NZS 4299:1998

Incorporating Amendment No. 1

STANDARDS NEW ZEALAND
PAEREWA AOTEAROA

New Zealand Standard

Earth buildings not requiring specific design

NZS 4299:1998

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COMMITTEE REPRESENTATION

This Standard was prepared by the New Zealand-only sub-committee, BD/83/2, of the Joint Australia/New Zealand Technical Committee BD/83 Earth Buildings for the Standards Council established under the Standards Act 1988. Sub-committee BD/6/2 consisted of representatives of the following organizations:

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AMENDMENTS

No.	*Date of issue*	*Description*	*Entered by, and date*
1	December 1999	Provides enhanced provisions for weather-proofing and aligns with the foundation provisions of NZS 3604:1999. Some over-designed details are amended to be more economic.	Incorporated in this reprint

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RELATED DOCUMENTS

Reference is made in this Standard to the following:

NEW ZEALAND STANDARDS

AS/NZS 2904:1995	Damp-proof courses and flashings
NZS 3101:- – – -	Concrete Structures Standard
Part 1:1995	The design of concrete structures
NZS 3109:1997	Concrete construction
NZS 3402:1989	Steel bars for the reinforcement of concrete
NZS 3421:1975	Specification for hard drawn mild steel wire for concrete reinforcement
NZS 3602:1995	Timber and wood-based products for use in building
NZS 3603:1993	Timber Structures Standard
NZS 3604:1999	Timber frame building construction
NZS 3631:1988	New Zealand timber grading rules
NZS 4203:1992	General structural design and design loadings for buildings
NZS 4210:1989	Code of practice for masonry construction: materials and workmanship
NZS 4218:1996	Energy efficiency – Housing and small building envelope
NZS 4222:1992	Material for the thermal insulation of buildings
NZS 4229:1986	Code of practice for concrete masonry buildings not requiring specific design
NZS 4297:1998	Engineering design of earth buildings
NZS 4298:1998	Materials and workmanship for earth buildings
NZS 4431:1989	Code of practice for earth fill for residential development

The users of this Standard should ensure that their copies of the above-mentioned New Zealand Standards or of overseas Standards approved as suitable for use in New Zealand are the latest revisions or include the latest amendments. Such amendments are listed in the annual Standards New Zealand *Catalogue* which is supplemented by lists contained in the monthly magazine *Standards* issued free of charge to committee and subscribing members of Standards New Zealand.

FOREWORD

General

This standard and the associated NZS 4297 *Engineering design of earth buildings* and NZS 4298 *Materials and workmanship for earth buildings* extend the range of construction and structural design standards to cater for the growing interest in earth building. Earth is becoming increasingly important in the context of the modern desire for construction materials which are less highly processed and have low toxicity. These standards formalize the current state-of-the-art knowledge of design and construction using a building method that has provided satisfactory shelter to millions of people around the world over many centuries. As earth is a heavy, low-strength material, its use in construction is expected to essentially be limited to single storey walls and ground floors.

The enthusiastic support of Yvonne Rust as a prime promoter of the need for earth building standards in New Zealand is recognized and the role of the Earth Building Association of New Zealand in supporting the development of this suite of standards is acknowledged. Many other people and organizations, too numerous to name have also made valuable contributions.

Earth wall construction includes a diverse range of techniques to build either monolithic walls or ones made from individually laid bricks. The action of the complete wall in respect of strength, deformation and damage depends very much on the standard of workmanship, and, in the case of earth brick walls, the strength and durability of the individual components and their arrangements. Frequently earth buildings are constructed from local soils available near the construction site. Because of these variables, and because of the restricted availability (compared with other materials) of rigorous laboratory test results, the performance of some elements under severe deformation is less well known or predictable than with other materials. However, earth wall construction is one of the oldest building techniques in the world and earth walls have performed adequately in many situations.

These three new standards have been prepared with the intention of seeking Building Industry Authority acceptance for referencing in the NZBC Approved Documents.

It is always a challenge in writing building standards to balance the need for versatility and flexibility with the need to keep it simple and compact. The scope of these standards therefore excludes items such as vaults and domes and walls which curve for lateral stability. The fact that something is not covered by a standard does not mean it is prohibited. What it does mean is that if one is wishing to build, say a dome, some other means of proving compliance with the requirements of the Building Code will need to be found. Such proof can rely in part but not solely on these standards.

The process of earth building usually involves the following steps, not necessarily in this order:

(1) Locate suitable building site.
(2) Select a preferred earth building technique.
(3) Consider suitability of local or nearby subsoils for various construction methods.
(4) Carry out field tests of possible construction soils to check their suitability for the preferred construction method. Modify method if necessary.
(5) Carry out pre-construction testing of earth building material. Modify mix as required.
(6) Design building and obtain building consent.
(7) Carry out site work and building construction including quality control testing.
(8) Obtain Code Compliance Certificate.

The manner in which the three standards cover these steps is set out below.

Engineering design of earth buildings
NZS 4297 is primarily aimed at structural and performance aspects of step (6). Together with NZS 4298, it gives limitations to consider for steps (1), (2), (3), (4), (5) and (7). It is intended for use by structural engineers. Other publications and expert help can provide additional advice covering all these points and issues of aesthetics.

In New Zealand, the seismic provisions of NZS 4297 will govern design in most cases. Many of the structural design principles are chosen to be similar to those for masonry (reinforced or unreinforced) and reinforced concrete, and it is assumed that users of this standard will have a knowledge of design in these materials. However, earth has unique characteristics that need to be considered apart from other forms of masonry.

Limit State Design Principles have been used in the formulation of this standard to be consistent with other material design standards. Durability is important and is covered by a design method which relates required durability test results to the annual rainfall and exposure of a building site.

Out-of-plane loading on unreinforced vertically spanning walls has been approached as ultimate limit state design based on the failure mode of walls at large deformation. Earthquake loads are analysed using the energy method proposed by the New Zealand National Society for Earthquake Engineering for strength assessment of unreinforced masonry earthquake risk buildings.

Materials and workmanship for earth buildings
NZS 4298 sets out requirements for the materials and workmanship requirements for the use of unfired earth in the form of adobe, pressed earth brick, rammed earth or poured earth. NZS 4298 gives significant help for steps (4), (5), (6) and (7) noted above. It applies to buildings which are designed in accordance with NZS 4297 *Engineering design of earth buildings* and NZS 4299 *Earth buildings not requiring specific design.*

Commentary to this standard takes heed of the long history of successful earth building worldwide. A feature of this experience is the diversity of building methods.

It is necessary to demonstrate that earthen materials used (with or without admixtures) produce results meeting at least the minimum standards of strength and durability. Tests and the required results are detailed so that assurance can be given that the earth building material will meet building code requirements.

Earth buildings not requiring specific design
NZS 4299 is the earth building equivalent of NZS 3604 but with its coverage limited to foundations, floor slabs and walls. It is intended that owner-builders or supervising owners with appropriate experienced help will be able to use NZS 4299 alongside NZS 4298 to carry out steps (1) to (8).

Again balancing the need for versatility and flexibility with the need for simplicity has produced restrictions on the scope of buildings covered. More ambitious structures can be designed by a structural engineer using NZS 4297.

The inclusion of many drawings of construction details which have been proved in the New Zealand setting is intended to help builders in earth to achieve durable, weatherproof and successful buildings.

REVIEW OF STANDARDS

Suggestions for improvement of this Standard will be welcomed. They should be sent to the Chief Executive, Standards New Zealand, Private Bag 2439, Wellington 6020.

NEW ZEALAND STANDARD

EARTH BUILDINGS NOT REQUIRING SPECIFIC DESIGN

1 SCOPE AND INTERPRETATION

1.1 Scope and objective

This Standard sets down design and construction requirements for adobe, pressed earth brick or rammed earth buildings not requiring specific design.

This Standard is intended to be approved as a means of compliance with clauses B1, B2 and E2 of the New Zealand Building Code.

