vertical and horizontal centres into continuous brickwork. Ties are to be installed at 300mm centres around openings (e.g. around windows).

B. Tie length to be selected according to the hardness and thickness of the masonry and the cavity width. Ties are to be embedded 35-70mm into the remote leaf depending on the hardness of the masonry, with harder materials requiring less embedment. By example, an embedment of 35mm will be sufficient when driving into reinforced concrete. Typically, an embedment of 60-70mm is to be achieved when installing into common, dry-pressed brickwork.

C. Depth of pilot hole to be RetroTie length + 10mm.

D. Ties may be installed from either side of the wall.

The above specification notes are for general guidance only and Helifix reserves the right to amend details/notes as necessary.

GENERAL NOTES

- Helifix product details available at www.helifix.com.au.
- If your application differs from this repair detail or you require specific technical information, call Helifix on 1300 66 70 71.

TEL. 1300 66 70 71

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Figure 301

Source: http://www.helifix.com.au/masonry_repair_details.html

Cheung, Moe and Foo, Simon and Granadino, Jaques. ***Seismic Retrofit of Existing Buildings: Innovative Alternatives.***

This article gives an overview of the use of innovative technologies for economically viable seismic retrofit as employed by Public Works and Government Services Canada (see Appendix 5). This article introduces the current nature of dwellings in Canada, explaining that many of the older buildings do not comply with current codes and are potentially vulnerable. A seismic mitigation approach is outlined including screening: assessing of buildings and their seismic risk; evaluation: a detailed investigation to identify the vulnerability of structural and non-structural elements; and retrofit: upgrading techniques to increase seismic performance and decrease damage. Seismic hazard mitigation technologies are then outlined. The first is a friction damper, consisting of coated steel plates, bolted together, as part of a steel brace mounted in a bay of a column-beam frame. A fluid viscous damper is a passive device which can reduce seismic loading on the structure of a building. Carbon fibre reinforced plastic can be used to wrap structural elements to increase strength and ductility without altering the stiffness. Fibre reinforced cement, composed of fibreglass mesh or a grid and a layer of fibre reinforced cement laid over an unreinforced masonry wall to increase strength and ductility. External prestressing involves wrapping structural columns with prestressed cable strands which increase strength without increasing stiffness. These techniques are outlined and then their use across different building case studies is documented. This article gives a comprehensive outline of each technology, however, no details are given and many methods are not appropriate for small scale buildings and timber frame dwellings in New Zealand.

http://jacobssf.com/Final_Liner_Spring_2009_0

This resource is a newsletter published by Jacobs Associates, who provide civil engineering consulting services, specialising in design and project management for subterranean projects. The first article examines the construction process of a 90-foot long, 36-intch-diameter trenchless drive to run beneath three active railway lines in Skykomish, Washington. A geotechnical investigation of the site was of paramount importance and data used to evaluate the feasibility of differing construction methods. Obstructions were also noted and mapped. The second article outlines a tunnel examination carried out on the 55 132 foot long Canyon Power Tunnel. Features were located to be documented and any loose rock assessed. Photographs, videos, recording devices and measurements are all vitally important. CADD images of the tunnels are then created. Although these articles do not specifically relate to seismic retrofit of dwellings, they do emphasise the need to understand site and soil conditions and the existing structure before attempting any remedial activity. This is very relevant to the process of seismic retrofit in New Zealand.

http://www.jtdweb.org/journal/2001
Katagihara, Kenichi. ***Preservation and Seismic Retrofit of the Traditional Wooden Buildings in Japan.***

This article begins by introducing the structural system of Japan's traditional buildings. This consists of the development of the wooden structure through Japan's history. The structural elements of the framework are then broken down into components (see Figure 302).

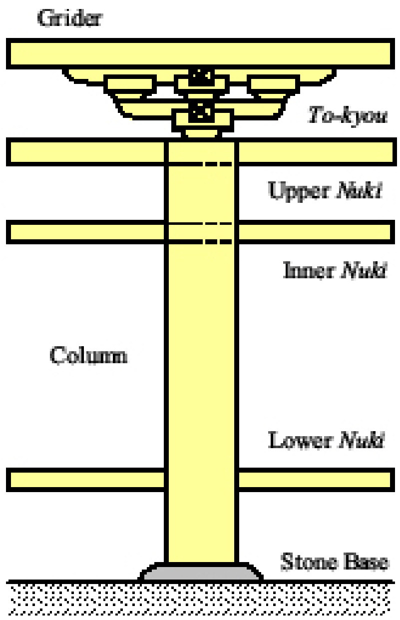

Figure 302
Structural Elements
Source: http://www.jtdweb.org/journal/2001

The assembly of these elements leads to a flexible, yet tough, structural frame. The investigation then documents a dynamic analysis conducted on the structure of a temple and the technical methods for seismic retrofit are analysed. A connecting type damper is selected as the ideal method, to increase the internal viscous damping of the building and improve seismic performance. A 3-D model of the proposed retrofit is developed (see Figure 303), the results indicating that the viscous damping ratio increases from 5% to 15% after retrofit and the deformation decreases by 25%.

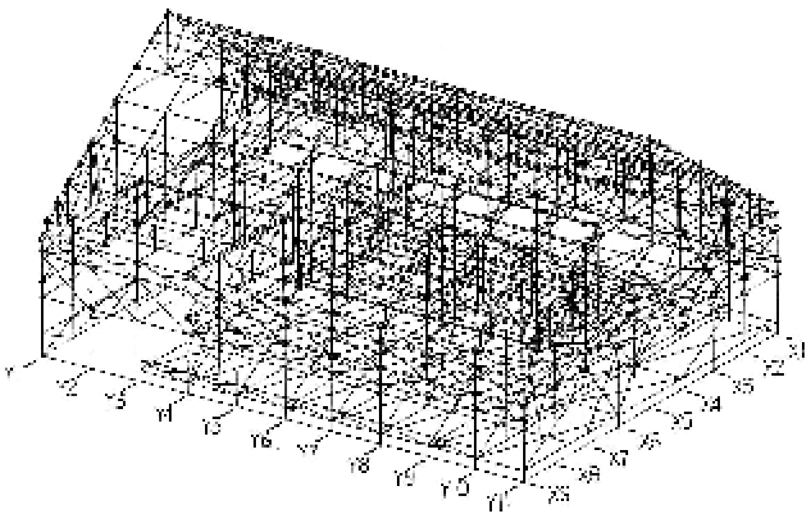

Figure 303
Analytical Model for Actual Temple
Source: http://www.jtdweb.org/journal/2001

This is a technique and method of application carefully developed for the unique structural system of traditional wooden buildings, thus it may not be relevant to New Zealand dwellings. However, it does emphasise the need to carefully consider retrofit measures for each individual situation which is very relevant to this report.

http://www.laquakeproofer.com

This is a website set up by Weinstein Retrofitting Systems, who specialise in earthquake-proofing dwellings in the Los Angeles and San Fernando Valley areas. They use select hardware fittings to retrofit foundations (see Figure304). Although this website does not delve into further details on these connections, it does demonstrate that many contractors are specialising in the retrofit area and utilise a selection of purpose made hardware to complete these projects.

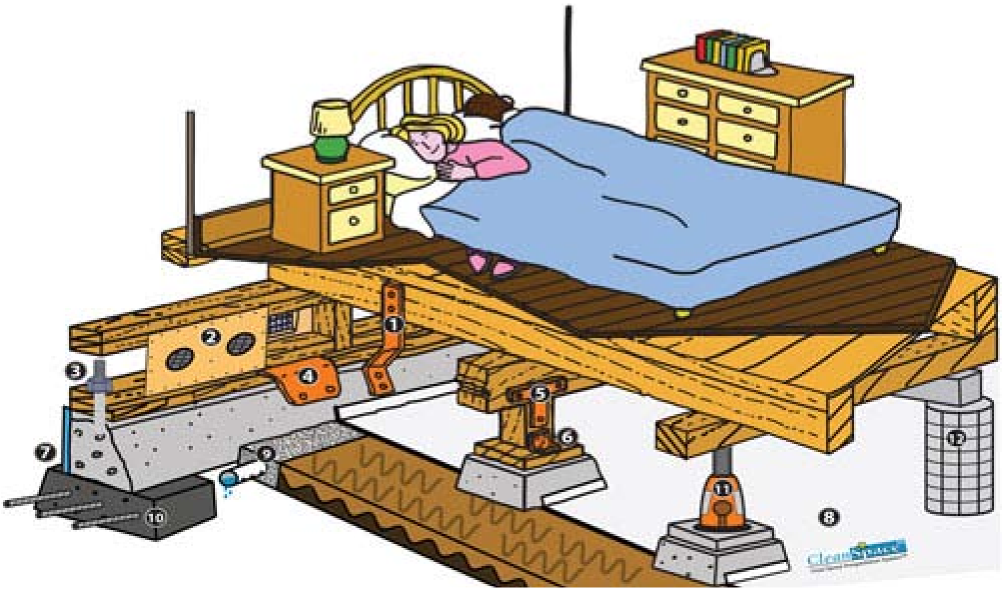

Figure 304

1. Foundation Joint Anchor
2. Cripple Wall Bracing
3. Retrofit Anchor
4. Foundation Bolting
5. T-Strap Tie
6. Framing Anchor
7. Water Proofing Protection
8. Crawl Space Protection
9. Drainage Systems
10. Foundation Replacement & repair
11. House Leveling
12. Caissons Work

Source: http://www.laquakeproofer.com

http://www.mii.com/newzealand/

This website is divided into four main sections: gang-nail truss systems, gang-nail lintels, beams and floors, BOWMAC structural brackets and LUMBERLOK timber connectors. The specialist section on timber fixings which is most relevant to this report. Specifically tailored to subfloor fixings, MiTek has developed a range of applications for its timber connectors.

For braced piles and anchor piles MiTek details the following fixing (see Figures 305, 306, 307, 308 and 309), which must have lateral lines of support to floor joists within 300mm of bearer or bracing lines, as per NZS3604:1999.

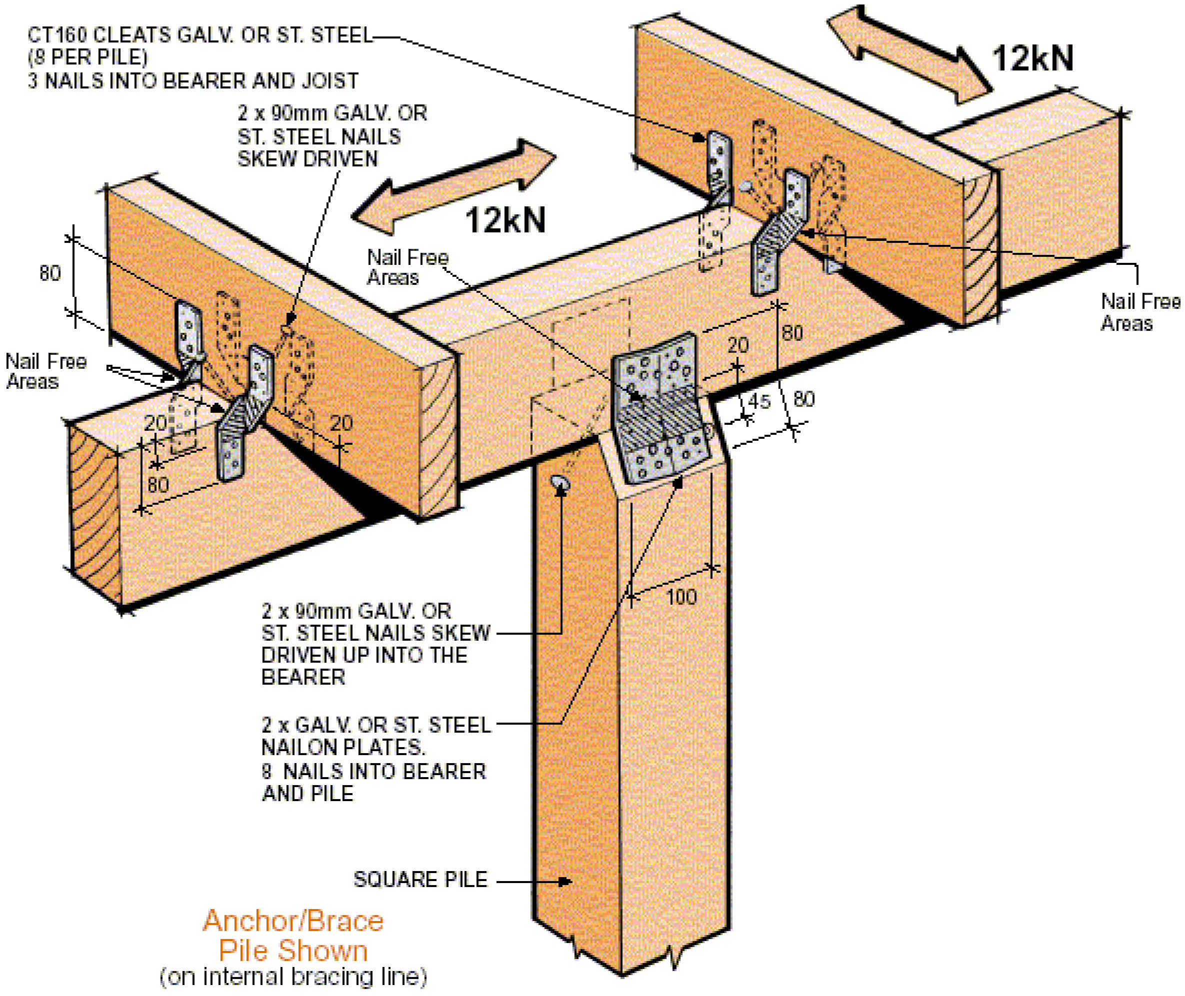

Figure 305
Anchor/Brace Pile Connection
Source: http://www.mii.com/newzealand/

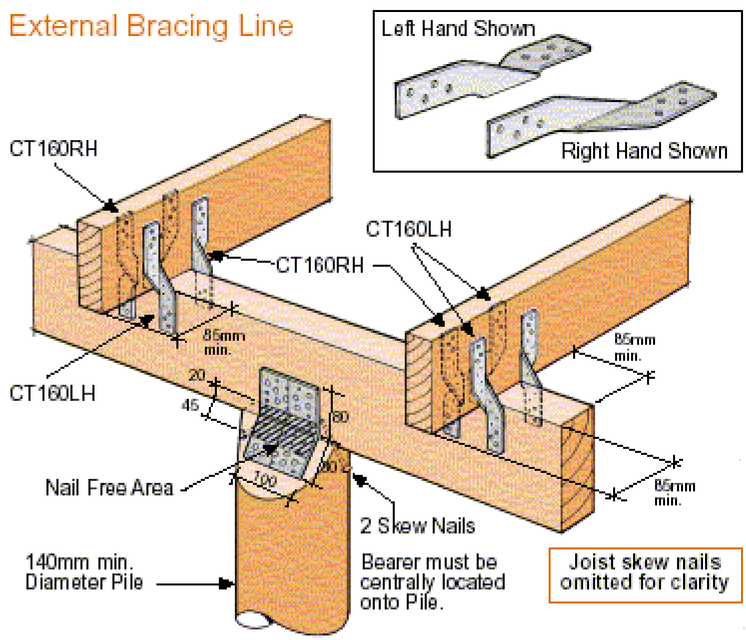

Figure 306
External Bracing Line Detail

Source: http://www.mii.com/newzealand/

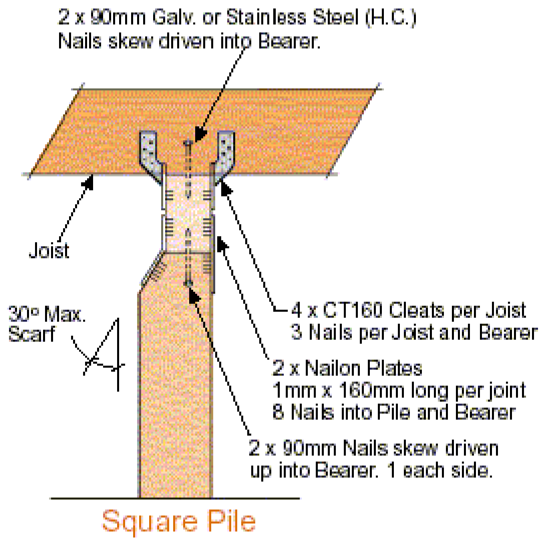

Figure 307
Square Pile Connection Detail
Source: http://www.mii.com/newzealand/

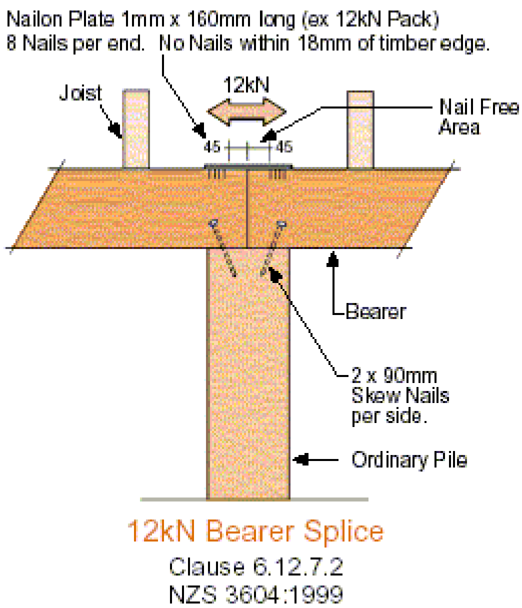

Figure 308
12kN Bearer Splice Connection Detail
Source: http://www.mii.com/newzealand/

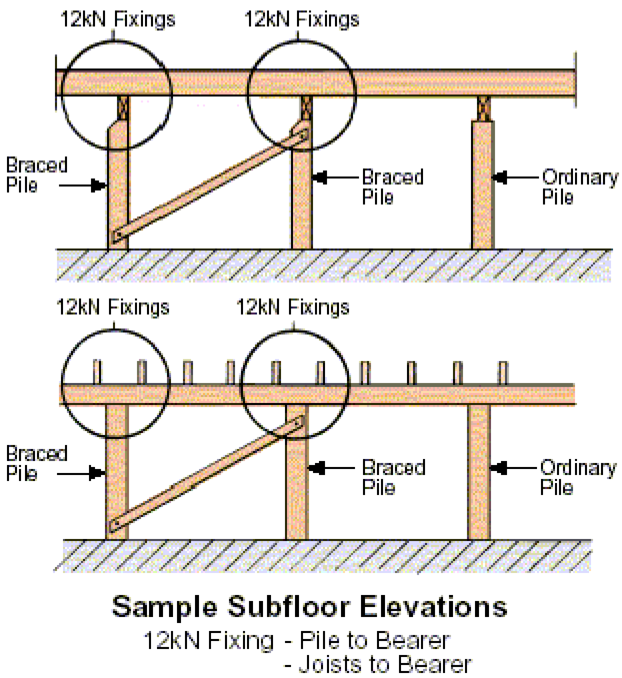

Figure 309
Sample Subfloor Elevations
Source: http://www.mii.com/newzealand/

For braced piles and anchor piles of a 6kN fixing, MiTek specifies the following detail (see Figures 310, 311 and 312), which must have lateral lines of support to floor joists within 300mm of bearer or bracing lines, as per NZS3604:1999.