The use of the Standard as a means of compliance with the New Zealand Building Code does not extend to provisions which are in non-specific or unquantified terms (such as where provisions are required to be appropriate, adequate, suitable, similar, satisfactory, acceptable, applicable or the like). Such provisions must be to the approval of the territorial authority.

C1.1

Many of the clauses and tables in this Standard contain specific or implied limitations. The use of values other than those given by the clauses and tables does not comply with this Standard. Furthermore, this Standard does not cover all of the requirements of the New Zealand Building Code. This Standard provides solutions within a specified range for a large number of building applications which, for most buildings, lead to some provisions being in excess of what would be provided for by specific design.

Particular details, materials or methods of earth building construction which are not covered by this Standard are not necessarily disallowed but are outside its scope as a means of compliance with the New Zealand Building Code. Note that poured earth although within the scope of NZS 4298, is not within the scope of this Standard. If such aspects are incorporated in a building consent application then they will be treated as an alternative solution to the New Zealand Building Code and need to be to the satisfaction of the territorial authority.

1.2 Limitations

This Standard applies to buildings within the following limitations:

(a) Buildings shall be limited to those of categories IV and V of table 2.3.1 of NZS 4203;

(b) The ground floor plan area shall not exceed:

(i) 600 m^2 for single storey buildings

(ii) 300 m^2 per floor for 2 storey buildings.

(c) The height of earth walls shall be limited as follows:

(i) Where the earthquake zone factor ≤ 0.6 (refer to figure 2.1):

Single storey earth walls with a maximum storey height of 2.75 m and maximum gable wall height of 3.6 m if reinforced and 3.3 m if unreinforced or partially reinforced.

(ii) Where earthquake zone factor > 0.6:

Single storey earth walls with a maximum wall height of 2.75 m and maximum gable wall height of 3.05 m. Unreinforced or partially reinforced earth walls are not permitted.

The storey or wall height is measured from the concrete foundation top, to the underside of the top plate or bond beam for the ground floor and between the floor level and underside of the top plate for the second storey.

Refer to figure 1.1 for illustration of the above.

(d) Building layout above an earth walled ground floor shall be limited to:

(i) A light or heavy roof as defined in 1.5, or

(ii) A timber first floor and a timber walled part storey in the roof space not exceeding 50 % of the ground floor, and a light roof, or

(iii) A timber first floor, timber walled second storey up to 2.75 m high and a light roof.

The timber floors of options (ii) and (iii) shall be structural diaphragms.

(e) Earth walls shall be 280 to 350 mm thick except for cinva brick walls which may have a minimum thickness of 140 mm. Exterior walls shall be a minimum of 280 mm thick to provide minimum thermal performance unless additional insulation is provided. The provision of such additional insulation is outside the scope of this Standard.

(f) The roof slope shall not be steeper than 45º;

(g) The design wind speed at the ultimate limit state for the building site, as determined in accordance with this Standard, shall not exceed 50 metres per second;

(h) The basic snow load as specified by NZS 4203 shall not exceed 1.0 kPa;

(j) The annual rainfall shall not exceed 2000 mm per year;

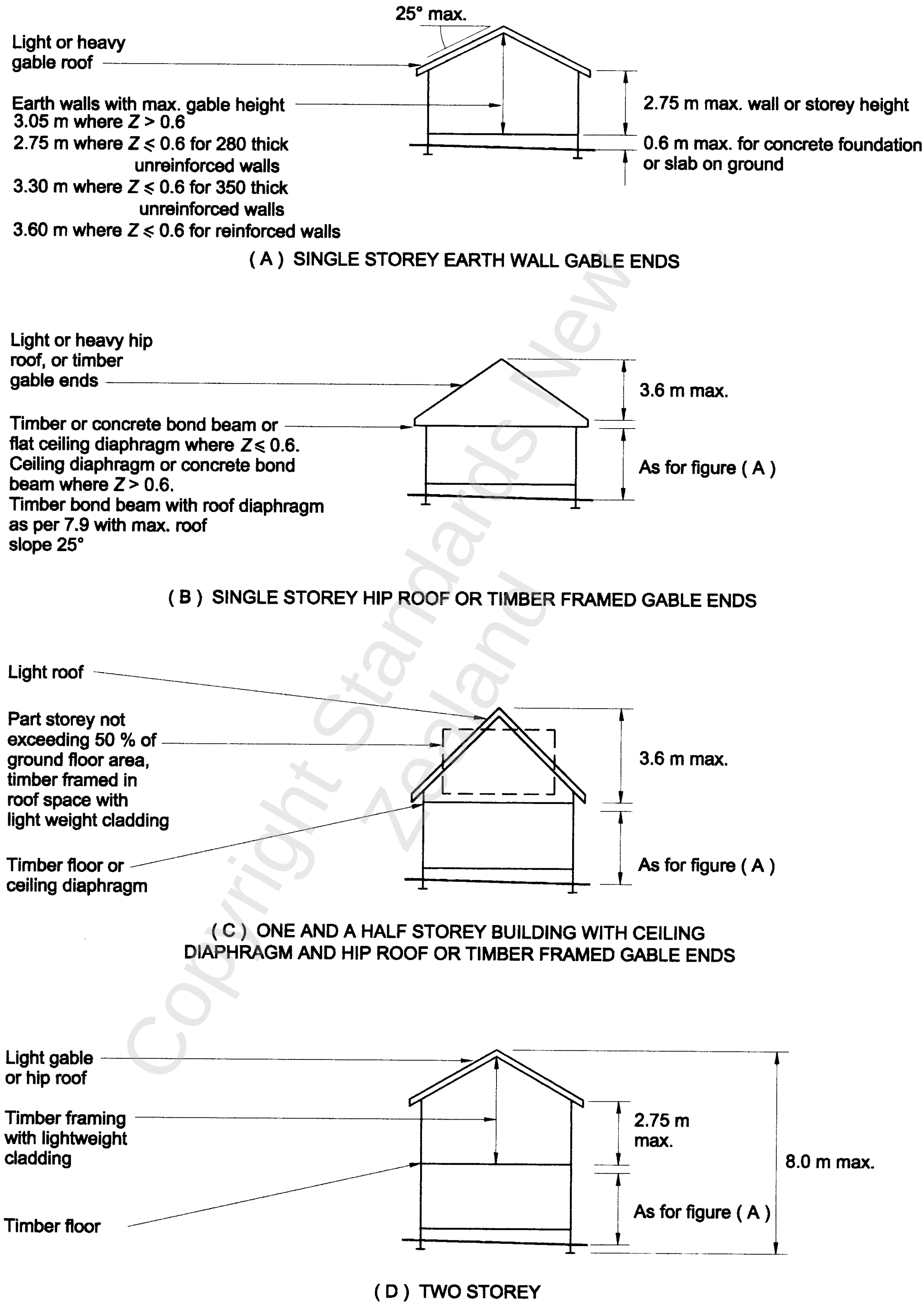
(k) Soil bearing capacity and site profile requirements shall be in accordance with section 3 of this Standard;

(l) The floor live load on suspended floors shall not exceed 1.5 kPa;

(m) Suspended floors and roof shall be of light timber construction complying with the relevant requirements of NZS 3604, unless otherwise modified by this Standard. A structural slab is not required at ground level; however, a wearing surface shall be provided to ensure at all times during the building's life that the minimum foundation depths are not compromised. Where a concrete slab-on-ground is proposed it shall be constructed in accordance with NZS 3604 or NZS 4229. This Standard does not describe what is necessary for an earth floor, therefore when one is proposed, full details of its design and maintenance shall be submitted to and approved by the territorial authority.

(n) Concrete foundation members shall be continuous around the perimeter of the building. The foundations of external wing walls may extend outwards from the perimeter foundations by up to 1.2 m. Concrete foundation members under internal walls shall be connected to perimeter members at both ends if longer than 1.2 m but may be connected at one end only if shorter than 1.2 m.

(p) Each part of the building shall be within the limitations stated or implied by the relevant clauses or tables of this Standard;



NOTE - Wall or storey height is defined in 1.2.

Figure 1.1 – Building types covered by this Standard

(q) Some combinations of eave protection, wall height, wind speed and exposure are excluded from the scope of this Standard by 2.5.5;

(r) Earth walled buildings including structural walls of materials other than earth except for non-loadbearing timber framed partition walls, shall be the subject of specific design to NZS 4297;

(s) Earth walls construction shall be either:

(i) All reinforced or,

(ii) Where permitted by 1.2(c)(i), one of:

(A) Partially reinforced

(B) Unreinforced

(C) A mixture of unreinforced and partially reinforced.

C1.2
Any building or part of a building which does not comply with 1.2 is outside the scope of this Standard and will require specific design.

(a) Examples of the types of buildings included are:

NZS 4203 Category IV:
Other buildings such as office buildings, residential buildings, industrial buildings, or warehouses, where not included in any other Category.

NZS 4203 Category V:
Outbuildings, some farm buildings and temporary buildings such as offices on a construction site.

(c) This Standard provides for earthquake-resistant unreinforced earth and partially reinforced walled buildings which will respond elastically to seismic loads, and for reinforced earth walled buildings which will respond with limited ductility.

(g) Wind loadings on earth walls may be disregarded except for cinva brick walls and the design wind speed need not be calculated except in mountainous areas and other areas where there are conditions likely to cause local wind accelerations including valleys and gorges shaped to produce funnelling of the wind, bluffs, very exposed hillsides, peaks and ridges. If there is doubt about the basic non-directional ultimate limit state wind speed not exceeding 50 m/s then reference should be made to specific design methods.

(h) In general 1.2(h) will be satisfied if the building is on a site where it will not be subjected to snow more than 250 mm deep.

(m) Advice on earth floors is provided in Appendix M of NZS 4298.

(n) These requirements ensure interconnection of building elements at foundation level. A ground floor slab is not required for this purpose.

1.3 Building components

1.3.1
Buildings constructed in accordance with this Standard shall incorporate structural components of earth, reinforced concrete, and timber. The timber components shall be in accordance with NZS 3604 except for those modifications to floor and roof construction provided by this Standard.

1.3.2
Systems to resist vertical loads shall be the following:

(a) Footings to earth walls to section 4;

(b) Walls

- (i) Internal and external walls to section 5
- (ii) Internal loadbearing timber framed walls supporting timber floors and roofs to NZS 3604 with external walls to section 5
- (iii) Roof and upper floor vertical loading supported by a post and beam frame specifically designed. Such designs are outside the scope of this Standard. Walls to be either in accordance with (b)(i) or (b)(ii) above.

(c) Lintels

- (i) Reinforced masonry or reinforced concrete lintels in accordance with section 8
- (ii) Timber lintels to support light timber frame to section 8 or NZS 3604

(d) Light timber roof and ceiling structure to section 6 and NZS 3604;

(e) Light timber floors to section 6 and NZS 3604;

(f) Arches complying with 9.4.

1.3.3
Systems to resist horizontal loads shall be:

(a) Internal and external walls of earth to section 5;

(b) Bond beams of timber or reinforced concrete to section 7;

(c) Structural diaphragms of timber supporting earth walls, to section 6.

1.4 Interpretation

1.4.1
For the purposes of this Standard the word “shall” refers to practices that are mandatory for compliance with the Standard, while the word “should” indicates a recommended practice.

1.4.2
Clauses prefixed by “C “ and printed in italic type are comments, explanations, summaries of technical background, recommended practice or suggest approaches which satisfy the intent of the Standard. Corresponding mandatory clauses are not always present. They are not to be taken as the only or complete interpretation of the corresponding clause nor should they be used for determining in any way the mandatory requirements of compliance within this Standard. The Standard can be complied with if the comment is ignored.

C1.4.2
There is a need for background comment and explanation on topics other than those within mandatory clauses. This is to enhance the relatively small pool of earth building experience and as a means of meeting the challenge of writing this first performance based suite of earth building standards. Accordingly, the unusual format has been adopted as having commentary clauses which have no corresponding mandatory clause.

1.4.3
Cross references to other clauses within this Standard quote the number only.

1.4.4
The terms "normative" and "informative" have been used in this Standard to define the application of the appendix to which they apply. A "normative" appendix is an integral part of a Standard, whereas an "informative" appendix is only for information and guidance.

1.4.5
The full titles of reference documents cited in this Standard are given in the list of related documents immediately preceding the Foreword.

1.4.6
Where the thickness or width is specified for earth walls in this Standard then, unless specifically stated otherwise, the thickness or width shall be the minimum dimensions.

1.4.7
Where any thickness or width is specified for a timber member in this Standard then, unless specifically stated otherwise, that member may have a greater thickness, or a greater width, or both.

1.4.8
Unless specifically stated otherwise cross sectional dimensions of timber given in this Standard shall be the nominal call dimensions.

C1.4.8
The actual dimensions of timber will differ from the call dimensions because of tolerances and according to its condition, e.g. green or dry, sawn, gauged or dressed.

1.5 Definitions

For the purposes of this Standard, the following definitions shall apply:

ADOBE. An air dried brick made from a puddled earth mix cast in a mould and which contains a mixture of clay, sand and silt. Sometimes contains straw or a stabilizer. Also known as mud-brick.

ASPHALT, or ASPHALT EMULSION. See bitumen.

BAGGING. The practice of rubbing an earth slurry or mortar over the surface of an earth wall with a thick cloth to produce a rendered surface.

BITUMEN EMULSION. Bitumen globules of microscopic size that are surrounded by and suspended in a water medium. When used as a stabilizer it is usually of the slow breaking cationic type. Also known as asphalt.

BOND BEAM. A continuous horizontal structural member in a wall which provides continuity and structural strength.

BOND, OVERLAPPING. The bond when the units of each earth brick course overlap the units in the preceding course by between 25 % and 75 % of the length of the units.

BOND, STACK. The bond when the units of each course do not overlap the units of the preceding course by the amount specified for overlapping bond. (Not permitted in this Standard).

BOUNDARY JOIST or BOUNDARY MEMBER. A joist running along the outer ends of floor or ceiling joists.

BRACING. Any method employed to provide lateral support to a building.

BRACING CAPACITY. The strength of building elements in resisting horizontal forces. Measured in bracing units (BU).

BRACING DEMAND. The horizontal force imposed on a building by earthquake or wind. Measured in bracing units (BU).

BRACING LINE. A line along or across a building for controlling the distribution of wall bracing elements.

BRACING PANEL. A panel section of earth in a structural wall of solid plan length (with no openings) which gives lateral stability to the building.

CHASE. A deep, wide groove cut into a constructed wall to accommodate services.

CINVA BRICK. A pressed earth brick meeting the dimensional and strength requirements of section 6 of NZS 4298.

CLAY. A fine grained, natural, earthy material composed primarily of hydrous aluminium silicates with grain diameters less than 0.002 mm.

COLUMN. An isolated, reinforced, vertical loadbearing member subjected primarily to compression having a cross section with a depth to breadth ratio between 3 and 0.33.

COMPRESSIVE STRENGTH. A physical property of a material that indicates its ability to withstand compressive forces, usually expressed in kPa or MPa.

CONSTRUCTION JOINT (in earth walls). Joint made within a rammed earth wall panel during production of the wall as a result of the stepwise building procedure.

CONTROL JOINT. A joint necessary to allow an earth wall to expand and contract and otherwise move.

DAMP PROOF COURSE. A durable waterproof material placed between materials as a protection against moisture movement. A painted on or a sheet damp proof course is referred to as a damp proof membrane.

DIAPHRAGM. A member such as a floor or ceiling capable of transferring loads in its own plane to boundary members.

DUCTILITY. The ability of a material, structural component or structure to deform or dissipate energy beyond its elastic limit i.e. into the post-elastic range.

DURABLE. Resistant to wear and decay. Durability has a corresponding meaning.

EARTH (for earth building). Natural sub-soil comprised of varying percentages of clay, silt, sand and gravel which is unfired and is free of significant organic matter.