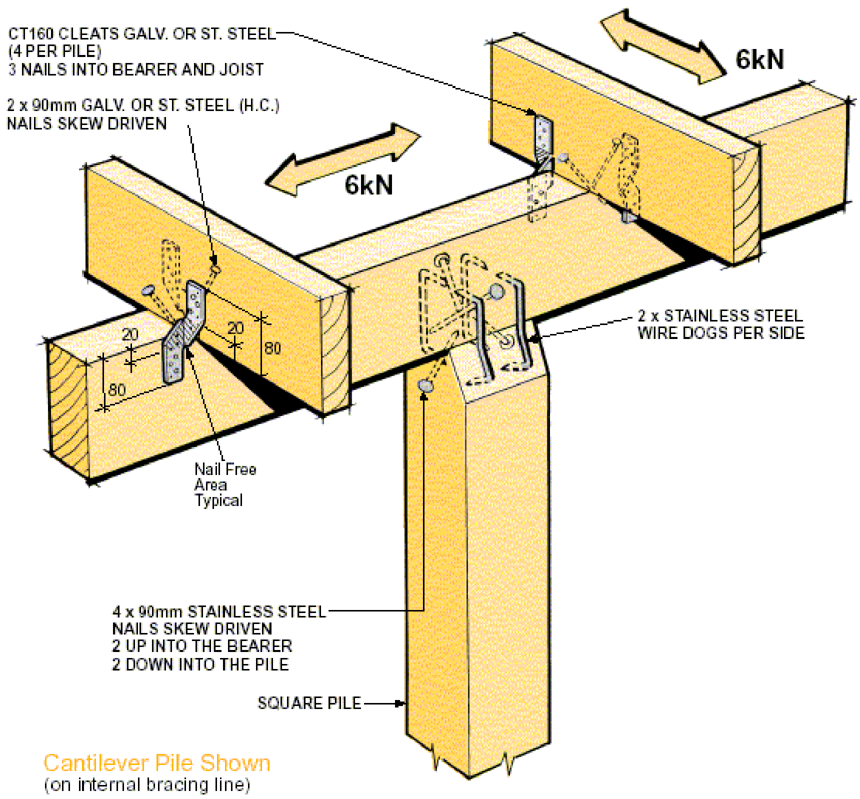

Figure 310
Cantilever Pile from Internal Bracing Line
Source: http://www.mii.com/newzealand/

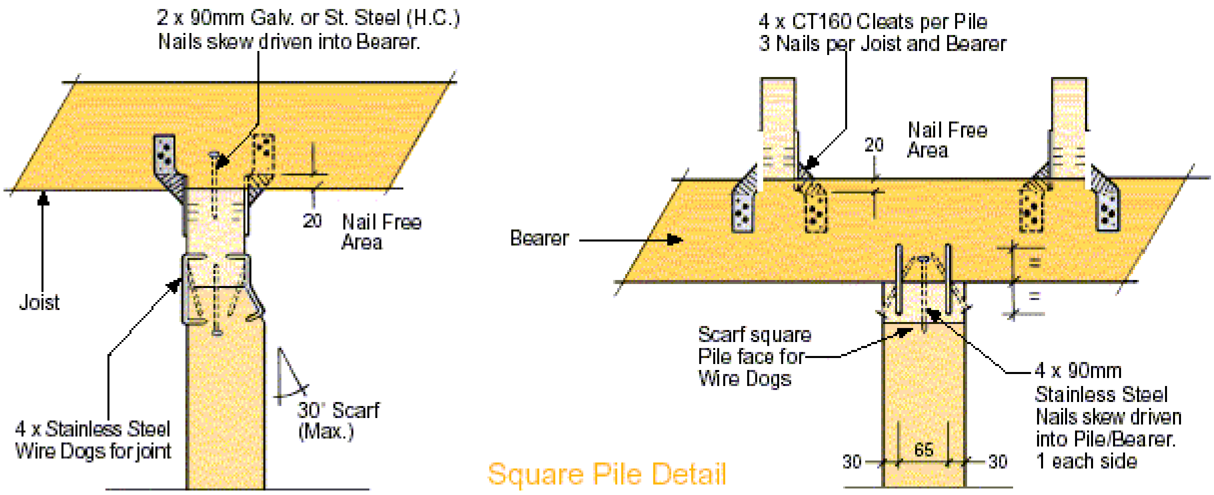

Figure 311
Square Pile Detail
Source: http://www.mii.com/newzealand/

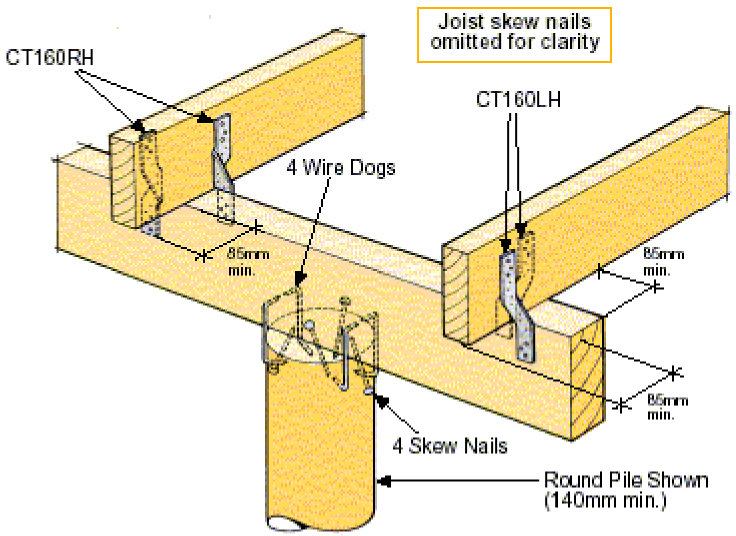

Figure 312
External Bracing Line Connection Detail
Source: http://www.mii.com/newzealand/

MiTek also details a 12kN retrofitted subfloor fixing (see Figure 313), to be used when the outside face of the bearer is not acceptable. The fixing is available in stainless steel to minimise corrosion in coastal areas.

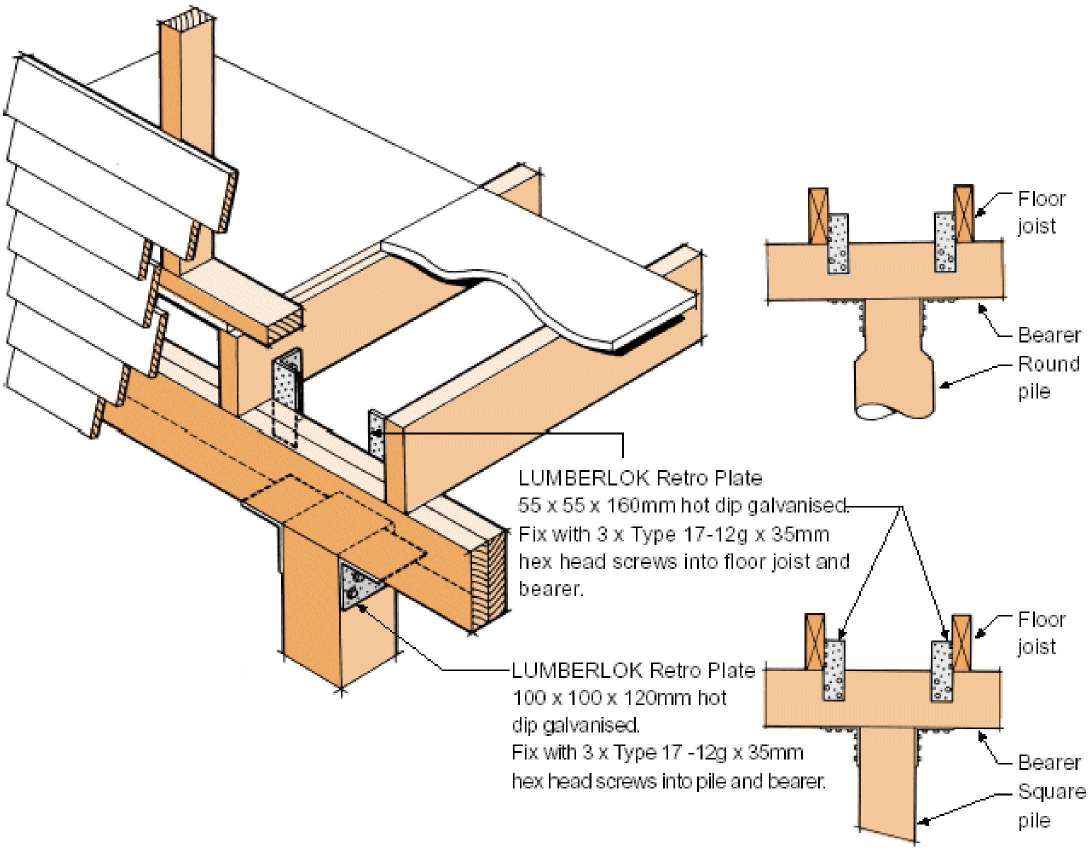

Figure 313
Retrofitted 12kN Connection Detail
Source: http://www.mii.com/newzealand/

http://www.ncpdpindia.org
Desai, Rajendra. Case Studies of Seismic Retrofitting – Latur to Kashmir and Lessons Learnt.
Presented as part of the International Conference of Construction "Managing Earthquake Risk", India, 2008, Jan.

This article examines retrofitting in India across for case studies: the first, a house in a village in the Latur region, the second, a Road and Building Department Office in a small Gujarat town, the third, a small school in mountainous Kashmir and the fourth, a large, three storey school of the Delhi Municipal Corporation in Delhi. Each case study is described in terms of its building system.
The first case study was retrofitted with cast in situ reinforced concrete stitching elements and a reinforced concrete band in the roof. Problems encountered include little retrofit expertise available and specific skills required for the stitching elements which was difficult to obtain.
The second case study was retrofitted with stitching elements also, a seismic belt at eave level, vertical reinforcing bars at wall junctions, encasing of wall openings with seismic straps and tie bracing in the roof. Problems encountered include absence of awareness of retrofit significance and skills.
The third case study was retrofitted with stitching elements, a seismic belt and vertical reinforcing bars also, as well as anchoring of attic floor to walls with vertical rebars and MS brackets. Problems encountered were similar to the second case study, with added difficulties of accessibility to the site, procurement of materials, security checks and unreliable power supply.

The fourth case study was retrofitted with a seismic belt at lintel and sill level, vertical reinforcing bars at wall junctions, encasing of wall openings and jacketing of masonry columns. Problems encountered included exercising caution for the safety of the schoolchildren and the unavailability of skilled masons and labourers.
These retrofit case studies yielded lessons in regards to how retrofitting is carried out. These include notions to employ in the future, such as increasing the awareness of retrofit in at risk communities, regular onsite training in retrofitting needs to be promoted, retrofitting skills must become easily available, materials required for retrofitting must become easily available and documentation systems need to be standardised to ease communication. This article is very relevant to this report as it illustrates the care and expertise necessary for seismic retrofit of ay kind and yields information on common retrofit practices utilised in other areas of the world, such as here in India.

http://www.pryda.co.nz

This website has a designer toolbox with details divided into eight main categories, including roof framing tie down connections; truss to truss connections; wallplate to stud joint fixings; lintel and beam fixings; girder to foundation tie down path; foundations, subfloors and bottom plates; roof and wall; and floor trusses. Within foundations, subfloors and bottom plates, details are presented for pile bearer kits, internal concrete foundation support systems and bottom plate fixings. Unfortunately the majority of these details involve nail plates, which are not ideal for retrofit details as space is often too tight to allow use of a hammer. However, one detail (see Figure 314) may prove useful; describing the fixing of sheet bracing to the dwelling which does not have the same space restrictions as the subfloor in terms of retrofitting.

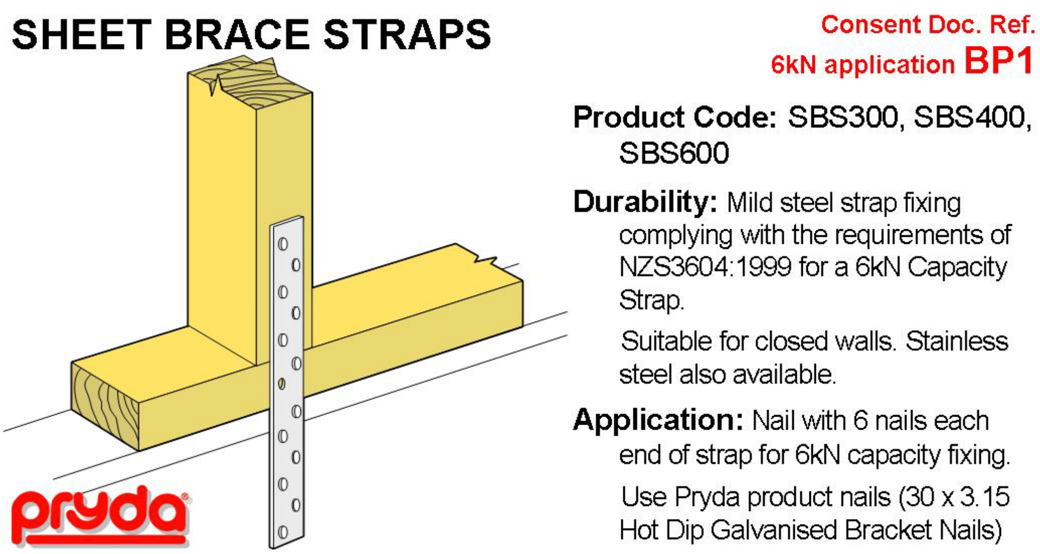

Figure 314
Sheet Brace Strap Detail
Source: http:// www.pryda.co.nz

http://www.pwri.go.jp/eng
Unjoh, Shigeki and Terayama, Toru and Adachi, Yukio and Hoshikuma, Jun-ichi. *Seismic Retrofit of Existing Highway Bridges in Japan.*

This article documents several technological developments for the seismic retrofit of highway bridges in Japan. The article begins by introducing Japan's seismic history and the development of seismic design codes and seismic design practices. This is followed by sections on the Hyogo-Ken Nanbu earthquake; the seismic repair program after the Hyogo-Ken Nanbu earthquake (in principle, including design principles, ensuring enough tie reinforcement in concrete piers and increased use of rubber bearings to absorb relative displacement); and the research and development on seismic evaluation and retrofit of highway bridges. This section details notes on seismic retrofit of wall type piers with a steel H-shaped beam, intermediate anchors or additional reinforcement (see Figure 315). Seismic retrofit of two-column bents is suggested to be carried out with jacketing, using materials of high elasticity and strength (see Figure 316). These same materials are suggested for use in reinforced columns (see Figure 317).