ELASTIC RESPONSE. The response range of a structure where the deformation is in direct proportion to the force applied (i.e. the material, structural component or structure obeys Hooke's law.)

EROSION. The physical and chemical processes by which a material is worn away. It includes the processes of weathering and mechanical wear.

FLOOR LOAD. The basic minimum uniformly distributed live load for floors as specified by NZS 4203.

FRAMING TIMBER. Timber members to which lining, cladding or decking is attached or which are depended upon for supporting the structure or for resisting forces applied to it.

GABLE. The triangular part of an outside wall between the planes of the roof and the lines of the eaves.

GOOD GROUND. Any soil or rock capable of permanently withstanding an ultimate bearing strength of 300 kPa (i.e. an allowable bearing pressure of 100 kPa using a factor of safety 3.0), but excludes:

(a) Potentially compressible ground such as top soil, soft soils such as clay which can be moulded easily in the fingers, and uncompacted loose gravel which contains obvious voids;

(b) Expansive soils being those that have a liquid limit of more than 50 % when tested in accordance with NZS 4402 Test 2.2, and a linear shrinkage of more than 15 % when tested in accordance with NZS 4402 Test 2.6, and

(c) Any ground which could foreseeably experience movement of 25 mm or greater for any reason including one or a combination of: land instability, ground creep, subsidence, seasonal swelling and shrinking, frost heave, changing ground water level, erosion, dissolution of soil in water, and effects of tree roots.

GROUND LEVEL

CLEARED GROUND LEVEL. The ground level after the site has been cleared and any site excavation has been completed but before building footings have been excavated. When topsoil is not stripped off a site, the cleared ground level shall be taken as the bottom of the topsoil layer.

FINISHED GROUND LEVEL. The ground level after all backfilling, landscaping and surface paving having been completed.

NATURAL GROUND LEVEL. The ground level before the site is cleared or excavated.

JOIST. A horizontal framing member to which is fixed floor decking or ceiling linings and which is identified accordingly as a floor joist or ceiling joist.

LINTEL. A horizontal member spanning an opening in a wall.

LOADBEARING. Refers to an element which serves in providing resistance to loads other than those induced by the weight of the element itself.

MOISTURE CONTENT. The amount of water contained in soil material expressed as the weight of the water divided by the weight of the dry soil material in percentage terms.

MUD BRICK. See ADOBE.

PARTIALLY REINFORCED EARTH WALL. An earth wall containing a vertical reinforcing bar at each end of a bracing wall but without any horizontal reinforcement.

PLATE. A horizontal timber member in a wall which supports and distributes the load from floors, walls, ceiling or roof.

PLASTERING. The action of covering an earth wall (for decoration or weather protection) with a coating of earth (with or without stabilizer) and water or sand, cement and water or gypsum plaster.

PRESSED EARTH BRICK (or PRESSED BRICK). An earth brick that is made in a mechanical press, either machine operated or hand operated.

R VALUE. A measure of the ability of a material to retard heat flow.

RAFTER. A framing timber normally parallel to the slope of the roof and providing support for sarking, purlins, or roof covering.

RAMMED EARTH. Damp or moist soil, with or without stabilizer, that is tamped in place between temporary moveable formwork. Also known as pisé.

RAMMED EARTH WALL PANEL. A section of rammed earth wall being of full height of the finished section but of length that is built at one stage.

REINFORCED EARTH CONSTRUCTION. Any earth building into which reinforcing is so bedded and bonded that the two materials act together in resisting forces.

REINFORCEMENT. Any form of steel reinforcing rod, bar or mesh that complies with the relevant requirements of NZS 3109, or plastic or other material cited in this Standard capable of imparting tensile strength to the earth building material.

ROOF. That upper part of the building having its upper surface exposed to the outside and at an angle of 60º or less to the horizontal.

The maximum slope of 60º in the definition of roof corresponds to the slope used in NZS 3604 to differentiate between a "roof" and "wall". Roofs steeper than 45º are outside the scope of this Standard.

> HEAVY ROOF means a roof with roofing material (cladding and any sarking) having a mass exceeding 20 kg but not exceeding 60 kg per square metre of roof area (typical examples are concrete tiles, slates and the like).
>
> LIGHT ROOF. A roof with roofing material (cladding and any sarking) having a mass not exceeding 20 kg per square metre of roof area. Typical examples of light roofing are steel, copper, and aluminium roof cladding of normal thickness, 6 mm thick fibre cement tiles, 6 mm thick corrugated fibre cement, shakes, shingles and the like without sarking.

SAND. Individual rock or mineral fragments that range in diameter from 0.06 to 2.0 mm.

SARKING. Sheet material or boards secured to rafters, trusses, or purlins and which may also serve as a ceiling lining or as a roof diaphragm.

SHRINKAGE. The decrease in volume of earth material or mortar caused by curing or the evaporation of water. Expressed as a percentage of linear dimension.

SILT. Individual mineral particles in a soil that range in size from the upper limit of clay (0.002 mm) to the lower limit of fine sand (0.06 mm).

SLURRY. A mixture of earth and water that results in a soupy mixture that is easily poured.

SOIL. See earth.

SPACING. The distance at which members are spaced measured centre to centre.

SPAN. The clear distance between supports measured along a member.

STABILIZATION. The improvement of the performance of earth building material properties by the addition of materials which bind the earth particles. Stabilization may increase the resistance of earth to moisture, reduce volume changes or improve strength or durability.

STABILIZER. A material which is used for stabilization.

STABILIZED ADOBE. Adobe bricks which have a stabilizer added, typically cement or asphalt emulsion.

STABILIZED POURED EARTH. Poured earth which has had stabilizer added, usually cement.

STABILIZED PRESSED BRICK. Pressed brick which has had a stabilizer added, usually cement.

STABILIZED RAMMED EARTH. Rammed earth which has had a stabilizer added, usually cement.

STOREY HEIGHT. The vertical distance measured from the concrete foundation top to the underside of the top plate or bond beam and between the floor level and the underside of the top plate for the second storey.

UNREINFORCED EARTH WALL. An earth wall containing less than the minimum reinforcement required by section 5 for reinforced earth walls.

WALL

WALL BRACING PANEL. A section of wall above the ground level that performs a bracing function.

EXTERNAL WALL. An outer wall of a building.

INTERNAL WALL. A wall other than an external wall.

LOADBEARING WALL. A wall supporting vertical loading from floors, ceiling joists, roof, or any combination thereof.

NON-LOADBEARING WALL. A wall other than a loadbearing wall.

PARTITION. A light timber wall which is used within the building.

STRUCTURAL WALL. Any wall which because of its position and shape contributes to the rigidity and strength of the building.

WALL PLATE. A horizontal timber member at either the top or bottom of studs in a timber wall frame, or the horizontal timber member on which rafters or roof trusses are supported.

WALL THICKNESS. Minimum thickness of wall remaining after chasing, or raking or tooling of mortar joints.

2 GENERAL

2.1 Materials

2.1.1 *Earth*
Earth materials and construction shall comply with the provisions of NZS 4298 for Standard grade earth construction.

2.1.2 *Concrete*
All concrete shall satisfy the requirements of NZS 3109 with a minimum specified strength of 17.5 MPa except as otherwise noted in this Standard.

2.1.3 *Concrete masonry*
Concrete masonry shall comply with the provisions of NZS 4210.

2.1.4 *Reinforcement*
Steel reinforcing shall comply with NZS 3402. Steel mesh reinforcing shall be hard drawn steel wire to NZS 3421.

> ***C2.1.4***
> *"Deformed" pattern reinforcing bars and designated "D" followed by the diameter in mm. Plain round reinforcing bars are designated "R" followed by the diameter in mm.*

2.1.5 *Bolts*
At bolted connections washers shall be provided at each timber surface under the bolt head or the nut. Washers for softwoods shall be of the following minimum sizes:

(a) For M12 bolts – 50 mm square x 3 mm or 55 mm round x 3 mm;

(b) For M16 bolts – 65 mm square x 5 mm or 75 mm round x 5 mm.

2.1.6 Corrosion protection
Steel connections and fixings including nails, bolts and nail plates, which are:

(a) Exposed to the weather; or

(b) In contact with earth wall or earth floor material; or

(b) In contact with other building materials which are below any damp proof membrane;

shall be hot dip galvanized or shall be fabricated from stainless steel.

2.1.7 *Mortar*
Mortar shall comply with the provisions of NZS 4298.

2.1.8 *Timber*

2.1.8.1
Timber specified in this Standard for top plates, bond beams and lintels shall be No. 1 Framing Grade to NZS 3631.

2.1.8.2
Timber for lintels not exposed to the weather, top plates and bond beams shall be treated to grade H1 of NZMP 3640, or heart timber from Macrocarpa, Lawsons or Mexican Cypress, Red Beech Eucalyptus species, or Douglas Fir in accordance with NZS 3602.

2.1.8.3
Timber for lintels exposed to the weather shall be treated to grade H3 of NZMP 3640.

2.1.8.4
Timber which is required to be durable and which may be in contact with earth wall construction shall meet the requirements of 2.1.8.2 where it is not exposed to the weather or shall meet the requirements of 2.1.8.3 where it is exposed to weather.

2.2 Methods of construction

This Standard covers the following methods of earth building construction:

(a) Rammed earth;

(b) Adobe;

(c) Pressed brick (including cinva bricks);

> ***C2.2***
> *Other earth building methods including cob, poured earth,* in situ *adobe and wattle and daub are not covered by this Standard.*

2.3 Earthquake zones

The earthquake zone factor for any locality shall be given by figure 2.1.

2.4 Wind zones

2.4.1
The location (urban, rural, open) of a site is determined by considering the obstructions over which the wind must pass as it approaches that site. At least 500 m of rougher ground is required to affect the wind profile. Sites within this 500 m wide fringe zone shall be considered as if they are in the less rough terrain.

Urban terrain is typical of most residential subdivisions. It is defined as that where the density of obstructions (houses or trees) is not less than 10 per hectare.

Rural terrain is typical farm land, with some trees and shelter belts, cropping and horticulture. Tussock land is also in this category.

Open terrain includes grazed pasture, areas adjacent to beaches and the sea, airfields and other areas with only isolated trees or shelter.

> ***C2.4.1***
> *The location classification indicates the drag effect on the wind profile as it passes over different terrains. Urban, rural and open terrains are equivalent respectively to Terrain Categories 3, 2.5 and 2 of Part 5 of NZS 4203.*

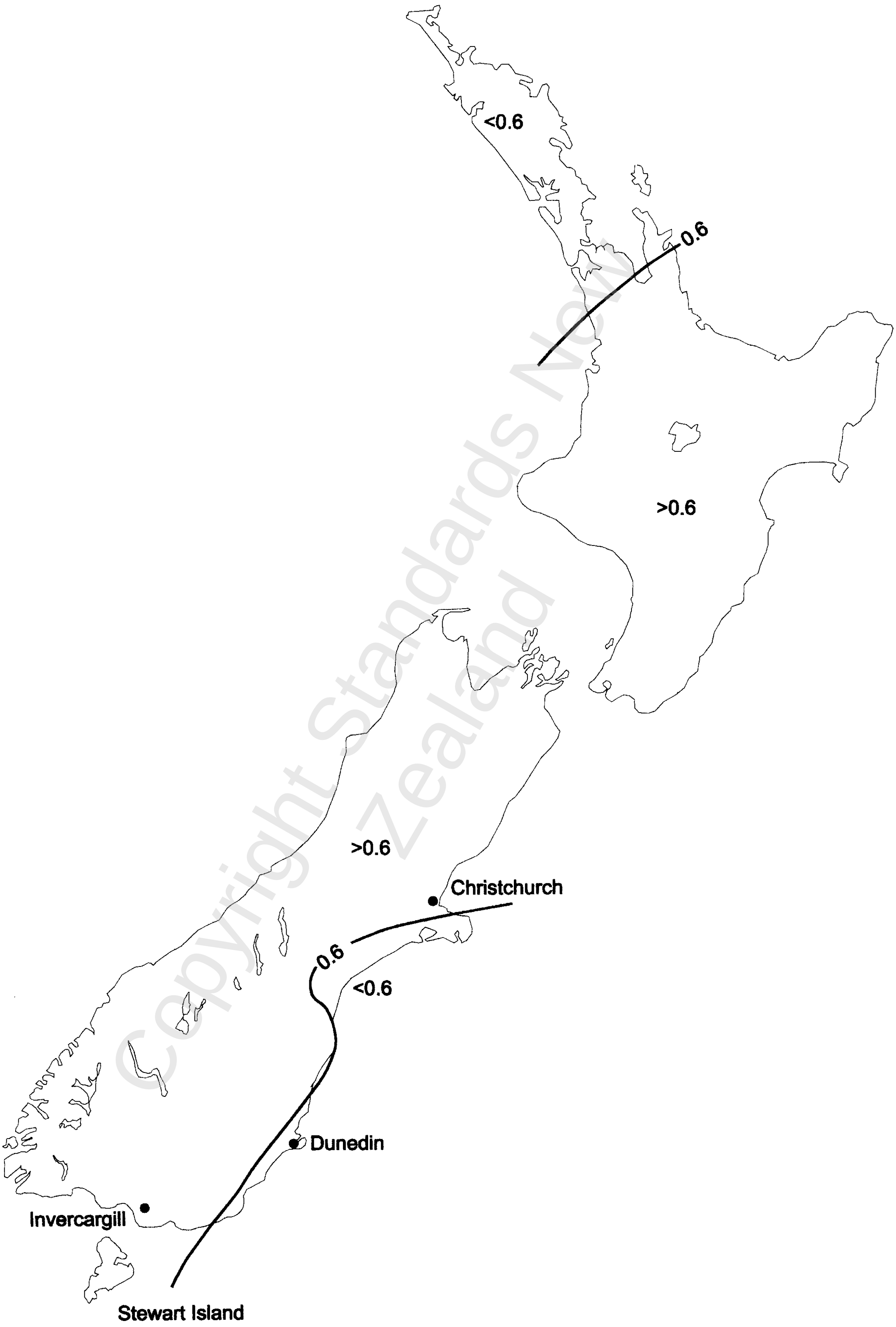


Figure 2.1 – Earthquake zone factors

2.4.2
The site exposure shall be determined by consideration of the shielding effects of obstructions to wind flow. At least 2 rows of permanent obstructions, similarly sized to the building, in each upwind direction are required for the site to be considered as "sheltered".

C2.4.2
Typical suburban developments on flat or gently undulating ground, will usually be "sheltered" unless they are adjacent to playing fields or other open spaces, beach fronts, large rivers, motorways, or wind channels greater than 100 m in width, in which case the 2 outer rows of buildings will usually be considered to be "exposed".

Most houses located on moderate or steep hillside sites should be considered as "exposed".

2.4.3
The wind zone for each building site shall be determined in accordance with table 2.1.

Table 2.1 – Building wind zones

Location	Sheltered	Exposed
Urban	L	H
Rural	M	VH
Open	H	SD

Key

Symbol	Design wind speed at ultimate limit state (m/s)
L	32
M	37
H	44
VH	50
SD	>50 specific design required (Outside the scope of this Standard)

2.5 Durability
Compliance with this section is necessary to satisfy the requirements of clause B2 of the New Zealand Building Code.

C2.5
Durability design is summarized in figure 2.3.

2.5.1 *General*

2.5.1.1
An earth wall will be deemed to comply with the durability performance criteria if, provided that normal surface maintenance has been carried out, its thickness has not decreased by more than 5 % nor by more than 30 mm at any point during the 50 year building life.