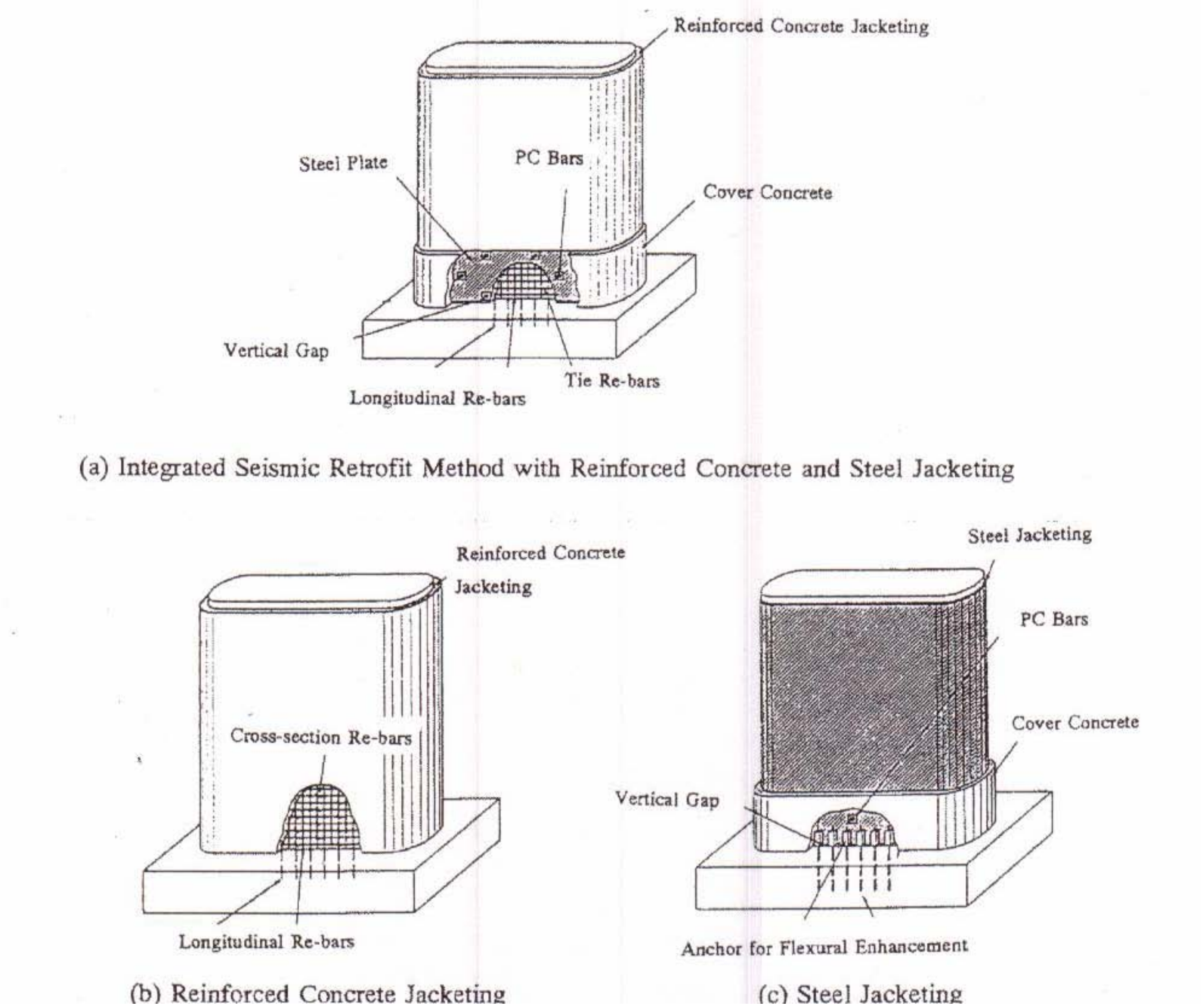

Figure 315
Seismic Retrofit of Wall Type Piers
Source: http://www.pwri.go.jp/eng

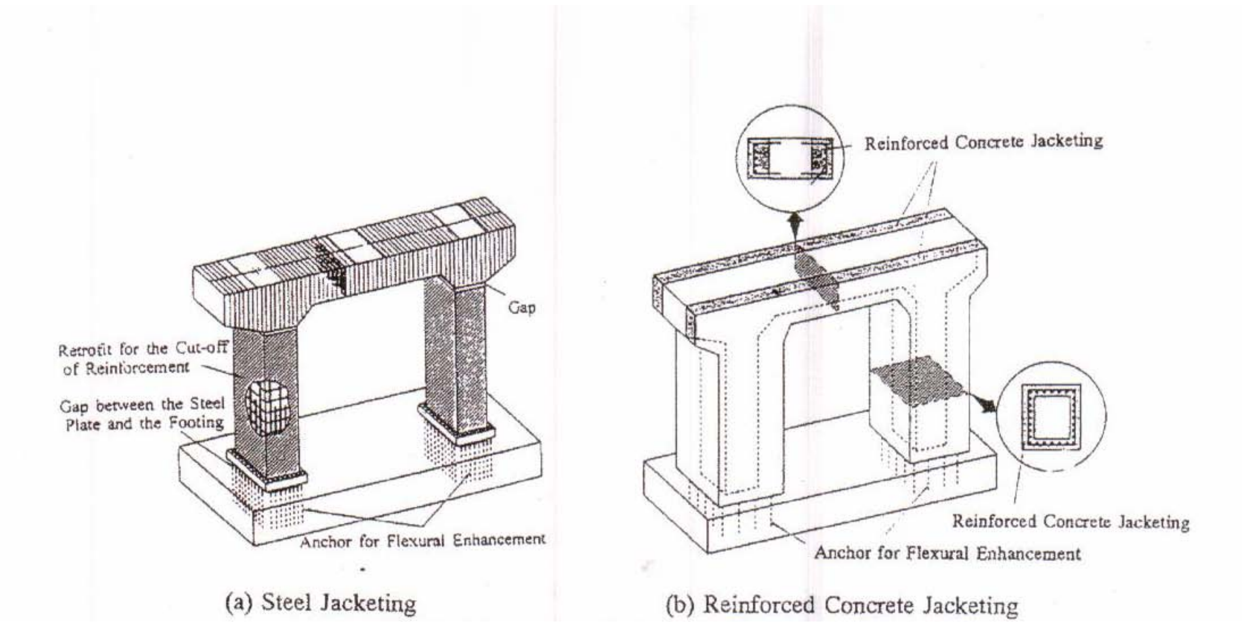

Figure 316

Seismic Retrofit of Two-Column Bents
Source: http://www.pwri.go.jp/eng

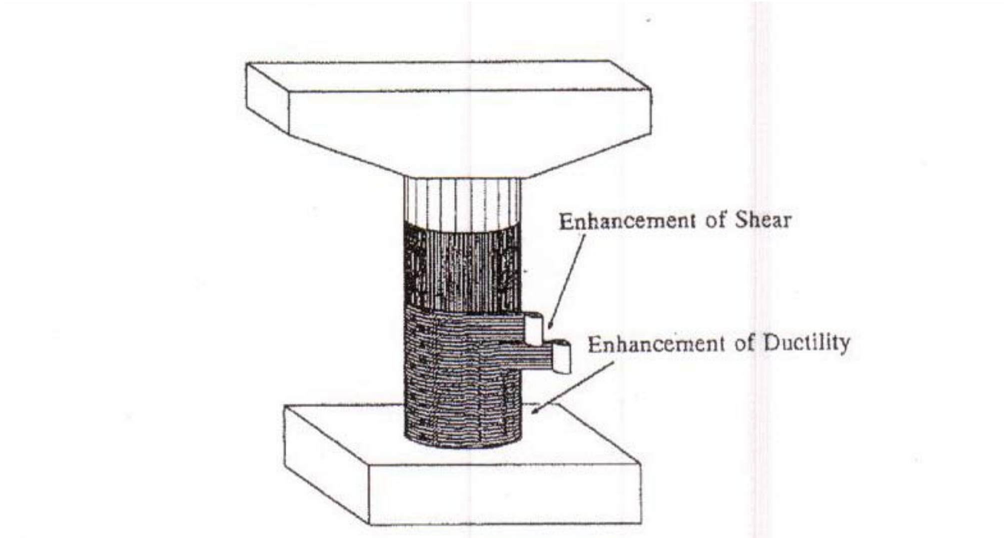

Figure 317
Application of New Materials to Reinforced Column
Source: http://www.pwri.go.jp/eng

Tables are also provided which detail past bridge design methods and their evaluation, and charts to determine seismic vulnerability (see Appendix 6). Although this article is related closely to bridge retrofit, it does emphasise consideration of methods used in retrofit, application of new technology and thorough analysis of the individual situation, which is very relevant to this report.

http://www.servicemagic.com/article.show.Retrofitting-Basements

The article at this web address has been written by Bill Brown, a specialty concrete contractor based in Saratoga, California. He describes the retrofitting of basements in California, where owners wish to build a new basement and due to height restrictions decide to add downward to create this extra space. This article outlines step by step how a basement storey is built without major disruption to site or structure.

Stitch piers are often used. "OSHA rules for shoring or sloping vary for different soil conditions. A typical basement excavation in reasonable soil will allow the lower 5 feet of the cut to stand vertical without shoring, with the balance to grade sloped back at a minimum of a 1-to-1 pitch. That's fine if you have the room, but it can be a problem when the house has a narrow side or back yard setback. If the excavation is 10 to 12 feet deep, for example, the back slope required is 5 to 7 feet -- an impossible demand when the setback is only 5 to 6 feet."[rrrrr] Dealing with tight lots, often the process is to shore the face of the soil to allow the vertical distance of the excavation. Stitch piers are placed around the perimeter of the foundation; these act as bearing points for the steel beams that support the house during excavation. Once the basement is completed the stitch piers are redundant.

[rrrrr] http://www.servicemagic.com/article.show.Retrofitting-Basements

The stitch piers are usually spaced four to five feet apart, allowing the installation of steel shoring beams on eight to ten feet centres, with every second pier supporting the end of a beam. A house moving sub uses heavy duty jacks under the beams to transfer the structural load from the original foundation to the temporary piers (see Figure 318). Excavation then takes place (see Figure 319). When the layout of the site does not allow for free span shoring, crib shoring will be used. This is a square wood frame with interior diagonal braces, stacked under beams for support (see Figure 320).

Figure 318
The steel beams that temporarily support the structure are inserted into holes that have been jackhammered through the stem walls. Once the beams have been raised into position with jacks and shimmed into place, the jacks are removed and the original foundation is demolished
Source: http://www.servicemagic.com/article.show.Retrofitting-Basements

Figure 319
Tracked skid-steer loaders are preferred for working beneath the house because they're highly manoeuvrable and provide excellent traction. The skid-steer pushes the excavated soil to an opening, where it's scooped up by an excavator and loaded into a waiting dump truck
Source: http://www.servicemagic.com/article.show.Retrofitting-Basements

Figure 320
Where full-length shoring beams are impractical, shorter beams are supported by cribwork as needed. No stitch piers were required to support the solid soil forming the face of the excavation shown here. The concrete vault will eventually house a sump pump
Source: http://www.servicemagic.com/article.show.Retrofitting-Basements

The area is then provided with drainage and waterproofing and the slab poured (see Figure 321). Basement walls are formed and concrete poured or, if space is tight, shotcrete will be used (see Figure 322 and 323).

Figure 321
A two-layer rebar grid reinforces the structural slab against seismic loads and eliminates the need for pad footings beneath point loads. After the slab has been poured, drain mat and waterproofing membrane will be applied to the face of the excavation -- which has been stabilized with stitch piers -- and shotcrete will be gunned against the bank. The above-grade portion of the wall will be backed by a single-sided form. To avoid puncturing the slab membrane with grade stakes, the screeds that will be used to level the slab are supported with temporary lumber braces nailed to the overhead joists
Source: http://www.servicemagic.com/article.show.Retrofitting-Basements

Figure 322
Gunning shotcrete against a single-sided form, rather than directly against the excavation, provides space for stone backfill and affords more control over the waterproofing on difficult sites
Source: http://www.servicemagic.com/article.show.Retrofitting-Basements

Figure 323
Formed shotcrete walls are waterproofed with a layer of Paraseal membrane -- visible near the top of the wall -- followed by dimpled drain mat. The upper edge of the drain mat will be secured with a termination bar provided by the manufacturer. The worker visible at top is standing in an excavated void reinforced with stitch piers
Source: http://www.servicemagic.com/article.show.Retrofitting-Basements

Although this article is an expensive retrofit measure to extend the home rather than earthquake-proof it, it does explore methods to deal with tight spaces and privileges excavation to ease tight subfloor areas.

http://www.sika.ca/con-bro-carbodur_composite_systems

Sika is a company which specialises in construction where building or maintaining a structure requires specialist concepts and technologies. Integrated system solutions are emphasises, and these solutions include concrete admixtures; supporting products; structural strengthening solutions;

epoxy resins; waterproofing solutions; and tunnelling.[sssss] The structural strengthening solutions are covered in the Sika brochure, which firstly details reasons for strengthening, including corrosion of reinforcement, corrosion of prestressing cables, inadequate design, modified standards and codes, excessive cracking of concrete and seismic retrofitting.[ttttt] Sika suggest use of FRP fabrics, which are “uni- and/or bidirectional fabrics with carbon, glass and aramid fibres.”[uuuuu] These are useful for seismic retrofit and to increase shear strength. CFRP Plates are also suggested, which are carbon plates produced by pultrosion processes and are useful for increasing flexural and shear strength for dynamically loaded structures. Sika systems have been designed to incorporate these products (see Figure 324 and 325). Sika is producing products specifically designed for retrofit application and continue to conduct research and development in this area. This may be relevant to seismic retrofit of New Zealand dwellings now or in the future.

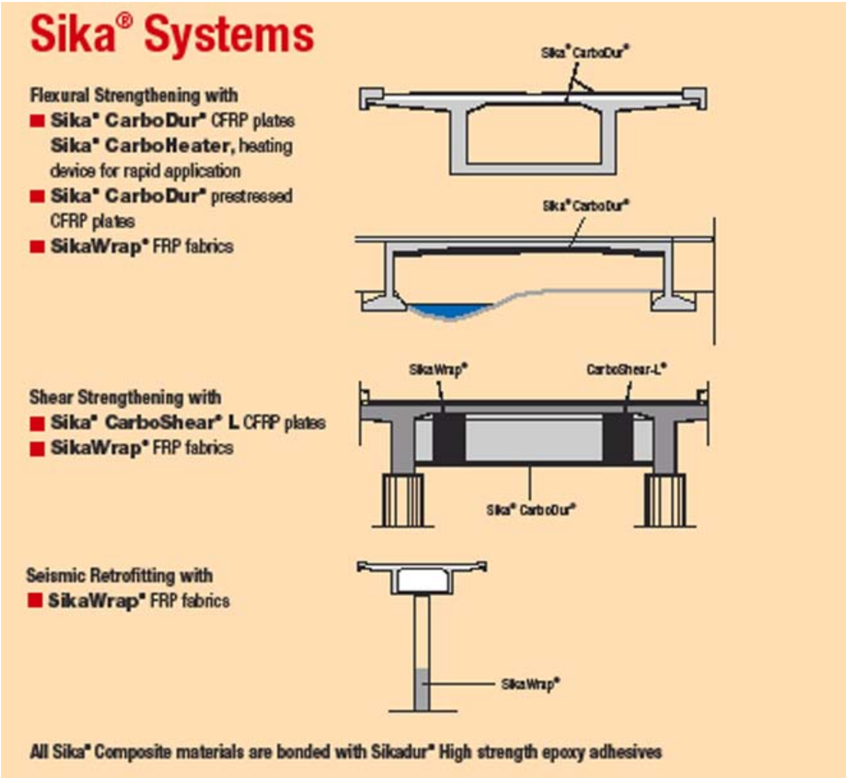

Figure 324
Sika Systems
Source: http://www.sika.ca/con-bro-carbodur_composite_systems

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[sssss] http://www.sika.co.nz/home
[ttttt] http://www.sika.co.nz/home
[uuuuu] http://www.sika.co.nz/home

CFRP Plates System Components

Sika® CarboDur®		Type S	Type M	Type H
CFRP plates	Elastic modulus	165 000 N/mm^2	210 000 N/mm^2	300 000 N/mm^2
	Tensile strength	2800 N/mm^2	2800 N/mm^2	1350 N/mm^2
Sika® Prestressing Systems	Prestressing of **Sika® CarboDur®** plates over 200 kN (20 tons) with **Sika® StressHead** or **Sika® LEOBA CarboDur®** prestressing system			
Sika® CarboHeater Heating device	Fast application (2 – 3 hrs) of **Sika® CarboDur®** plates			
Sika® CarboShear® L	Min. tensile load	126 kN/40 mm width		
L-shaped CFRP plates	Elastic modulus	120 000 N/mm^2		
Sikadur®		**Sikadur®-30**	**Sikadur®-30 LP**	**Sikadur®-41**
Epoxy adhesives	Application temperature	10 – 35 °C	25 – 55 °C	10 – 35 °C
and mortars	Elastic modulus	12 800 N/mm^2	10 000 N/mm^2	9000 N/mm^2
	Bond strength	> 4 N/mm^2 (concrete failure)	> 4 N/mm^2 (concrete failure)	> 4 N/mm^2 (concrete failure)
	Use	Plate adhesive	Plate adhesive	Repair mortar

Fabrics System Components

SikaWrap® FRP Fabrics	Several types of **SikaWrap®** FRP fabrics are available to meet the requirement of specifier and contractor. Unidirectional woven and non-woven fabrics made of glass, aramid and different types of carbon fibers are available. Bi-directional types can be offered with carbon and glass fibers. The range of areal weight is between 200 and 600 g/m^2 for carbon, 400 to 1000 g/m^2 for glass and 300 to 600 g/m^2 for aramid fiber fabrics. Further possibilities and fiber combinations are available on request.
Sikadur® Epoxy impregnating resins	All **SikaWrap®** fabrics can be impregnated with the system tested **Sikadur®** impregnating resins that are all suited for the most common substrate types. are all suited for the most common substrate types.

Figure 325
Sika Systems Components
Source: http://www.sika.ca/con-bro-carbodur_composite_systems

http://www.sika.co.nz/nz_con_conbro_sika_tunnellingandmining_overview

This article explores Sika's specialty groups concerning construction chemicals, equipment solutions and waterproofing systems. Sika's concrete admixtures and supporting products for tunnelling include Sigunit –L53AF, SikaTard 930, Sika ViscoCrete 5-555 and Sika ViscoCrete SC-305.

Sigunit –L53AF is a high performance alkali free accelerator for shotcrete in liquid form. It is to be used in applications such as shotcrete with high initial strength, in shaft and gallery construction, in lining stabilisation and underground works and for rock and slope stabilisation.

SikaTard 930 is an admixture which controls cement hydration: it facilitates stabilisation of the concrete mix for long periods. Its applications include shotcrete applications and where the prevention of hydration is required.

Sika ViscoCrete 5-555 is a polymer based high range superplasticiser for ready mix and precast concrete. It is used where extreme water reduction, excellent flowability and optimal cohesion is required.

Sika ViscoCrete SC-305 is a superplasticiser with set retarding and mix stabilising properties. Its use will result in a reduction in water and cement content, better pumpability and reduced pumping pressures and a better dispersion of accelerators to increase early strengths.

Sika has also developed products for tunnel waterproofing, including SikaPlan, SikaSwell s2 and Sika Waterbars. SikaPlan is a waterproofing membrane with a high resistance to ageing, natural aggressive mediums in ground water and soil and mechanical impact. SikaSwell S2 is a polyurethane sealant that swells in contact with water and is permanently water resistant. Sika Waterbars are soft PVC or FPO waterbars which seal construction and expansion joints in concrete structures.

Although not specifically related to retrofit, this resource is relevant as it details the development of subterranean technologies and products which may in future be useful in foundations and basement areas of dwellings.

http://www.sika.co.nz/nz_con_conbro_sika_tunnellingandmining_brochure

This brochure is a more in depth resource than the Sika Tunnelling and Mining overview publication. It details the same Sika concrete admixtures for tunnelling, as well as some additional products: Sika Rugasol C, SikaFilm and Separol WB230. Sika Rugasol C is used to improve adhesion between concrete panels; SikaFilm retards moisture evaporation from the concrete surface and acts as a finishing aid; Separol WB230 acts as a bondbreaker between formwork or moulds and freshly placed concrete. Examples of tunnels that have used Sika products are outlined in this brochure, including in Isilisberg, Switzerland, at NBS Frankfurt, Germany, and at DMRC, India.
Sika tunnel waterproofing products are also covered in this resource, giving their specifications also. Although this resource does not specifically relate to dwelling retrofit, it does explore new products which may be useful to subfloor and foundation projects in the future.

http://www.simpsonanchors.com

This website has been set up by Simpson Strong Tie Anchor Systems, a company specialising in the manufacture of anchors for cracked and uncracked concrete, and utilised in many retrofit projects. These anchors will be specified in a project if conditions exist that may cause the concrete to crack, in line with the new 2006 International Building Code. These anchor systems include the Strong-Bolt, the IXP Anchor, the Titen HD anchor and SET-XP epoxy.
The Strong-Bolt is a wedge anchor, providing reliability in performance in cracked concrete under static and seismic loading (see Figure 326). It has a tri-segmented clip which may be attached and adjusted independently increasing follow-up expansion should the hole increase in size as a result of a crack. Dual embossments on each clip segment allows the clip to undercut into the concrete should a crack occur.

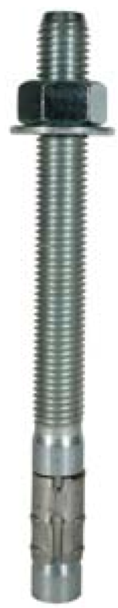


Figure 326
Strong-Bolt
Source: http://www.simpsonanchors.com

The IXP Anchor is a torque-controlled adhesive anchor, used with Simpson Strong Tie SET-XP epoxy. It has a conical shape (see Figure 327) which allows it to mimic the follow up expansion behaviour of a torque-controlled expansion anchor when tension-zone cracks occur in the base material and intersect with the placement of the anchor.[vvvvv] The shape also prevents the anchor from unscrewing.

Figure 327
IXP Anchor
Source: http://www.simpsonanchors.com

Its test criteria are outlined, including:

- Seismic and wind loading in cracked and uncracked concrete
- Static tension and shear loading in cracked and uncracked concrete
- Horizontal and overhead applications
- Long-term creep
- Static loading at elevated-temperatures
- Damp holes
- Freeze-thaw conditions
- Critical and minimum edge distance and spacing [wwwww]

[vvvvv] http://www.simpsonanchors.com
[wwwww] http://www.simpsonanchors.com

Its suggested specifications are also included (see Figure 328).

Characteristic	Symbol	Units	Nominal Anchor Diameter (inch)			
			⅜	½	⅝	¾
Installation Information						
Drill Bit Diameter	d	in.	½	⅝	¾	⅞
Baseplate Clearance Hole Diameter	d_c	in.	0.438	0.563	0.688	0.875
Installation Torque	T_{inst}	ft-lb	30	60	100	160
Embed. Depth & Eff. Embed Depth	h_{nom} & h_{ef}	in.	3⅜	4⅞	6⅝	8⅜
Critical Edge Distance	c_{ac}	in.	5	7¼	10	12½
Minimum Edge Distance	c_{min}	in.	3⅜	4⅞	6⅝	8⅜
Minimum Spacing	s_{min}	in.	5	4⅞	6⅝	8⅜
Minimum Concrete Thickness	h_{min}	in.	6¾	9¾	13¼	16¾
Additional Data						
Anchor Category	category	-	1			
Yield Strength	f_{ya}	psi	105,000			
Tensile Strength	f_{uta}	psi	125,000			
Minimum Tensile Stress Area	A_{se}	in²	0.0494	0.0886	0.1414	0.2064

Figure 328
IXP Anchor Specifications
Source: http://www.simpsonanchors.com

The Titen-HD is a heavy duty screw anchor for concrete and masonry (see Figure 329). The non-expansive characteristics of this anchor make it ideal for structural applications, even at reduced distances and spacings. It has a high load capacity and vibration resistance as the mechanical interlock of the threads and the ratchet teeth on the underside of the head help prevent the anchor from loosening. Less spacing is required as the anchor does not exert expansion forces on the base material. Serrated teeth on the tip of this anchor facilitate cutting and reduce installation torque (see Figure 330).

Figure 329
Titen-HD Anchor
Source: http://www.simpsonanchors.com

Figure 330
Titen-HD Anchor Head
Source: http://www.simpsonanchors.com

SET-XP is a structural epoxy-tie anchoring adhesive, a high solids formula for cracked and uncracked concrete. It is used in tension and seismic zones where there is rick that a crack may intersect with where an anchor is placed. Its test criteria are outlined:

- Seismic and wind loading in cracked and uncracked concrete
- Static tension and shear loading in cracked and uncracked concrete
- Horizontal and overhead installations
- Long-term creep at elevated-temperatures
- Static loading at elevated-temperatures
- Damp holes
- Freeze-thaw conditions
- Critical and minimum edge distance and spacing[xxxxx]

Its specifications are also given (see Figure 331).

Characteristic		Symbol	Units	Nominal Anchor Diameter				
				½ / #4	⅝ / #5	¾ / #6	⅞ / #7	1 / #8
Installation Information								
Drill Bit Diameter		d	in.	⅝	¾	⅞	1	1⅛
Maximum Tightening Torque		T_{inst}	ft-lb	40	90	130	200	300
Permitted Embedment Depth (h_{ef}) Range[2]	Minimum	-	in.	2¾	3⅛	3½	3¾	4
	Maximum	-	in.	10	12½	15	17 1/2	20
Minimum Concrete Thickness		h_{min}	in.	2.25 x h_{ef}				
Critical Edge Distance		c_{ac}	in.	3 x h_{ef}				
Minimum Edge Distance		c_{min}	in.	1¾				
Minimum Anchor Spacing		s_{min}	in.	3				

Figure 331
SET-XP Specifications
Source: http://www.simpsonanchors.com

This website is very relevant to this report in that it details specific hardware utilised in retrofit projects and anchors designed for adverse seismic conditions.

http://www.soundseismic.com/live/page/project-impact
Project Home Retrofit Information Series, Booklet 1.

[xxxxx] http://www.simpsonanchors.com

This booklet is an overview of the standard home earthquake retrofit plan, summarising the information contained in each of the series booklets. It begins by introducing the Pacific Northwest earthquake hazards as well as building codes and practices and how they are applied, earthquake building practice for home construction and the benefits of home retrofit. The resource then outlines the home earthquake retrofit plan. The goals of this are to encourage the understanding and use of a standardised strengthening method, promoting home earthquake projects and expediting building permits for projects qualifying t use the standard retrofit plan. However, an engineer or architect will need to be contacted in certain situations, such as when other building deficiencies need to be repaired before the provisions in the retrofit plan can be carried out.
The resource then briefly outlines the reasons to retrofit buildings in our community. This is very relevant to the retrofit of New Zealand dwellings as it promotes retrofit and community awareness of earthquake damage which too needs to be fostered in New Zealand.

http://www.soundseismic.com/live/page/project-impact
Project Home Retrofit Information Series, Booklet 2.

This booklet is a home assessment checklist. This is divided into two parts; part one details the qualification requirements which determines the suitability of the home for the retrofit plan which has been set out, and part two which identifies the retrofit needs for the home. The questions are clear and concise and enable the homeowner to be directly involved in the retrofit process. The home assessment checklist has been included in this report in Appendix 7.

http://www.soundseismic.com/live/page/project-impact
Project Home Retrofit Information Series, Booklet 3.

This booklet, the third in the series, was published by Project Impact Seattle: Building Disaster Resistant Community. It is titled the Guide to Completing an Earthquake Retrofit Plan for Wood Frame Residential Buildings. It forms the third and most comprehensive part of the home earthquake retrofit information series.
It begins with a detailed introduction, covering if your home qualifies for this type of retrofit, if a building plan is needed and how to obtain a building permit. How to complete the retrofit plan is then explored. This is divided into five tasks: drawing the foundation outline, selecting the method of replacing sections of damaged concrete foundation wall if necessary, selecting the method of anchoring the sill plate to the foundation wall, selecting the method of strengthening the pony wall, and selecting the method of connecting the floor framing system to the pony wall on to the foundation wall. Figures are given to explain a retrofitted wall (see Figure 332) and the retrofitted subfloor area (see Figure 333). Each task is then described in depth.

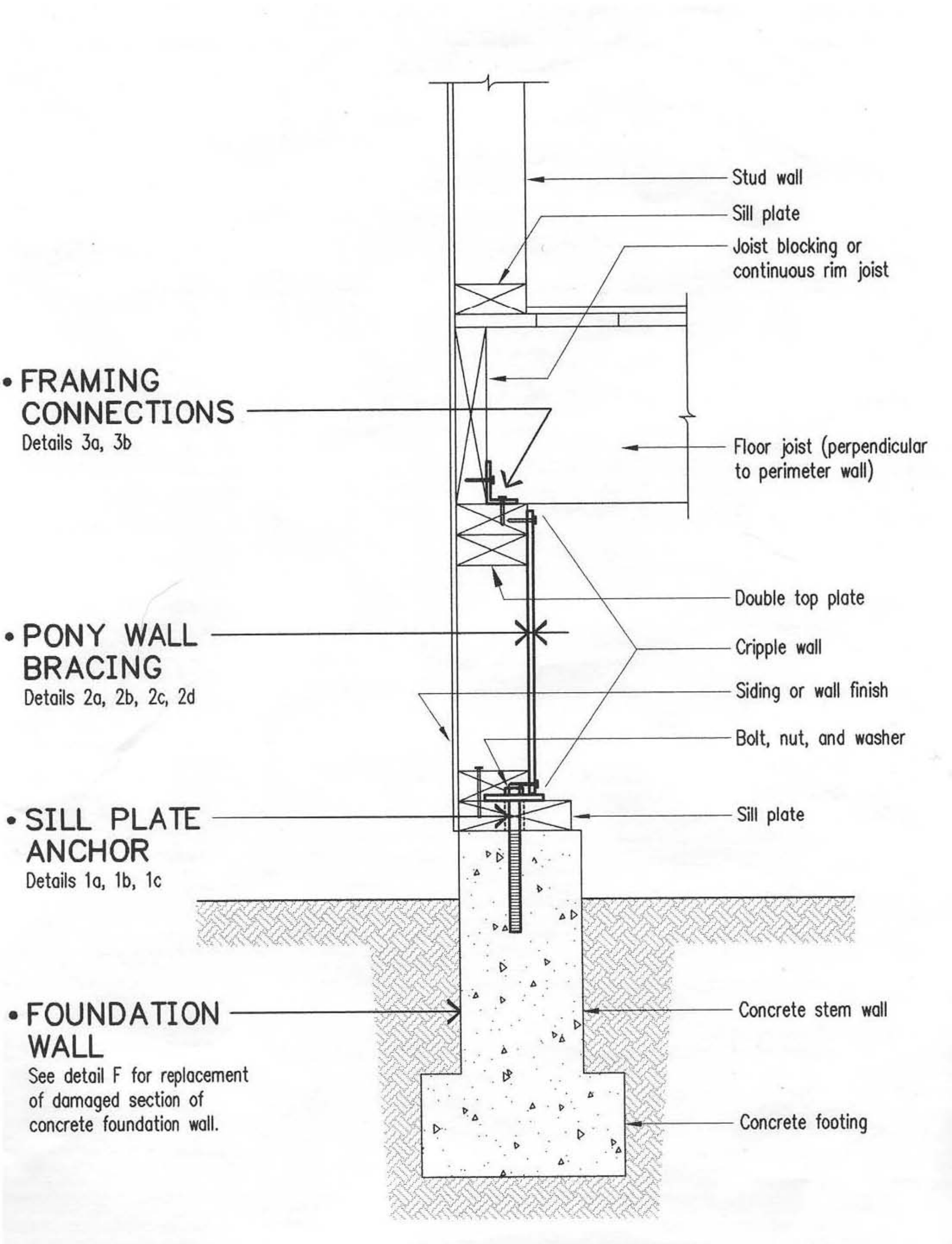


Figure 332
Side View of a Typical Wall Section
Source: http://www.soundseismic.com/live/page/project-impact

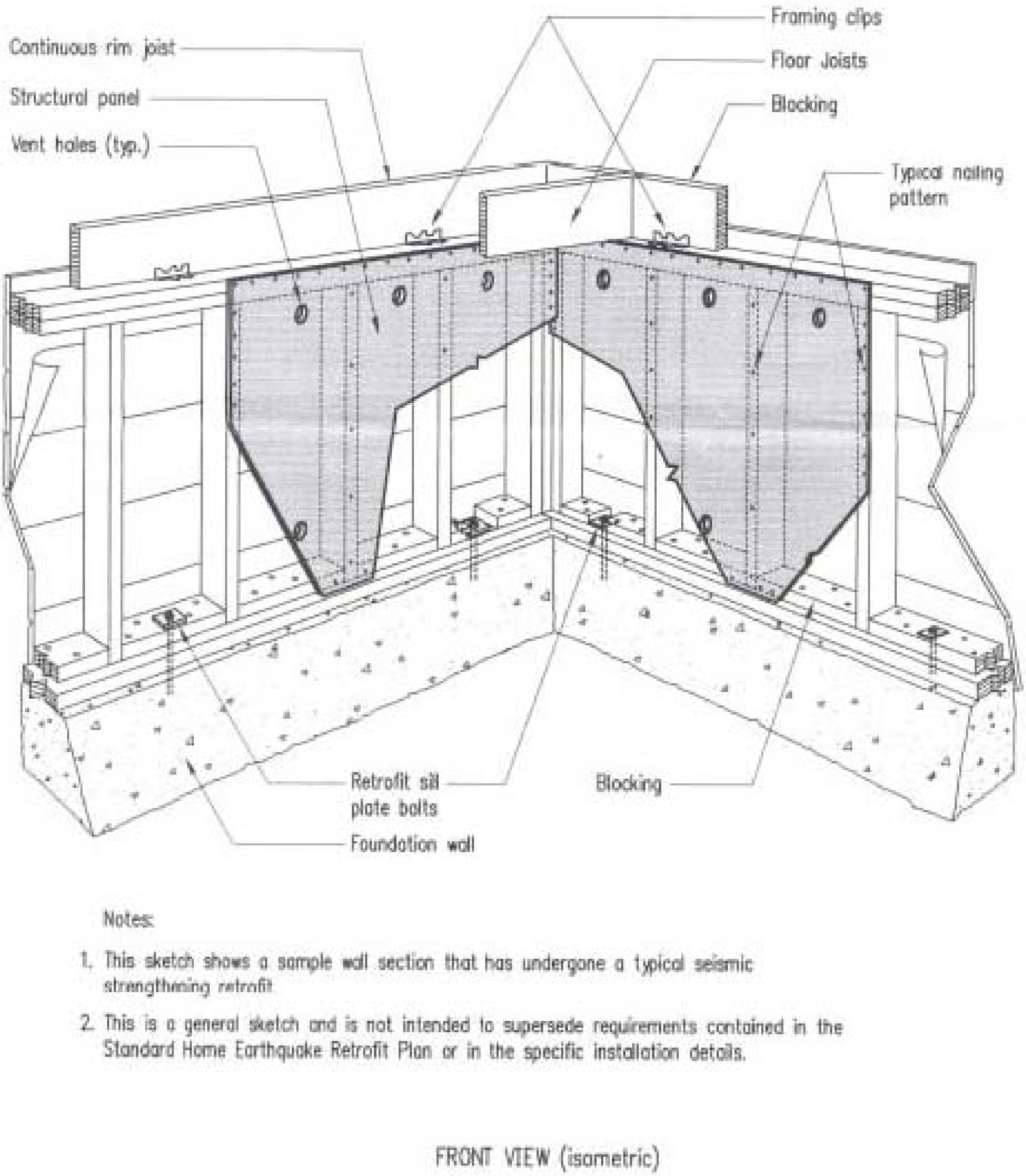
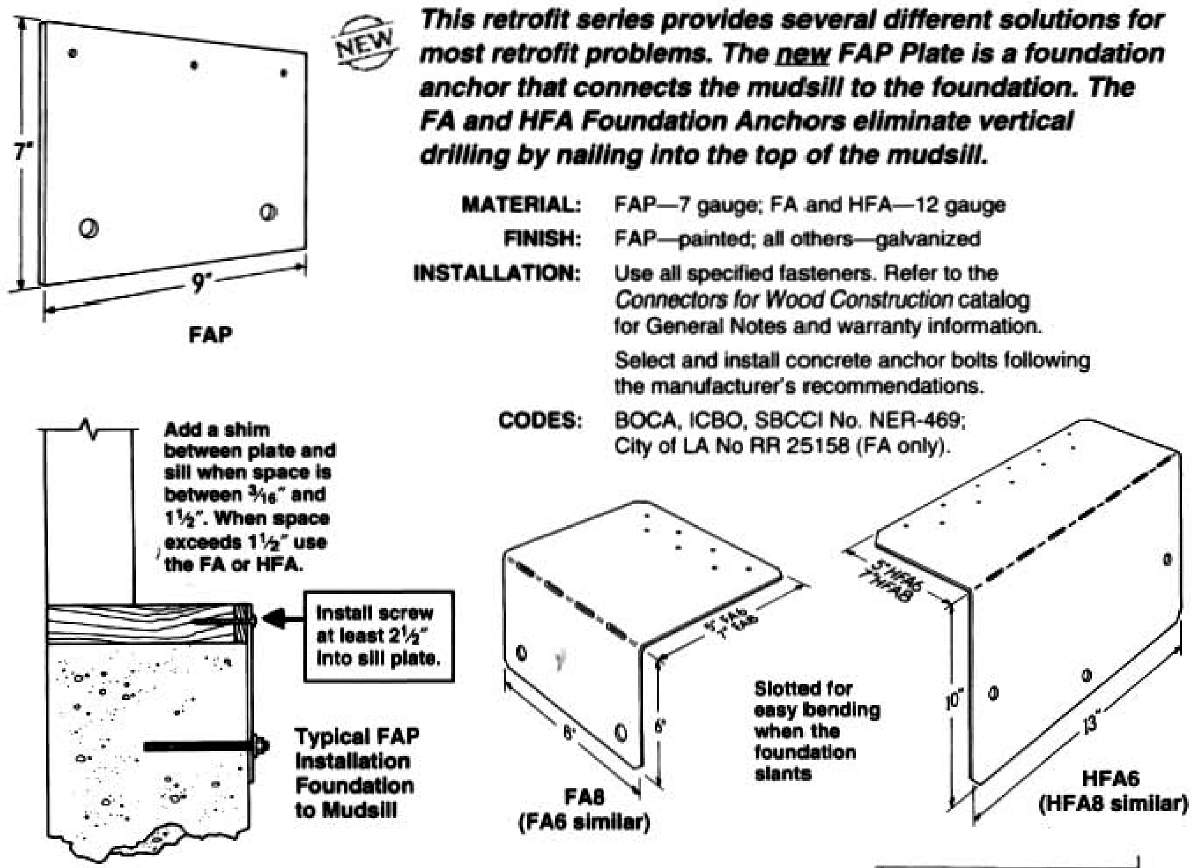


Figure 333
Isometric View of a Typical Retrofit, showing foundation anchor bolts, pony wall bracing, and framing clips, from inside the basement or crawlspace
Source: http://www.soundseismic.com/live/page/project-impact

Task one, drawing the foundation line, involves the measuring of each segment of exterior foundation wall, marking on openings and the direction of floor and joist beams.
Task two involves the selection of the concrete foundation replacement method and reviewing installation information.