2.5.1.2
Normal maintenance of earth building material shall include the repair of damage or deterioration of the wall surface including any surface coating and the removal of any source of moisture which is capable of causing localized elevation of earth wall moisture content. Such sources may include plumbing or roofing leaks, channelling of rainwater, bridging or other loss of integrity of the damp proof course, vegetation or build up of ground levels. Repair of earth building material is to be carried out using the same material as that from which the earth wall is constructed and be applied in accordance with NZS 4298. Curing of lime or cement containing repair mixtures shall be carried out in accordance with

the provisions of NZS 4298. Surface coatings which are impervious to water vapour and air shall not be used.

C2.5.1
Earth walls are particularly susceptible to moisture, whether this is from rising damp, water ingress from the top, driving rain, water splashing, or moisture generated internally in a building. For this reason it is important that any design considers the need to protect earth walls from excessive moisture. Care is to be taken with all weathering details including flashings and eave protection of wall tops. Any applied coatings or surface finishes shall allow the wall to "breathe" to prevent moisture becoming trapped inside an earth wall. To "breathe" in this context means to allow the diffusion of air and water vapour.

A structure is durable if it withstands expected wear and deterioration throughout its intended life without the need for undue maintenance. Deterioration of earth-walls depends on the severity of wind-driven rain, on the orientation of the wall, the height and width of the eaves, on the weather resistance of the wall material, on surface coatings, on the surface finish and on the stability of the material whether naturally occurring or achieved by the addition of stabilizers.

An eaves width of 600 mm is a recommended minimum requirement for earth walls to satisfy the durability requirements of this Standard. More detailed requirements are provided in the following clauses.

2.5.2
The earth wall material erodibility index shall be less than or equal to the site specific building limiting erodibility index.

2.5.3
The earth wall material shall meet the acceptance criteria of the wet/dry appraisal test detailed in Appendix C of NZS 4298.

2.5.4
The earth wall material erodibility index shall be determined by the Erosion Test (Pressure Spray Method) or the Erosion Test (Geelong Method) detailed in Appendices D and E respectively of NZS 4298. In cases where Erodibility Index of 1 is required or where eaves widths are 600 mm or less, the Pressure Spray Method shall be used.

2.5.5
The site specific building limiting erodibility index shall be as given by table 2.2.

Table 2.2 – Site specific building limiting erodibility indices for different wind zones, wall exposures, eaves heights and widths in areas with up to 2000 mm per year average rainfall

	Building eaves width (*b*) mm						
	0	300	600	900	1200	1800	2400
Wind zone, wall exposure and eaves height (*h*) (mm)	**Limiting erodibility index**						
Wind zone H and VH							
Exposed, 2400	OS	OS	1	1	1	2	2
Exposed, 3000	OS	OS	1	1	1	2	2
Exposed, 3600	OS	OS	OS	1	1	2	2
Sheltered, 2400	OS	1	1	2	2	2	3
Sheltered, 3000	OS	1	1	1	2	2	3
Sheltered, 3600	OS	OS	OS	1	1	2	2
Wind zone M							
Exposed, 2400	OS	OS	1	2	2	2	3
Exposed, 3000	OS	OS	1	1	2	2	3
Exposed 3600	OS	OS	1	1	2	2	2
Sheltered, 2400	OS	1	2	2	3	3	4
Sheltered, 3000	OS	1	1	2	2	2	3
Sheltered, 3600	OS	OS	1	1	2	2	3
Wind zone L							
Exposed, 2400	OS	OS	1	2	2	3	3
Exposed, 3000	OS	OS	1	2	2	2	3
Exposed, 3600	OS	OS	1	1	2	2	2
Sheltered, 2400	OS	1	2	2	3	3	4
Sheltered, 3000	OS	1	2	2	2	3	4
Sheltered, 3600	OS	OS	1	1	2	2	3

NOTE –

(1) OS – Outside the scope of this Standard. In these cases specific design following Appendix A of NZS 4297 will be required.

(2) Eaves width, *b*, and eaves height, *h*, as defined in figure 2.2.

(3) For eaves widths 600 mm or less, refer to 2.5.4.

(4) Exposed and sheltered sites are as defined in 2.4.2.

C2.5.5

Providing very wide opaque overhangs, without reference to the orientation of walls could lead to very poor thermal (passive solar) performance. Balancing passive solar design and building durability may give rise to a need to substitute a material with a lower erodibility index.

Table 2.2 is concerned with durability. Moisture penetration especially in areas of high exposure to driving rain and small (<900 mm) eaves is dealt with by conforming to other provisions of this Standard and NZS 4298.

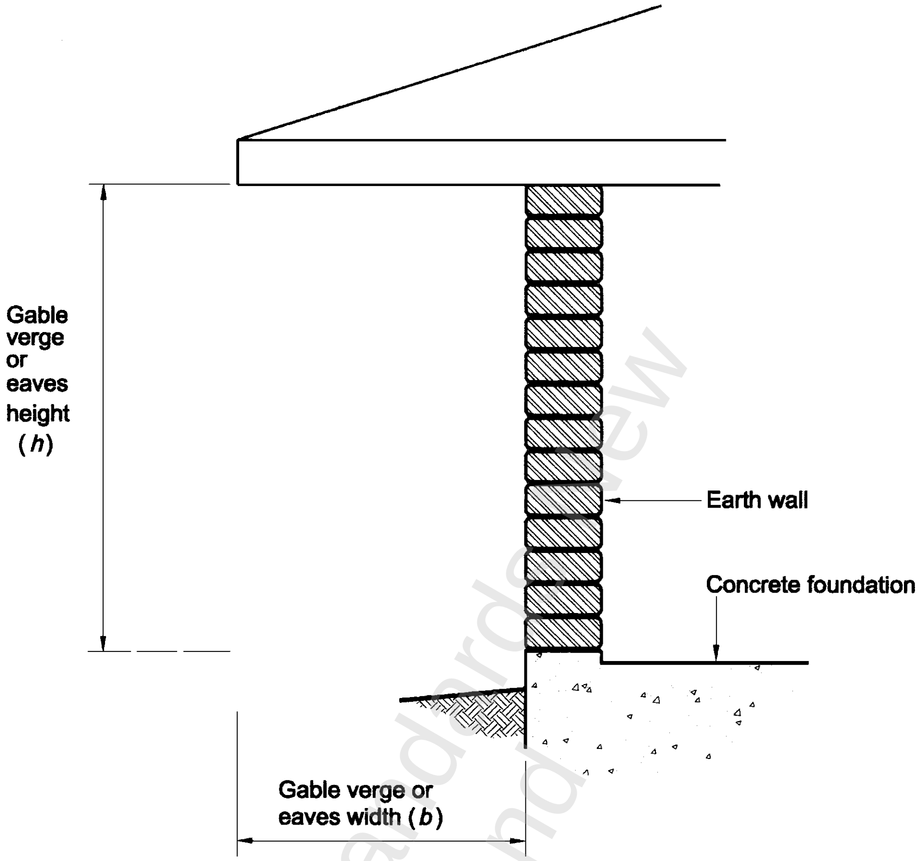


Figure 2.2 – Definition of eaves height and eaves width

2.5.6
The wind zone shall be as given by table 2.1.

2.5.7
The earth wall material erodibility index may be improved by stabilization of the earth wall material by the addition of cement or asphalt emulsion. The improved earth wall material shall be retested using the Spray Erosion Test or the Geelong Drip Test (Appendices D and E of NZS 4298) where appropriate to determine the improved earth wall erodibility index.