Task three involves identifying how to anchor the sill plate to the foundation. Several types of manufactured side plates are designed for specific foundation and sill plate conditions (see Figure 334). The anchors used must also be selected, commonly an expansion bolt or a chemical anchor.



MODEL NO.	FASTENERS			O.C. SPACING TO REPLACE ANCHOR BOLT 6' O.C.		ALLOWABLE LOADS	
	ANCHOR BOLT		MUDSILL			F_1	F_2
	QTY	DIA		½" DIA	⅝" DIA		
FAP	2	½	3-¼ x (2½"+shim thickness) length lag bolt	6'	5'	950	365
FA6, FA8	2	½	7-10d x 1½	3'	2'	400	515
HFA6, HFA8	3	½	11-10d x 1½	6'	6'	1350	365

1. Allowable loads have been increased 33% for wind or earthquake loading with no further increase allowed. Reduce where other load durations govern.
2. For redwood mudsills, reduce F_1 on HFA to 1215 lbs and 840 lbs on FAP.
3. Use the RFB#4x6 with the Epoxy-Tie for the anchorage system.
4. Spacing is based on F_1 loading.

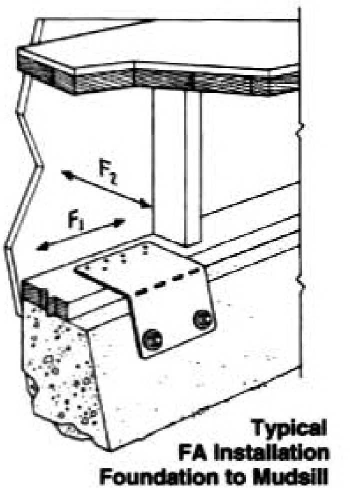


Figure 334
Sample Manufacturer's Sheet for Anchor Side Plates
Source: http://www.soundseismic.com/live/page/project-impact

Task four involves strengthening of the pony walls (also known as cripple walls or jack-studs). Structural panels will be installed on the exterior face of the pony wall studs. These panels must be reviewed in terms of their wood species, durability, intended us, span rating, and the number of plys, or wood layers, in the plywood. The amount and location of panels for installation must also be decided.

Task five involves the method selection to connect the floor framing to the pony wall. The repair condition will often have lack of blocking above the pony wall and no framing elements on which to install framing clips (see Figure 335). Framing modifications are thus necessary to provide the required nailing surfaces for the framing clips and to ensure connections that complete the load path between the pony wall and the floor system. Two methods can be used, method one when the joist is perpendicular to the foundation wall, method two when the joist is parallel to the foundation wall (see Figure 336, 337 and 338).

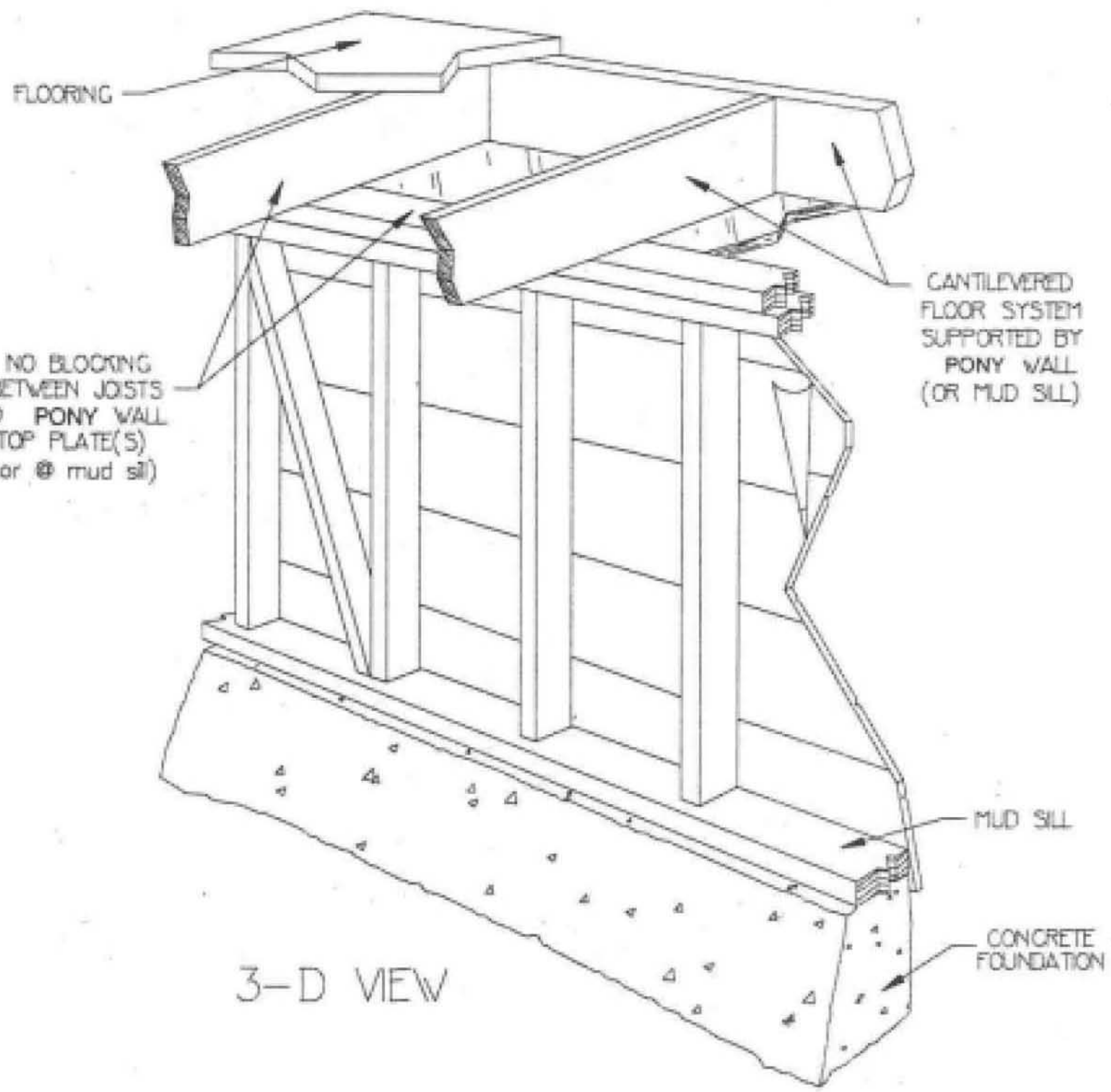


Figure 335
Repair Condition of Pony Wall
Source: http://www.soundseismic.com/live/page/project-impact

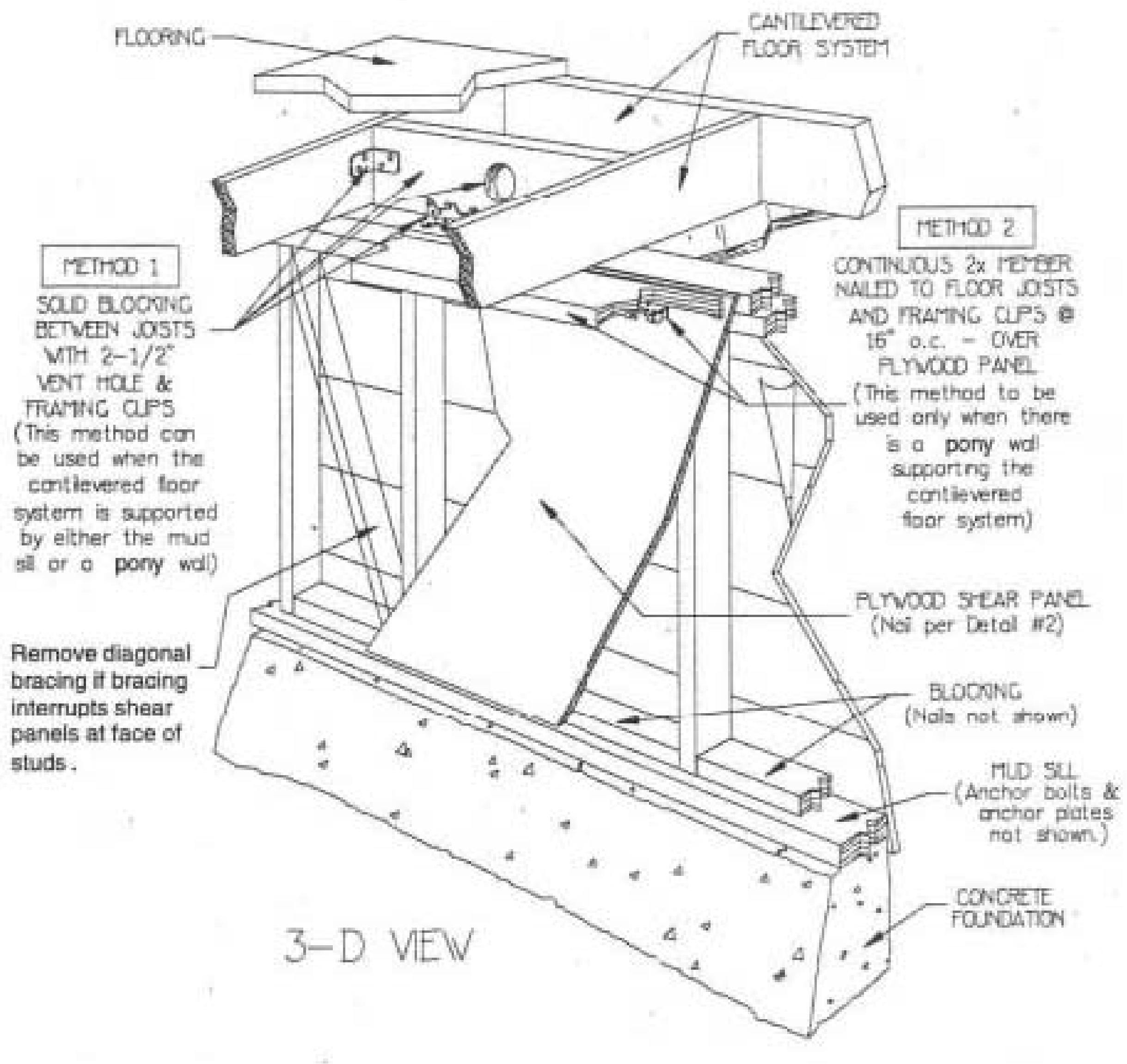


Figure 336
Detail Showing Two Methods for Installing Framing Clips for a Cantilevered Floor with No Blocking above the Pony Wall
Source: http://www.soundseismic.com/live/page/project-impact

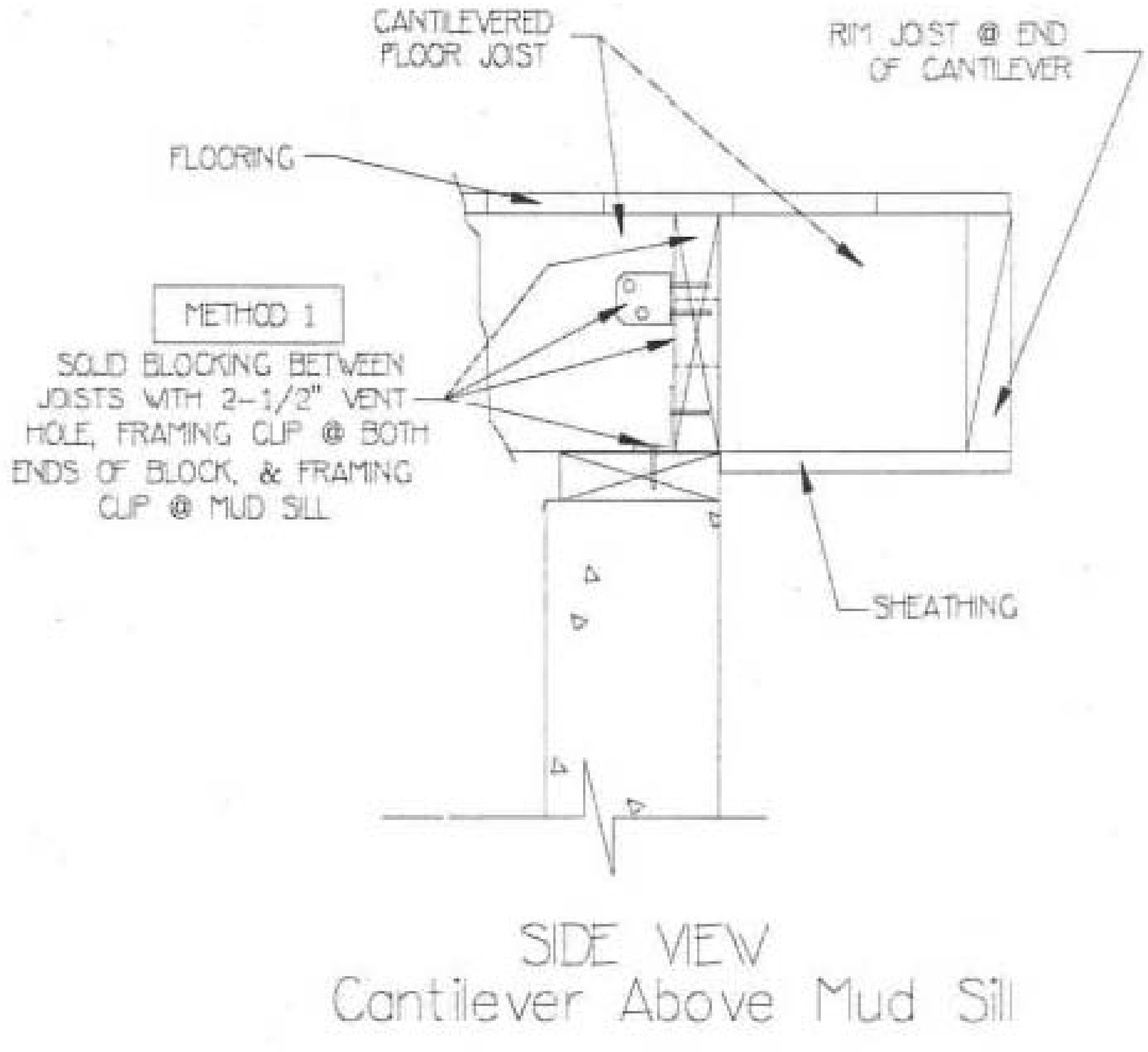


Figure 337
Repair Detail for a Cantilevered Floor with No Blocking above the Sill Plate
Source: http://www.soundseismic.com/live/page/project-impact

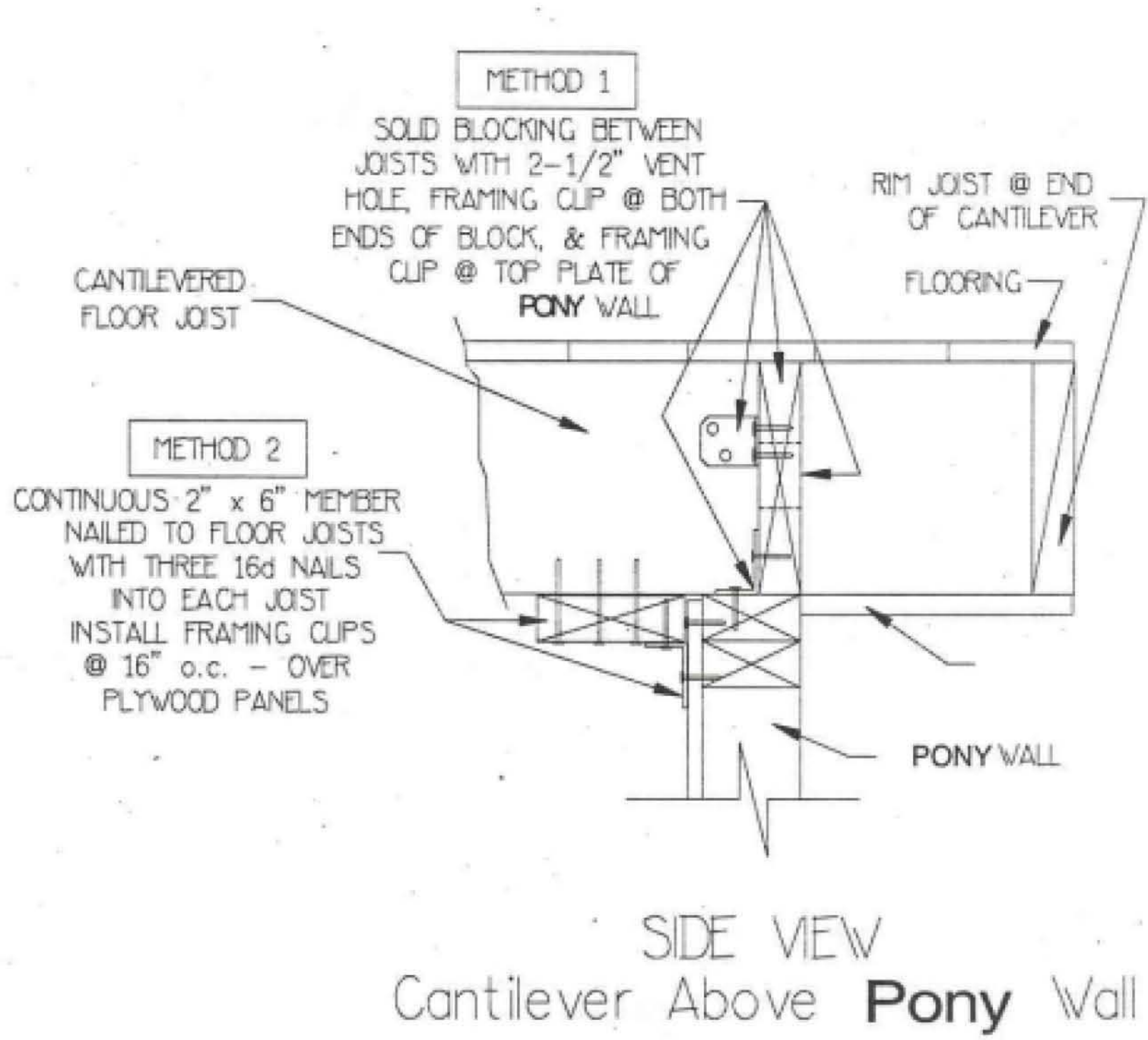


Figure 338
Repair Detail for a Cantilevered Floor with No Blocking above the Pony Wall
Source: http://www.soundseismic.com/live/page/project-impact

When there is no pony wall top plate (see Figure 339) and the rim joist rests on top of the pony wall studs, framing modifications are necessary to provide the required nailing surfaces for the ply shear panels. Framing clips and blocking can be used (see Figures 340 and 341).

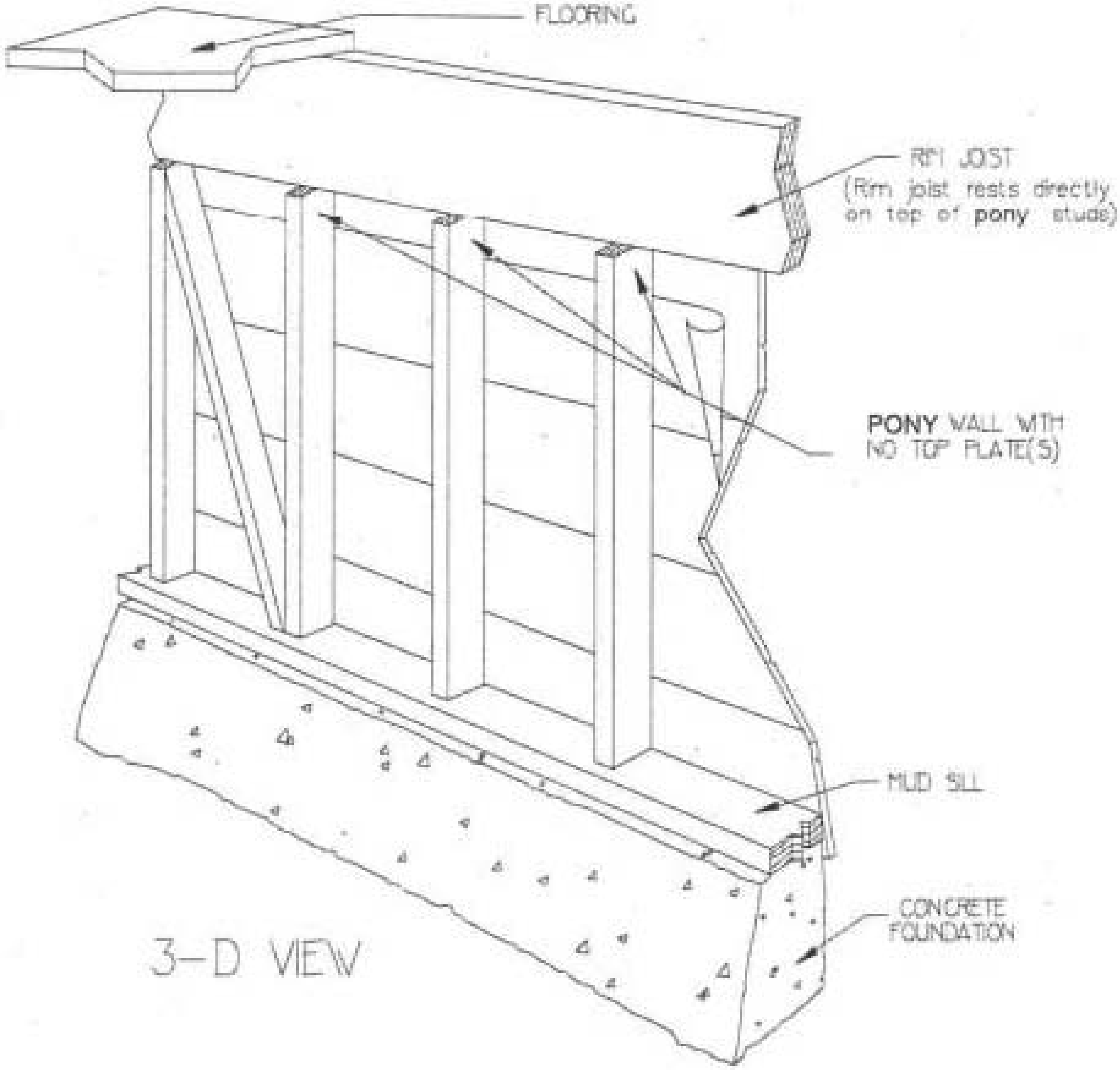


Figure 339
Repair Condition No Pony Wall Top Plates
Source: http://www.soundseismic.com/live/page/project-impact

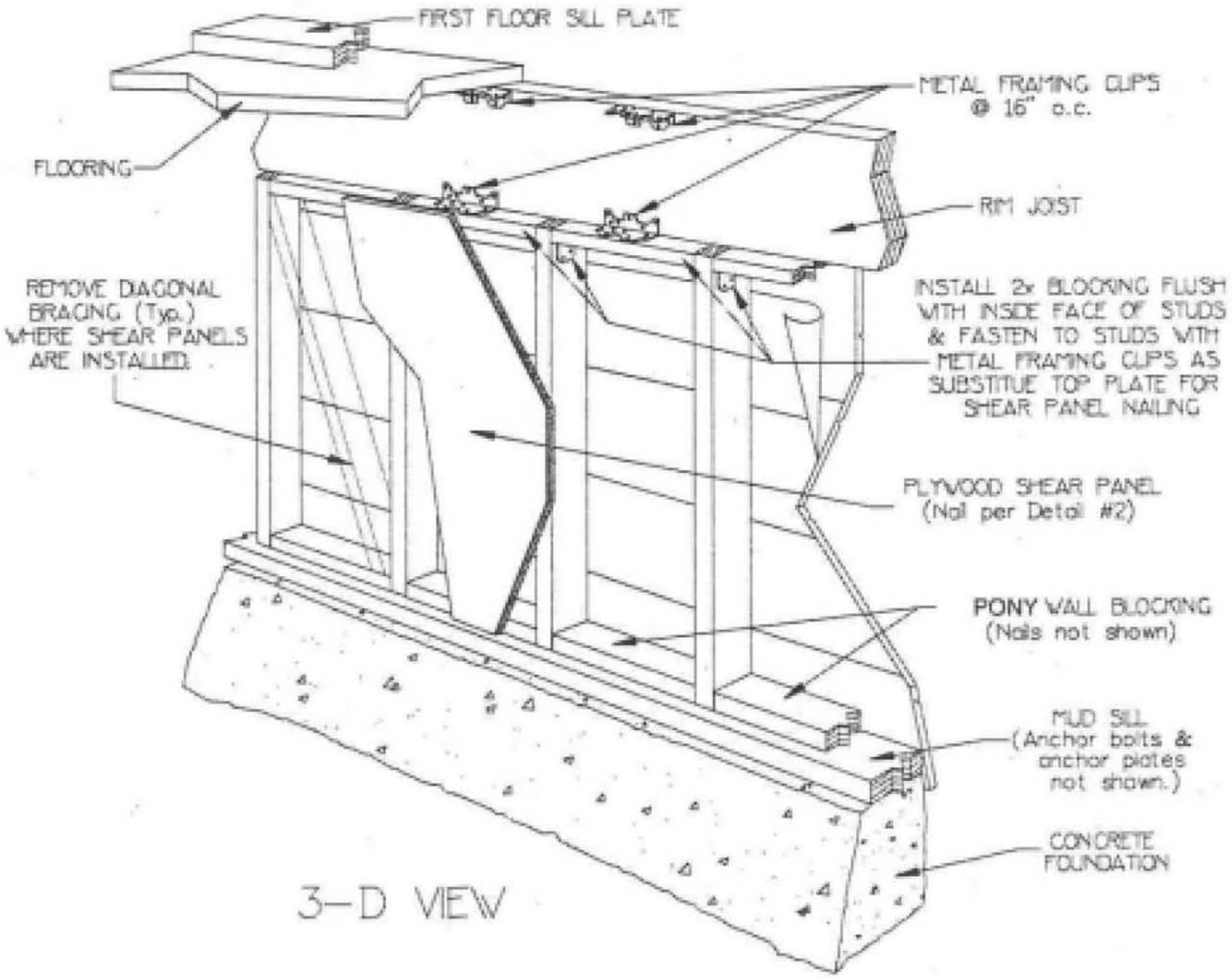


Figure 340
Repair Detail for Pony Wall with No Top Plate
Source: http://www.soundseismic.com/live/page/project-impact

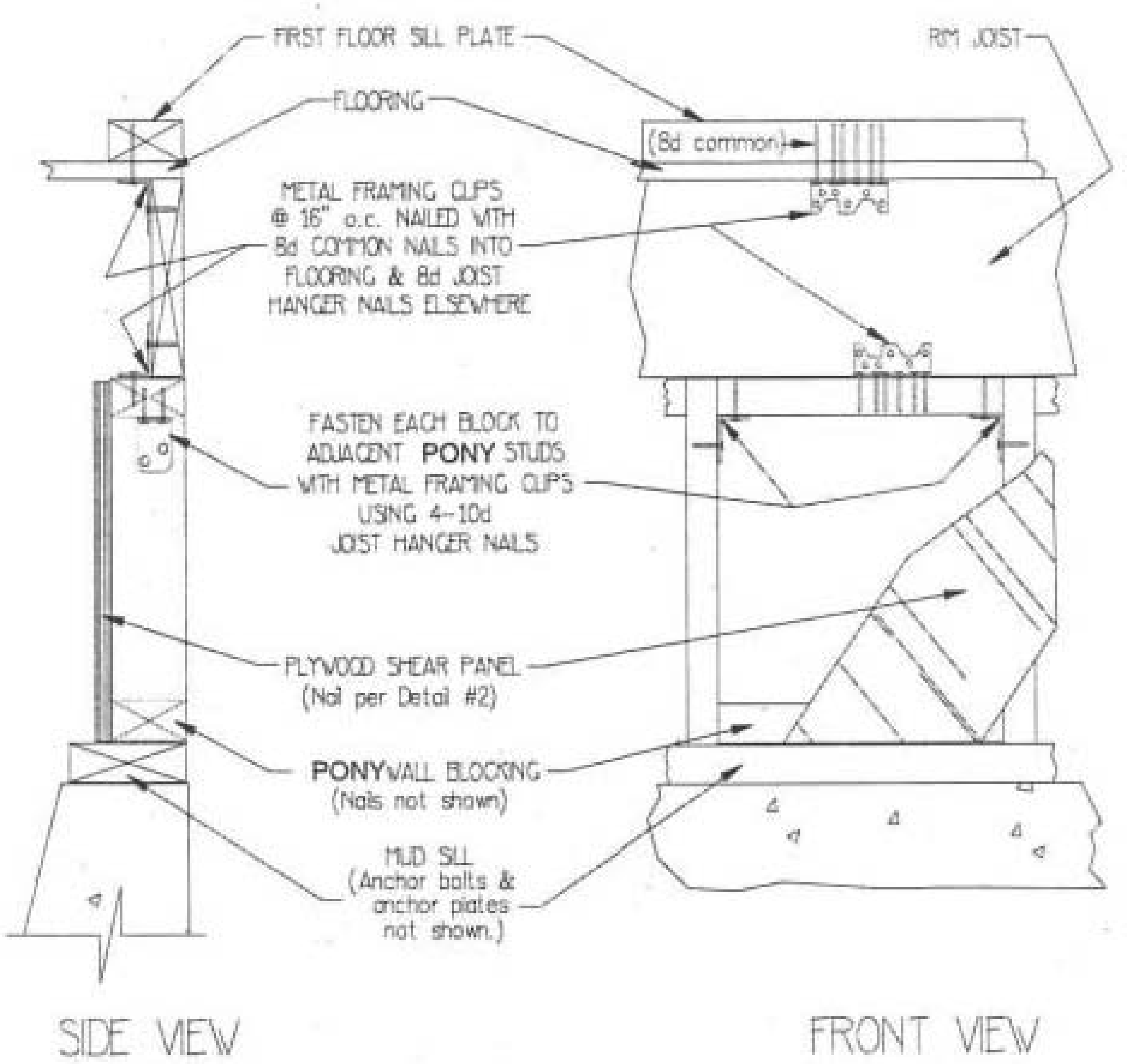


Figure 341
Repair Detail for Pony Wall with No Top Plate
Source: http://www.soundseismic.com/live/page/project-impact

If the parallel floor joists are too close to the sill plate or pony wall to allow access for the installation of framing clips, framing modifications are necessary to allow access to the rim joist and the mud sill to permit the installation of the required framing clips and/or mud sill anchors. This resource then details the process to obtain a building permit and complete the required inspections. This resource is very relevant in providing clear details which may be beneficial for the retrofit of jack-stud foundations which occur in New Zealand dwellings.

http://www.soundseismic.com/live/page/retrofitting-basics

This website details the process of retrofitting as carried out in the California area. A house is analysed before the retrofit (see Figure 342) and after (see Figure 343).

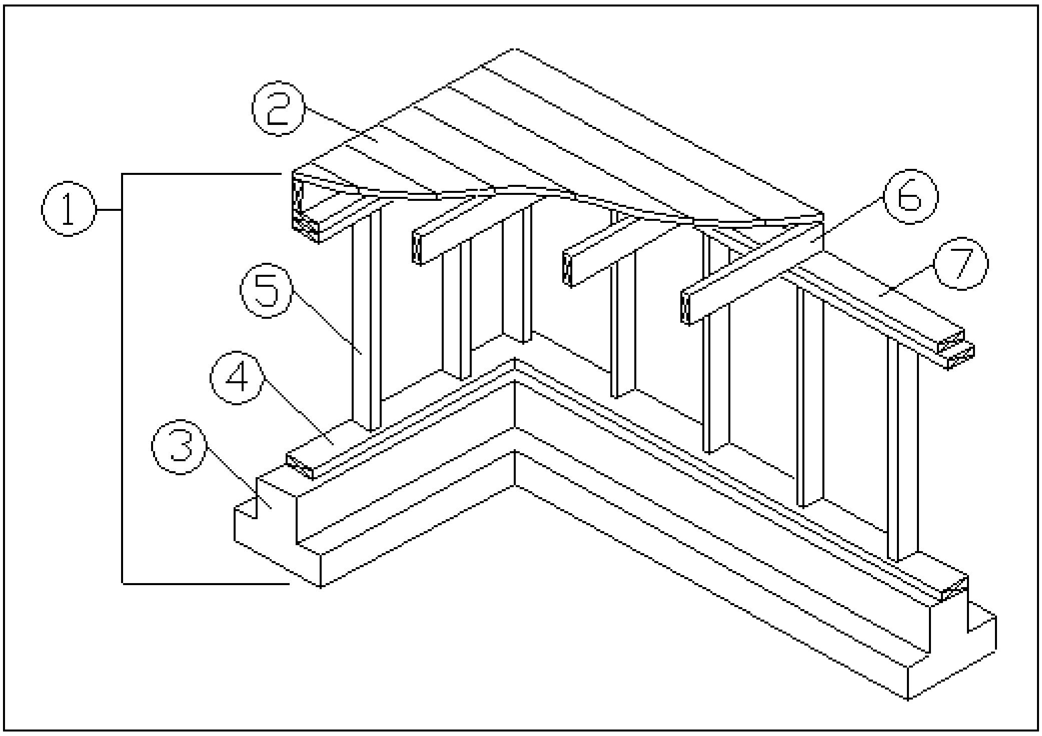


Figure 342

1-Crawlspace - The space between the ground under the house and the floor. How much space there is to crawl in depends on how tall the foundation and cripple wall are.

2-Floor

3-Foundation - This is the cement structure that supports the house and gives it stability. The primary goal of seismic retrofit is to attach the house to the foundation so it doesn't 'fall off' the foundation during an earthquake.

4-Mudsill - This is a timber piece that rests on top of the concrete foundation. When an earthquake hits, the mud sill can be jolted off the foundation causing the house to collapse.

5-Cripple wall - Not all houses have a cripple wall. Un-reinforced cripple walls are the weakest part of a house because they readily collapse in an earthquake.

6-Floor framing - also called floor joists. In an earthquake, the floor framing can be jerked off the cripple wall, causing the floor of the house to collapse.

7-Top plate - This is made of 2x4 lumber lying on top of the cripple wall. The floor framing is nailed into this.

Source: http://www.soundseismic.com/live/page/retrofitting-basics

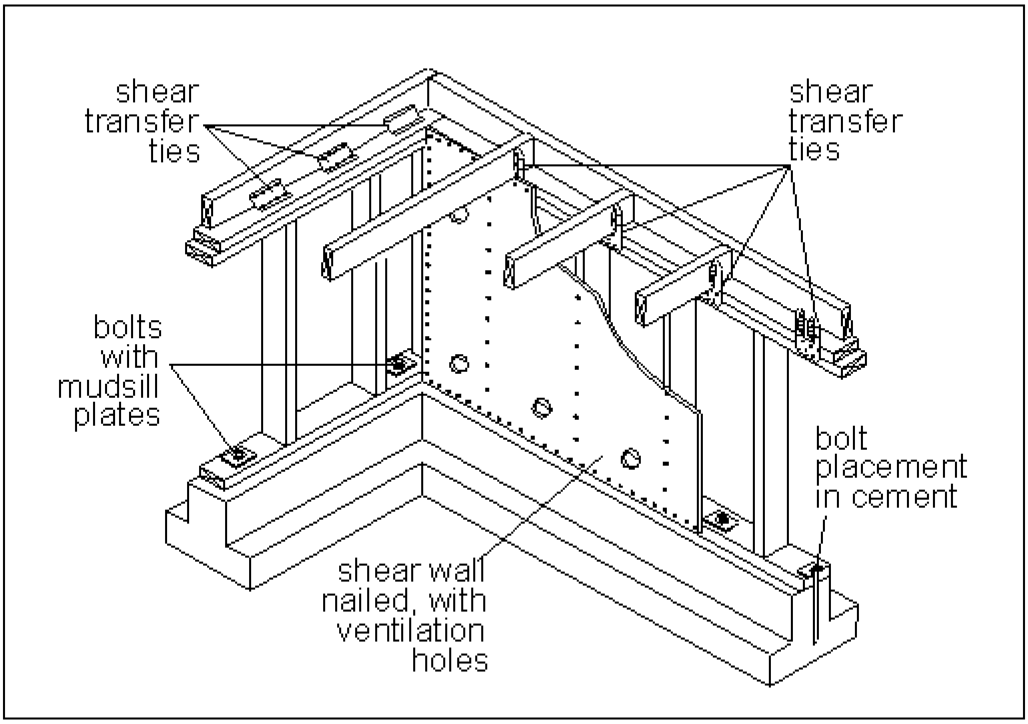


Figure 343
After Retrofit
Source: http://www.soundseismic.com/live/page/retrofitting-basics

Bolts attach the mudsill to the foundation. These are long-threaded steel rods passing through the mudsill and deep into the foundation. Mudsill plates are square washers, specially designed to increase the strength of a bolt by around 60%. Plywood nailed to the cripple wall forms a shear wall and shear transfer ties attach the floor framing to the cripple wall.