C2.5.7
Eaves or gable verges are required by 2.10 to protect against external moisture penetration. Amd 1 Dec '99

2.6 Snow loads
Snow loads shall be determined in accordance with NZS 4203.

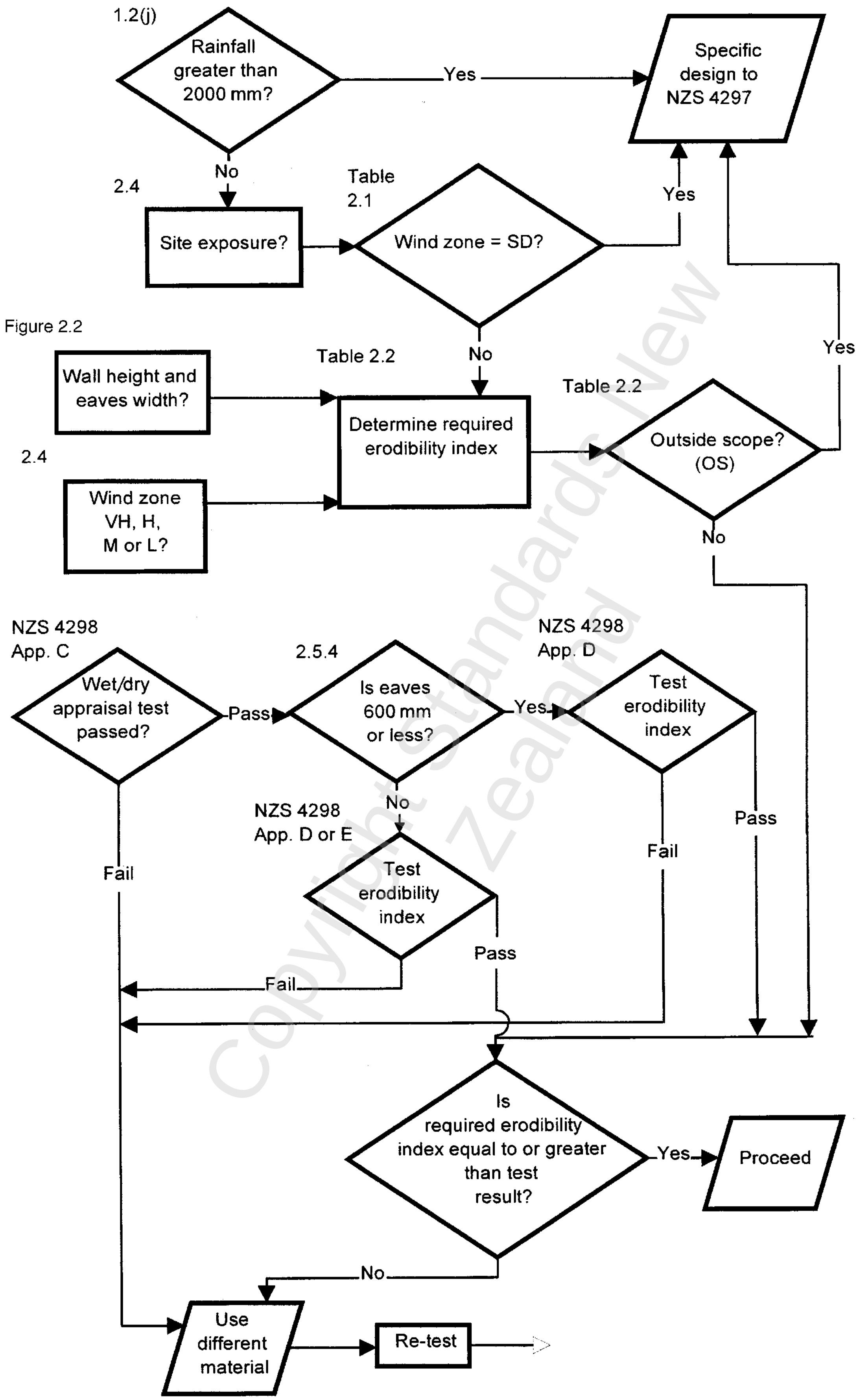


Figure 2.3 – Durability design

2.7 Concrete durability

2.7.1
Minimum concrete cover to steel reinforcement shall be 50 mm.

2.7.2
Minimum specified concrete strength shall be:

(a) 17.5 MPa for unreinforced concrete, for concrete not exposed to weather or for concrete exposed to the weather within a low concrete reinforcing corrosion risk area as defined in 2.7.3;

(b) 20 MPa for concrete exposed to weather and from 500 m from the Mean High Water Springs mark to the boundary of a low concrete reinforcing corrosion risk area as defined in 2.7.3;

(c) 25 MPa for concrete exposed to weather and within 500 m of the Mean High Water Springs mark.

2.7.3
Low concrete reinforcing corrosion risk areas are defined as:

(a) In the North Island:

- (i) Near the West Coast from Cape Reinga to Cape Terawhiti, except Taranaki Region, Manawatu District and Palmerston North City, areas further than 30 km from the Mean High Water Springs mark
- (ii) In Taranaki Region, Manawatu District and Palmerston North City, areas further than 40 km from the Mean High Water Springs mark
- (iii) Elsewhere in the North Island, areas further than 20 km from the Mean High Water Springs mark.

(b) In the South Island:

- (i) Near the West Coast from Cape Farewell to Puysgur Point, areas further than 40 km from the Mean High Water Springs mark
- (ii) Elsewhere in the South Island, areas further than 20 km from the Mean High Water Springs mark.

(c) No areas within offshore islands are included.

C2.7
The provisions of this clause are based on NZS 3101 and provide for an intended life of 50 years. More economic designs may result in some cases if the more detailed provisions of NZS 3101 are followed but such designs are not within the scope of this Standard.

Some of the areas described will be outside the scope of this Standard by virtue of rainfall or wind exposure.

2.8 Materials testing

Standard grade earth construction as defined in NZS 4298 shall be used for earth buildings deemed to comply with this Standard. Test procedures and results required are detailed in the Appendices to NZS 4298.

2.9 Thermal insulation

2.9.1
For housing, as defined in NZS 4218, the thermal insulation requirements of NZS 4218 are satisfied by earth walled buildings having a minimum wall thickness of 280 mm provided the conditions of table 2.3 are met.

Table 2.3 – Earth wall construction for thermal performance

Building thermal envelope component	Climate zones 1 & 2	Climate zone 3
Floor	Minimum R = 1.3 m^2. ^{o}C/W	Minimum R = 1.3 m^2. ^{o}C/W
Roof	Minimum R = 2.3 m^2. ^{o}C/W	Minimum R = 2.3 m^2. ^{o}C/W
Glazing area maximum	30 % of wall area	30 % of wall area
Glazing type	Single or double	Double

NOTE –

(1) Climate zone boundaries are given by 2.9.2.

(2) Temporary floor coverings such as carpets or floor coverings shall not be included in the floor *R*-value.

(3) The floor *R*-value is met by:

(a) Concrete slab-on-ground in accordance with NZS 3604; or

(b) Suspended timber floors in accordance with NZS 3604 with drooped foil in accordance with NZS 4222 with a continuous enclosed perimeter wall which has from 3500 to 7000 mm^2 per m^2 of sub-floor ventilation; or

(c) Earth floors constructed in accordance with Appendix M of NZS 4298.

(4) Double glazing shall have a minimum *R*-value of 0.33 m^2.°C/W in accordance with NZS 4218.

C2.9.1
Glazing above 30 % of wall area may lead to solar overheating and excessive heat loss. Use of the Calculation Method or Modelling Method of NZS 4218 is advised for over 30 % glazing.

R = 3.0 for roof insulation is recognized as a minimum desirable value for passive solar design.

2.9.2
Zones 1 and 2 comprise the whole of the North Island excluding Taupo District, Ruapehu District and the northern part of the Rangitikei District.

Zone 3 comprises the remainder of the country i.e. Taupo District, Ruapehu District, northern part of the Rangitikei District, South Island and all other islands not in Zones 1 and 2.

C2.9.2
The climate zone boundaries are based on climatic data taking into consideration territorial authority boundaries, providing for 3 zones.

The climate zones follow NZS 4218 and a map may be found in that Standard.

2.10 Protection of earth walls from external moisture

2.10.1

Suitable protection from exterior moisture to all earth walls shall be provided by minimum eave and verge widths to all earth walls in accordance with table 2.4.