A sill plate is first secured by using a high powered roto-hammer to create a pilot hole for the sill plate screws (see Figure 344). The sill plate bolt is then driven into the hole (see Figure 345). This is followed by setting the bolts (see Figure 346) and drilling the final hole (see Figure 347). The final bolt is then driven in (see Figure 348).

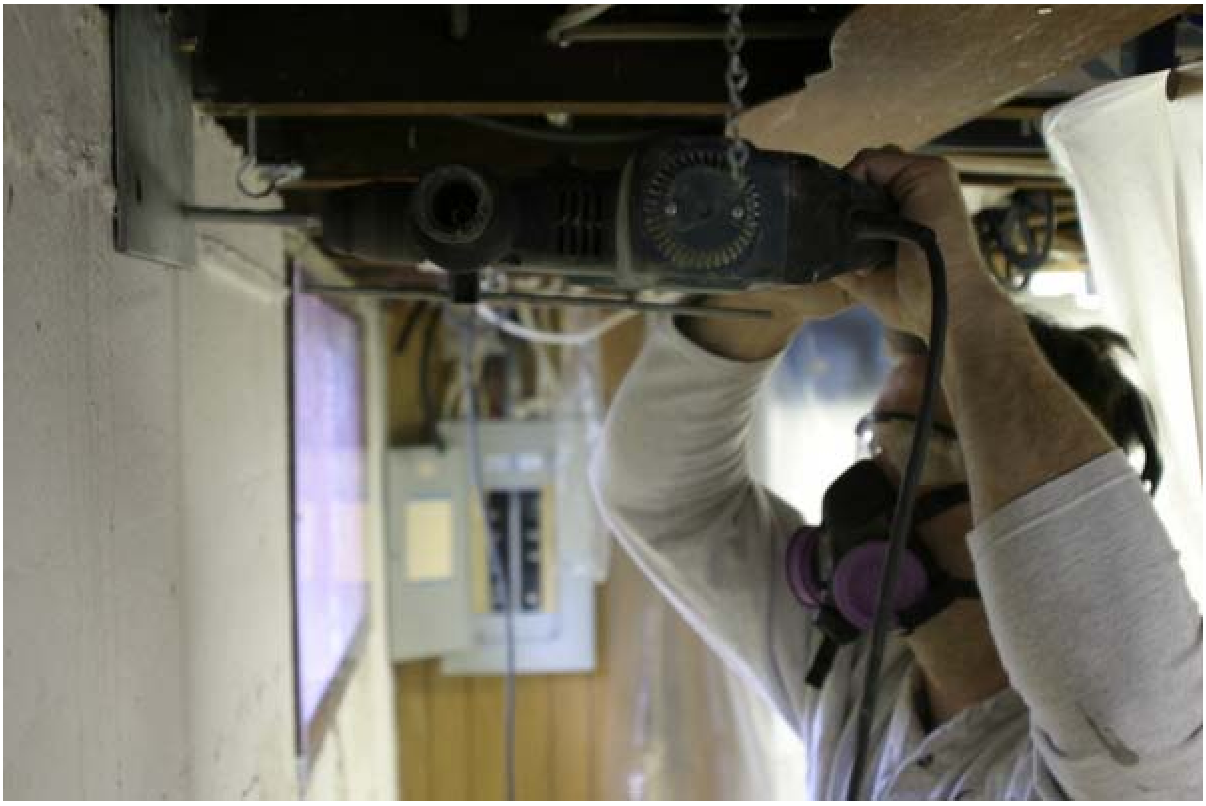


Figure 344
Source: http://www.soundseismic.com/live/page/retrofitting-basics

Figure 345
Source: http://www.soundseismic.com/live/page/retrofitting-basics

Figure 346
Source: http://www.soundseismic.com/live/page/retrofitting-basics

Figure 347
Source: http://www.soundseismic.com/live/page/retrofitting-basics

Figure 348
Source: http://www.soundseismic.com/live/page/retrofitting-basics

This website is relevant to illustrate seismic retrofit concepts from overseas as well as providing a step by step process of a particular fixing. This relates closely to the retrofit of New Zealand dwelling foundations and subfloors to resist earthquakes.

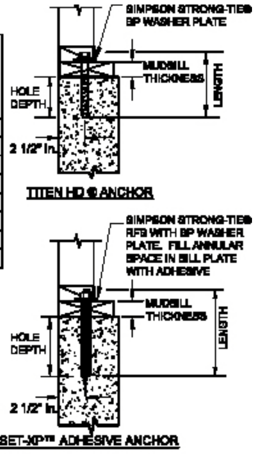
http://www.strongtie.com

This website has been developed by Simpson Strong-Tie Company, Inc., a corporation which has developed and produces strong-ties for seismic retrofit. The company also produces resources explaining their use. Details are provided on this website, including a retrofit sheet with details based on the 2006 International Building Code (see Appendix 8). These details are for cripple walls, which may be useful in jack stud foundations (see Figures 349, 350, 351, 352, 353, 354, 355 and 356).

POST INSTALLED ANCHOR SOLUTIONS

MUDSILL THICKNESS (IN)	HOLE DEPTH IN FOUNDATION (IN)	SIMPSON STRONG-TIE ● TITEN HD ● MG DIA. X LENGTH (IN)	SIMPSON STRONG-TIE ● SET-XP™ ADHESIVE	SIMPSON STRONG-TIE ● WASHER PLATE HDG
1 1/2	5	1/2" x 6"	RFB#4X8HDG	BP 1/2"
		5/8" x 6"	RFB#5X8HDG	BP 5/8"
2	4 1/2	1/2" x 6"	RFB#4X8HDG	BP 1/2"
		5/8" x 6"	RFB#5X8HDG	BP 5/8"
2 1/2	4 1/2	1/2" x 6 1/2"	RFB#4X10HDG	BP 1/2"
		5/8" x 6 1/2"	RFB#5X10HDG	BP 5/8"
3	5	1/2" x 8"	RFB#4X10HDG	BP 1/2"
		5/8" x 8"	RFB#5X10HDG	BP 5/8"

NOTE: SEE DETAIL 2 FOR MINIMUM ANCHOR DIAMETER AND SPACING.
NOTCH BLOCKING AT ANCHOR BOLT.



ANCHOR AND WASHER PLATE SELECTION FOR DIFFERENT SILL THICKNESS | **3.**

Figure 349
Anchor and Washer Plate Selection
Source: http://www.strongtie.com

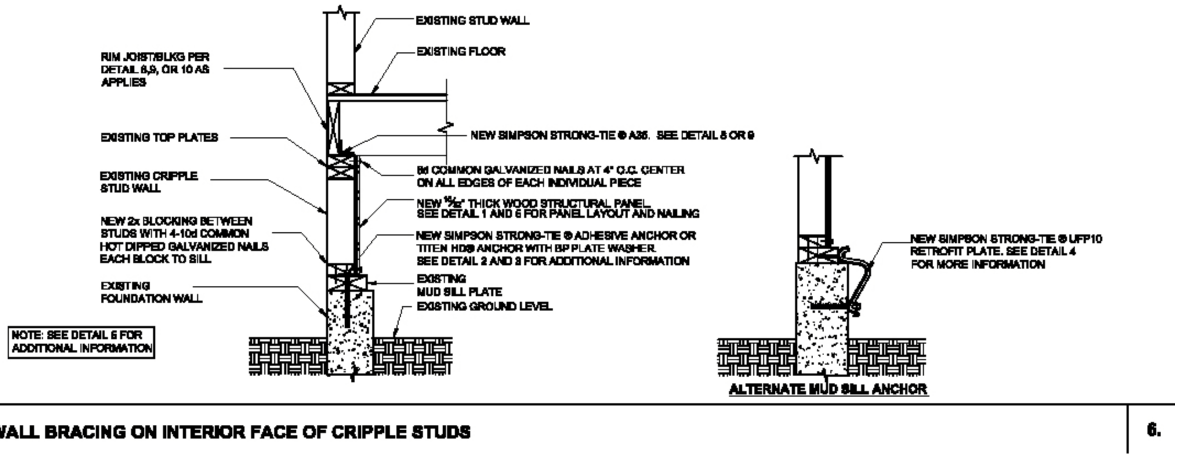


Figure 350
Cripple Wall Bracing
Source: http://www.strongtie.com

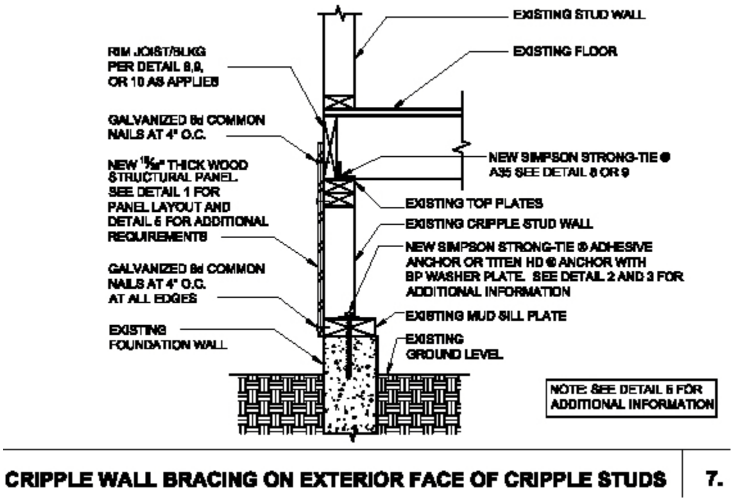


Figure 351
Cripple Wall Bracing
Source: http://www.strongtie.com

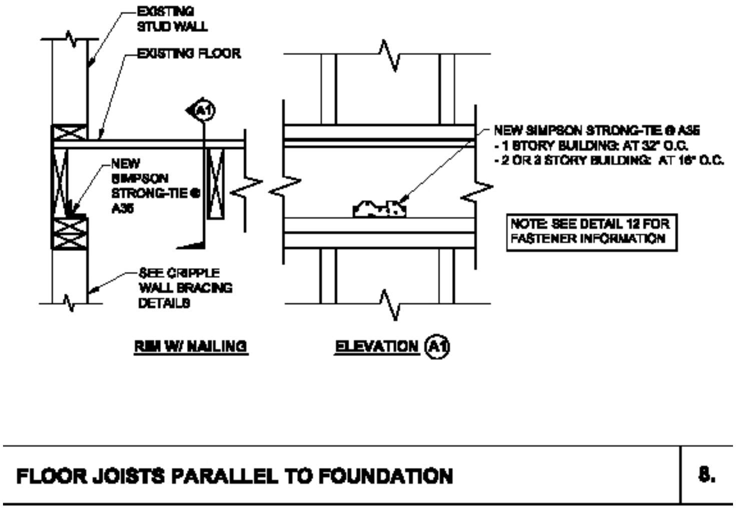


Figure 352
Floor Joist Connection
Source: http://www.strongtie.com

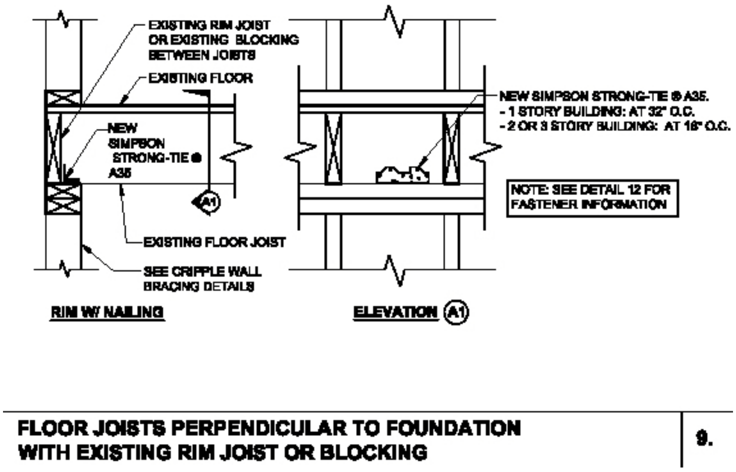


Figure 353
Floor Joist Connection
Source: http://www.strongtie.com

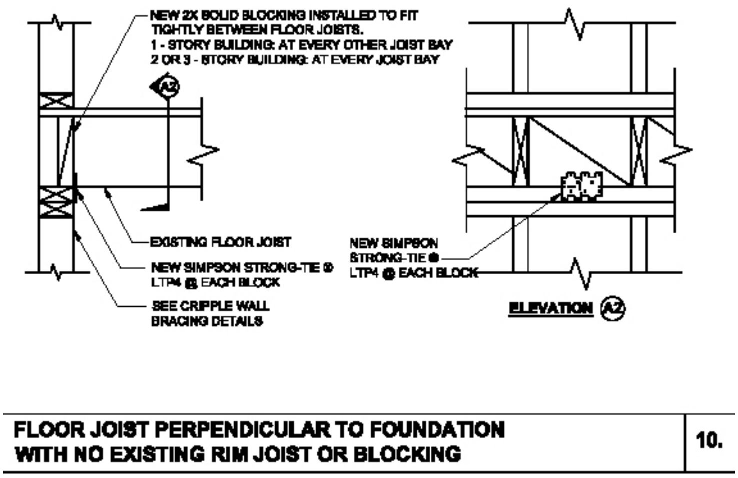


Figure 354
Floor Joist Connection
Source: http://www.strongtie.com

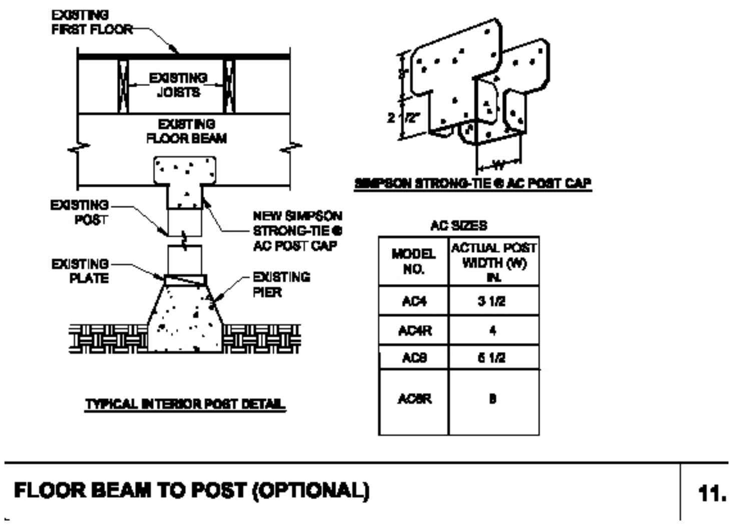
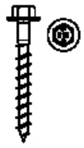


Figure 355
Floor Joist Connection
Source: http://www.strongtie.com

SIMPSON STRONG-TIE ® SD SCREWS

CONNECTOR MODEL NO.	NAILS	SCREW OPTIONS MODEL NO.	
		SIMPSON STRONG-TIE ® SD#9 X 1 1/2"	SIMPSON STRONG-TIE ® SD#10 X 1 1/2"
A35	8d X 1 1/2"	•	
LTP4	8d X 1 1/2"	•	
AC	16d COMMON		•



NOTE:

- DESIGNED TO REPLACE NAILS IN CERTAIN PRODUCTS, THE SD9 AND SD10 HAVE BEEN DESIGNED AND TESTED FOR USE IN THE MOST POPULAR SIMPSON STRONG-TIE ® PRODUCTS.
- CONTACT SIMPSON STRONG-TIE ® FOR ADDITIONAL PRODUCTS APPROVED FOR USE WITH SD STRONG-DRIVE SCREWS.

ALTERNATE SCREW FASTENER TO REPLACE NAILS 12.

Figure 356
Screw Fastener Connection
Source: http://www.strongtie.com

Their website features a catalogue of their products, information on corrosion and a seismic retrofit guide resource (see Appendix 9). This explains reasons to retrofit, the basics of earthquake movement and how this impacts the home, and how to conduct a survey of your own home. Diagrams illustrating pre- and post-retrofit are given (see Figure 357), as well as how to anchor a mudsill to a foundation (see Figures 358 and 359), how to install blocking (see Figure 360), how to install sheathing (see Figure 361) and how to install shear angles (see Figure 362). Instructions are given alongside each detail (see Appendix 9).

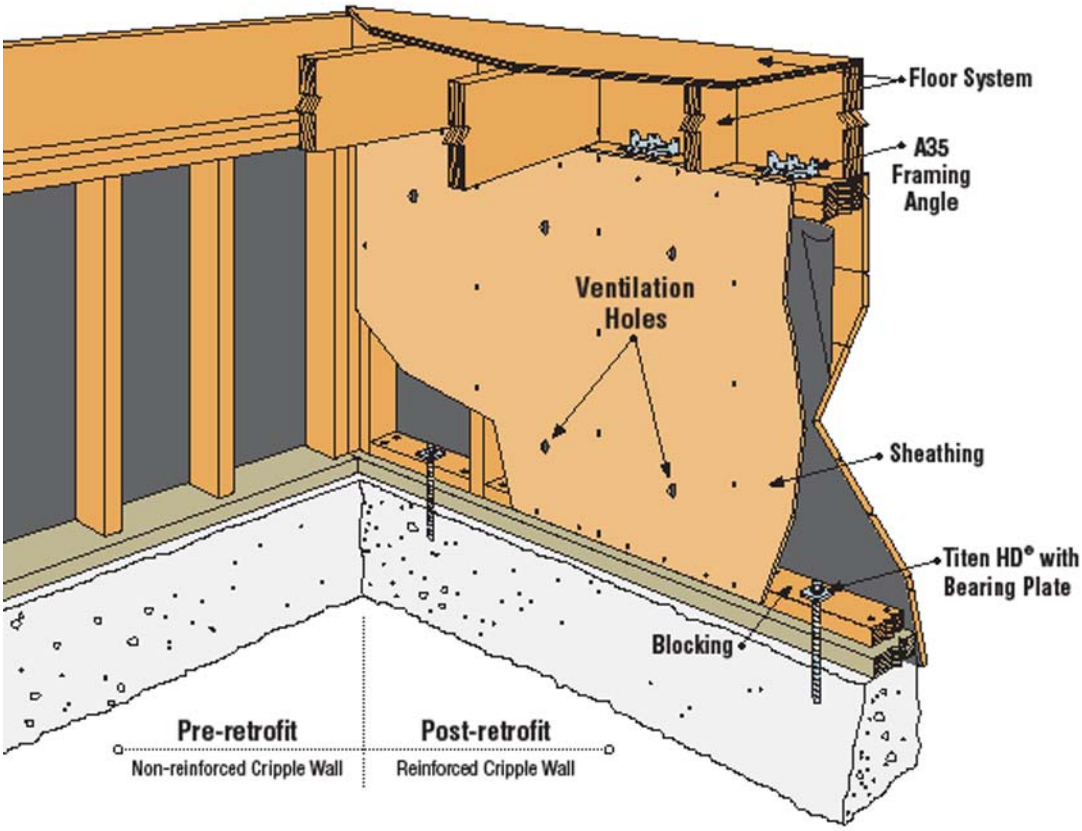
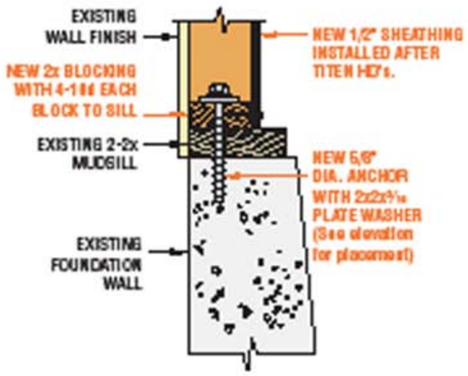


Figure 357
Pre- and Post-Retrofit
Source: Seismic Retrofit Guide, http://www.strongtie.com, p 7.

Installation Details

- Anchor diameter: ⅝ in.
- Drilled hole depth: See table for embedment depth
- Anchor length: This will be determined by the thickness of the mudsill. See table.
- Anchor spacing: 6 ft. on center (o.c.) for one and two-story homes
- Washer: A 2 in. by 2 in. by $^{3}/_{16}$ in. thick steel plate washer (sold separately) is required in seismic areas (Simpson Bearing Plate model BP⅝-2 fulfills this requirement.)



Anchoring Mudsill to Foundation with Titen HD

Table 1 | Determining Titen HD Length

Mudsill Thickness[1] (in)	Hole Depth in Foundation[2] (in)	Titen HD Model No. (Size)
1½	5	THD62600H (⅝" x 6")
2	4½	THD62600H (⅝" x 6")
2½	4½	THD62612H (⅝" x 6½")
3	5½	THD62800H (⅝" x 8")
3½	5	THD62800H (⅝" x 8")

Note: 1. Mudsill may be single thickness or double if blocking is required for sheathing purposes.
2. Minimum required embedment for the Titen HD in this application is 3¼". Hole depths above have been adjusted for available anchor sizes.

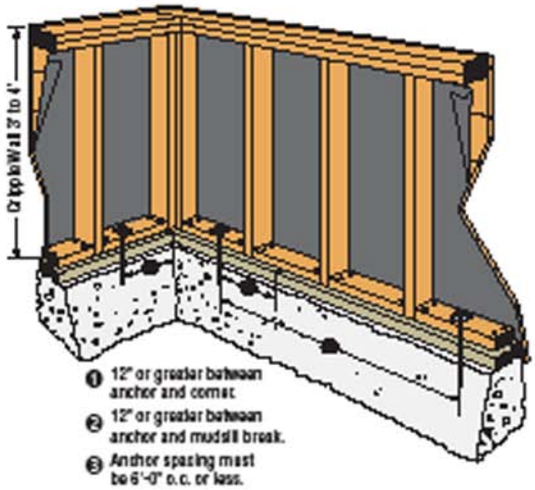


Figure 358
Installing the Titen HD to Anchor the Mudsill
Source: Seismic Retrofit Guide, http://www.strongtie.com, p 10.

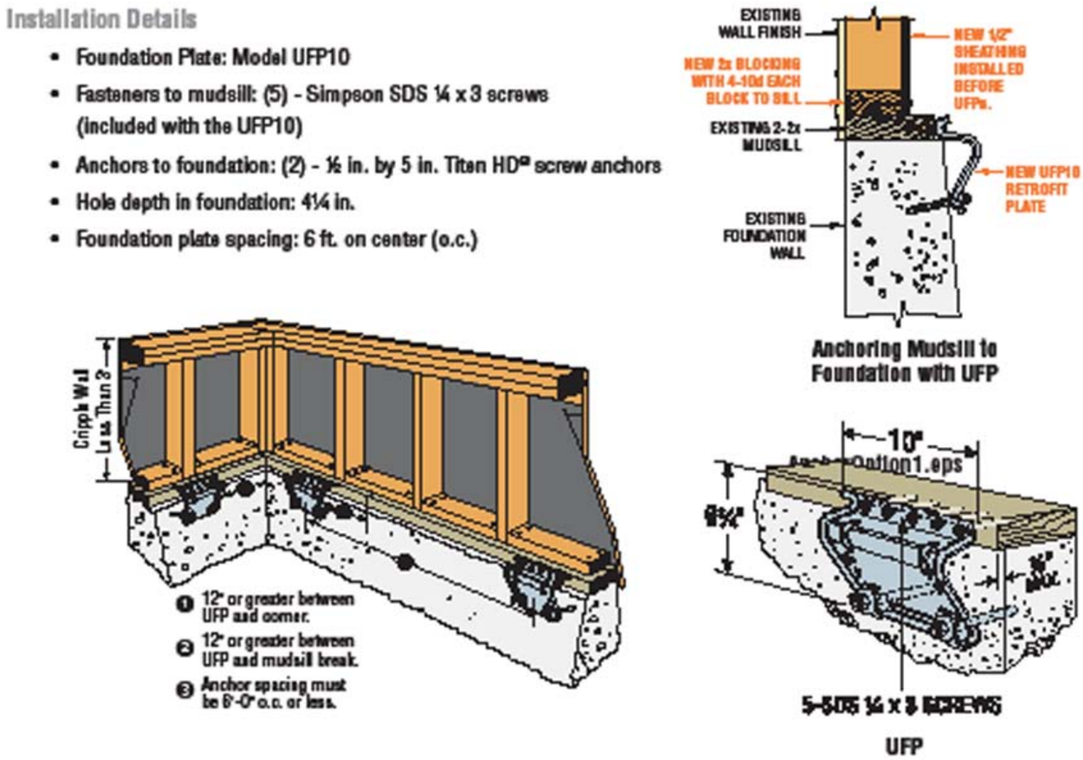


Figure 359
Installing the Universal Foundation Plate
Source: Seismic Retrofit Guide, http://www.strongtie.com, p 11.

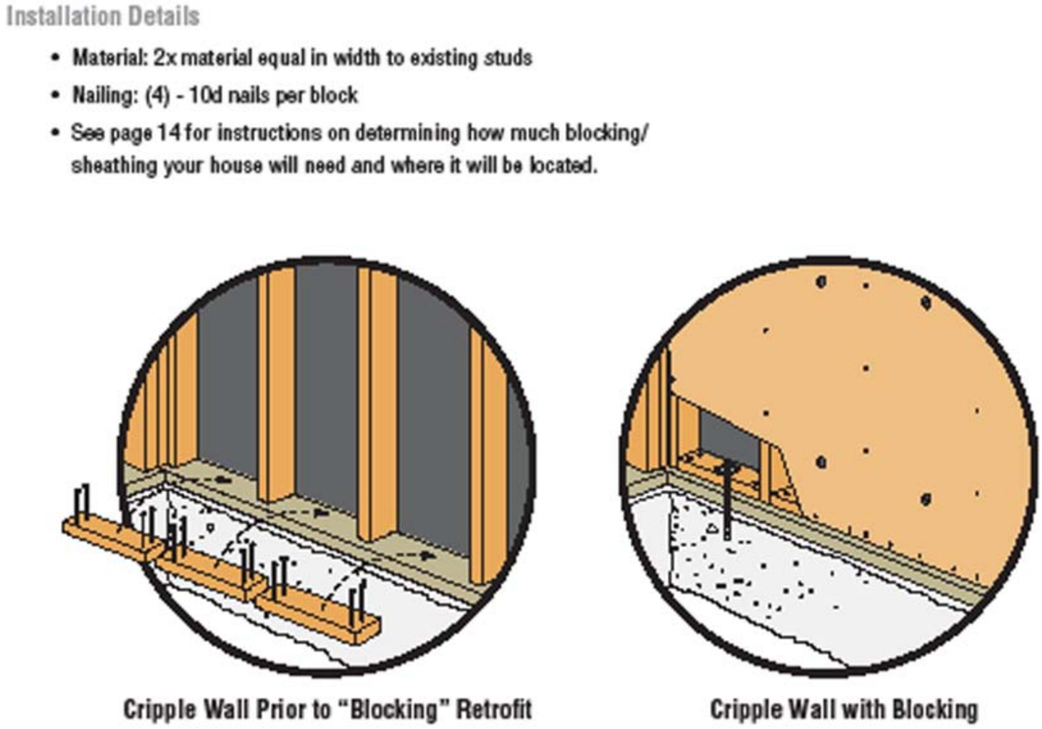


Figure 360
Installing Blocking
Source: Seismic Retrofit Guide, http://www.strongtie.com, p 12.

Installation Details

- Material: ½ in. thick plywood or OSB
- Nailing: 8d common nails
  - Every 4 inches on center (o.c.) into the studs at the edges of the panel
  - Every 12 inches o.c. into the studs
- See page 14 for instructions on determining how much blocking/ sheathing your house will need and where it will be located.

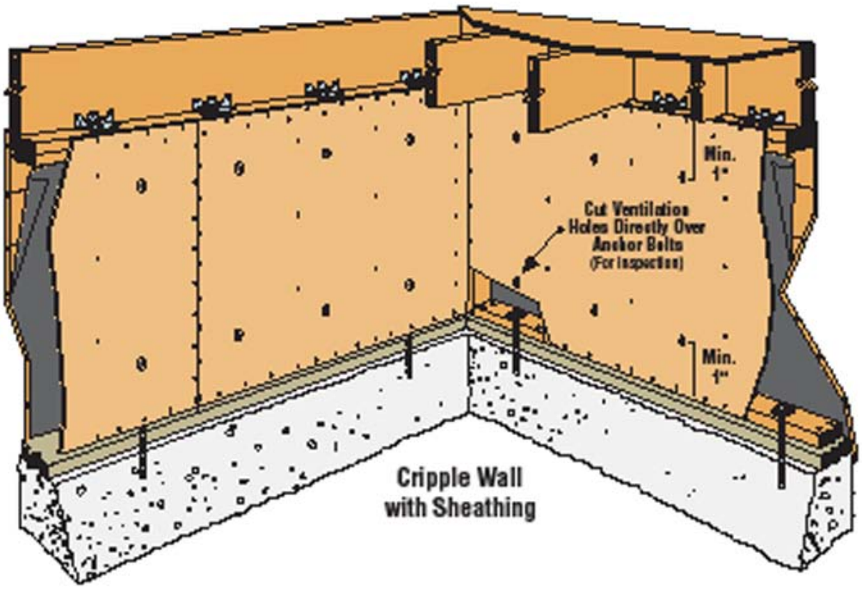
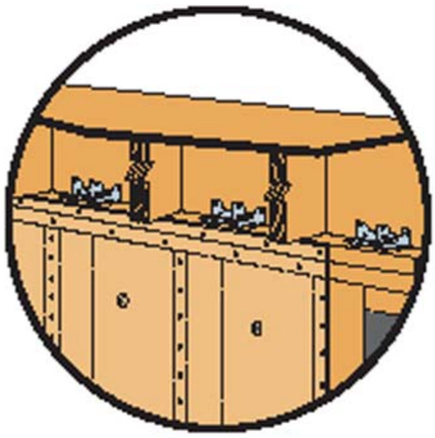


Figure 361
Installing Sheathing
Source: Seismic Retrofit Guide, http://www.strongtie.com, p 13.

Installation Details

- Framing angle: Model A35
- Fasteners: (12) - 8d x 1 ½ in. nails
- Spacing: 16 inches o.c.



A35 Framing Angles Connect the Cripple Wall to the Floor System

Figure 362
Installing A35 Shear Angles
Source: Seismic Retrofit Guide, http://www.strongtie.com, p 15.

This resource is very relevant to this report as it describes a step by step retrofit approach for cripple wall foundations which could be applied to New Zealand dwellings. Also, unusually, the website emphasises a do-it-yourself approach, providing instructions for how to install their products to the home owner.

Author's Note:

There is a conference to be carried out organised by the Applied Technology Council and the Structural Engineering Institute of ASCE on December 8-11 2009 which may be relevant to this report. The conference is focused on improving the seismic performance of existing buildings and other structures. The conference proceedings were not available before the completion of this report, however the reference has been provided (see Appendix 10).

Appendices

Note: Electronic references have been omitted to reduce the length of this document, but urls are provided below

Appendix 1
Source: http://www.ci.san-leandro.ca.us

Appendix 2
Source: http://www.helifix.com.au/masonry_repair_details.html

Appendix 3
Source: http://www.bayarearetrofit.com

Appendix 4
Source: http://www.bayarearetrofit.com

Appendix 5
Source: http://www.icomos.org/iiwc/seismic

Appendix 6
Source: http://www.pwri.go.jp/eng

Appendix 7
Source: http://www.soundseismic.com/live/page/project-impact

Appendix 8
Source: http://www.strongtie.com

Appendix 9
Source: http://www.strongtie.com

Appendix 10
Evaluation of the Performance of Existing Buildings and Other Structures: Reference

Appendix 10

Victoria University of Wellington Document Register 3.61
School of Architecture

LOGO OR ACRONYM CBPR Centre for Building Performance Research	RECIPIENT'S REF/CODE AUTHOR'S REF/CODE
TITLE AND SUBTITLE OF REPORT *Retrofitting House Foundations to Resist Earthquakes* A Literature Review	SPONSOR'S REF/CODE REPORT DATE
AUTHOR(S) Stephanie Liddicoat and Geoff Thomas Centre for Building Performance Research.	ISSN/ISBN NUMBER Not Assigned
AUTHOR ORGANISATION (name and address) Centre for Building Performance Research, Victoria University of Wellington, P.O. Box 600, Wellington, New Zealand	DISTRIBUTION - report issued to: Sponsor, research organisations and interested parties on request
SPONSORING ORGANISATION (name and address) N/A	-report available from: CBPR Website, http://www.victoria.ac.nz/cbpr/publications/index.aspx
KEYWORDS House Foundations, Earthquakes, Retro-fit	ENQUIRES/COMMENT TO: Dr Geoff Thomas School of Architecture Victoria University of Wellington PO Box 600 139 Vivian St Wellington 6001 NEW ZEALAND Ph. 64 4 463 6247 Fax. 64 4 463 6204 Email. geoff.thomas@vuw.ac.nz Director, Centre for Building Performance Research. PAGES / PRICE on application
ABSTRACT Figures, Tables & References provided	
SUPPLEMENTARY NOTES	

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Title: Evaluation of the performance of seismically retrofitted buildings / by Applied Technology Council.
Publisher: Redwood City, Calif. : Applied Technology Councill, 1992.
Description: xiii, 75 p. : ill. ; 28 cm.
Subject: Earthquakes and buildings.
Building failures --Prevention.
Earthquake resistant design.
Structural stability --Evaluation.
Series: ATC (Applied Technology Council (U.S.)) : 31.

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ATC & SEI Conference on Improving the Seismic Performance of Existing Buildings and Other Structures

Organized by the Applied Technology Council and the Structural Engineering Institue of ASCE

December 9-11, 2009

Welcome

Improving the Seismic Performance of Existing Buildings and Other Structures

A state-of-the-art conference organized by the Applied Technology Council and the Structural Engineering Institute of ASCE, December 9-11, 2009

Buildings are the backbone of the world's infrastructure - they house our families and businesses, provide emergency shelter, provide places for education, enable our industries, and bring about an improved standard of living for people throughout the world. Without this backbone, civilization doesn't exist. Each year buildings and other structures are designed and built with a continually improving understanding of their performance during earthquakes, yet the vast majority of structures were built with substantially less understanding of seismic actions than we currently possess.

The challenges to improving the seismic performance of existing buildings and other structures are as broad and varied as the individual structures themselves. How should they be evaluated and strengthened? What plans exist? What materials were used? What assumptions were made? Were they built as designed, and if not, what modifications were made but possibly (probably) not documented?

This inaugural conference, organized by the Applied Technology Council and the Structural Engineering Institute of the American Society of Civil Engineers (ASCE), is dedicated solely to improving the seismic performance of existing buildings and other structures. The program is being planned to provide a forum for the presentation and exchange of new information on the seismic evaluation and seismic rehabilitation of existing buildings, including case studies, new discoveries, innovative use of new technologies and materials, implementation issues, needed improvements to existing standards and methods, and socio-economic issues. The goal is to provide an invaluable opportunity to advance your understanding of the tools, techniques and innovations available to assist you in meeting the challenges of seismic evaluation and rehabilitation. For those new to the profession, the conference will also provide an opportunity to get up to speed on core issues.

Whether you're a practicing engineer, an architect, involved with research or teaching, make plans now to attend and participate in this premiere event. With 42 states having some degree of earthquake risk and 18 of those having areas of high or very high seismicity, meeting the needs of our clients by solving the challenges posed by existing structures is paramount to protecting the life, safety and welfare of the general public.

We look forward to seeing everyone in San Francisco.

Barry Goodno, Steering Committee Chair

Christopher Rojahn, ATC Executive Director

James A. Rossberg, SEI Director

For additional questions please email us at: **atc@atcouncil.org (mailto:atc@atcouncil.org)**

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