Table 2.4 – Exterior moisture protection for earth walls

Building wind zone (from table 2.1)	**Ratio of eaves height to eaves width, *h*:*b*** (see figure 2.2)
L	4:1
M	8:3
H	3:2 (see clause 2.10.2)
VH	1:1

C2.10.1

Walls that comply with table 2.2 may still be susceptible to problems from penetration of external moisture over time and these provisions ensure against this.

The ratios in table 2.4 are minimums and greater eaves widths may be specified. Lesser eaves widths combined with other weather protection measures such as fences, pergolas or other permanent landscaping features may also be possible in some cases by using specific design but this is outside the scope of this Standard.

NZS 3604 provides for eaves overhangs of up to 750 mm and cantilevered overhangs greater than this will require specific engineering design. Verandahs may be provided in accordance with NZS 3604 where an eaves width greater than 750 mm is required.

2.10.2

In high wind zones the ratio may be reduced to 2:1 for earth walls not stabilized with cement or lime and that have open exposure and face northerly between north east and north west.

C2.10.2

In the High Wind Zone, the improved waterproofing properties of clay surfaces, which are free to swell to form a waterproof layer, are recognized. When these materials get wet they have superior waterproofing properties compared to the more porous matrices formed by cement and lime stabilizers, especially when combined with the effect of the sun on the northern aspect in helping keep these walls dried out. Amd 1 Dec '99

3 SITE REQUIREMENTS

C3
The site requirements of this Standard are concerned with drainage and soil conditions under or adjacent to the building. Compliance with these requirements does not necessarily mean that the site is suitable for the building in terms of subdivisional and planning legislation.

3.1 Soil bearing capacity and site profile requirements

C3.1
If a site does not comply with 3.1, then it will be necessary for the footings to be the subject of specific design. However, this Standard may still apply to the rest of the building provided it complies with 1.2 and the footings are designed to suit.

3.1.1 *Location of footings*
The footing provisions of this Standard shall apply only for building sites such that:

(a) The foundation of the building shall be supported by "good ground" as defined in 1.5;

(b) Any footing for a building erected at the top of a slope, shall be no nearer any point on the slope than shown in figure 3.1(a);

(c) Where the ground level rises above floor level adjacent to earth wall, there shall be a minimum of 1000 mm between the toe of a slope and the earth wall. A lined drain with a longitudinal fall of at least 1:150 and paving shall be provided where the toe of the slope is less than 1200 mm from the wall as shown in figure 3.1(b);

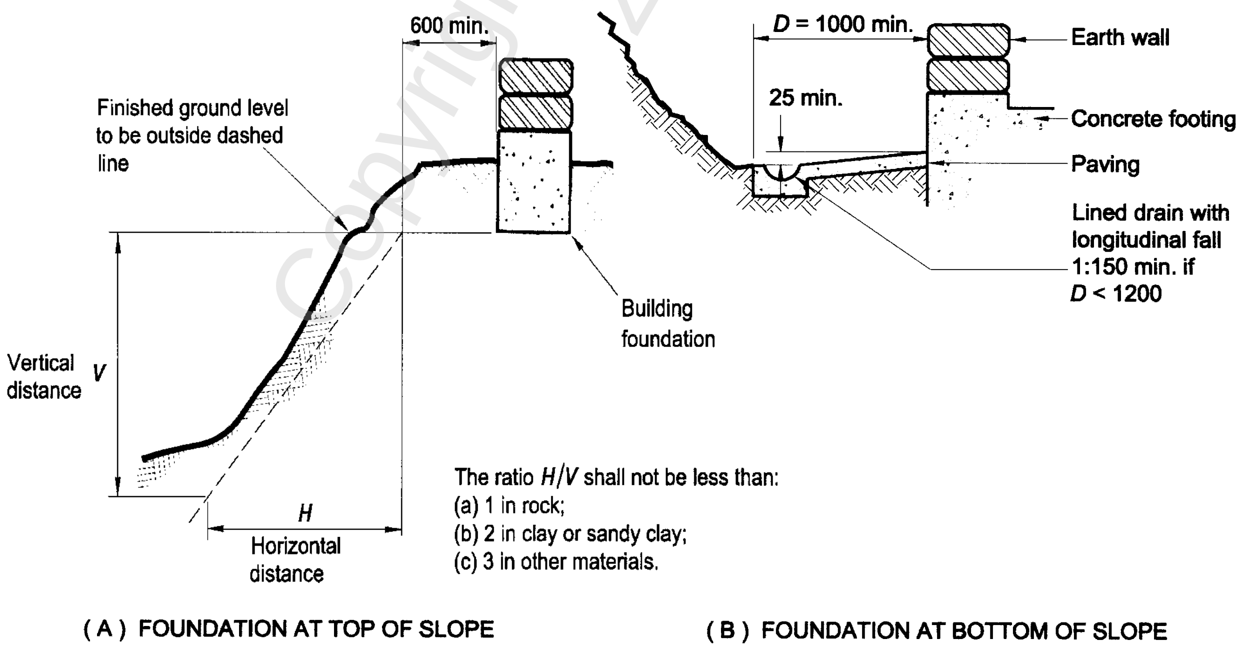


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Figure 3.1 – Relationship of foundation to sloping ground surface

(d) Any ground within 1.5 m horizontal distance from any footing and more than 300 mm above the cleared ground level at the footing shall be natural undisturbed ground.

C3.1.1

(c) Clause 3.1.1(c) is intended to ensure that footing loadings do not cause adjacent slopes to become unstable.

(d) Moderate depths of earth fill over a large area adjacent to building footings can cause the soil to consolidate at greater depths than are influenced by the footings specified in this Standard. Such consolidation can cause differential settlement of the building footings and thus damage the building. Typically, earth fills are placed adjacent to footings for the construction of stairs, terraces, landscaping, and built up ground under concrete floor slabs.

3.1.2 *Soil bearing capacity*

The test and the investigations required by this clause shall be performed by people with appropriate skills to the approval of the territorial authority.

3.1.2.1

The soil supporting the footings shall be assumed to be good ground if:

(a) Adjacent established buildings of a similar type supported on footings similar to those required by this Standard and on similar soils show no signs of unsatisfactory behaviour attributable to soil conditions; or

(b) Dynamic cone penetrometer (also known as Scala Penetrometer) tests in accordance with NZS 3604 have been performed establishing that the supporting soils are good ground; and

(c) Provided all of the conditions of 3.1.2.2 are met. Amd 1 Dec '99

C3.1.2.1

Good ground may also be verified by a subsoil investigation but this is outside the scope of this Standard.

Tests in accordance with NZS 3604 offer a comparatively simple method for establishing whether or not an ultimate bearing strength of 300 kPa may be assumed.

3.1.2.2

Site and soil conditions required to be met are:

(a) Reasonable enquiry, the project information memorandum (PIM) and site observation show no evidence of buried services and none are revealed by excavation for footings; and

(b) Reasonable enquiry the PIM and site observations show no indications or records of land slips having occurred in the immediate locality; and

(c) Reasonable enquiry shows no evidence of earth fill on the building site and no fill material is revealed by excavation for footings; provided that this shall not apply where a certificate of suitability of earth fill for residential development has been issued in terms of NZS 4431 in respect of the building site and any special limitations noted on that certificate are complied with; and

(d) Excavation for footings does not reveal buried organic topsoil, soft peat, soft clay or loose sand (see 3.2.1).

3.2 Soil types

3.2.1 Soft peat and soft clay

For the purposes of 3.1.2 (e) peat or clay soil shall be regarded as soft if a natural chunk of the soil (not remoulded material or loose shavings) can be easily moulded in the fingers. (Soil that exudes between the fingers when squeezed in a fist shall be regarded as very soft.)

3.2.2 Loose sand

For the purpose of 3.1.2(e) loose sand shall be that sand which when in a dry state has a natural angle of repose when poured into a heap of less than 3 horizontal to 2 vertical (33º to the horizontal).

C3.2.2
The design bearing capacity of a footing bearing on sand depends on the width of the footing and its depth below the surface, the density of the sand and, in particular, bearing capacity factors which are dependent on the internal angle of friction of the sand. The natural angle or repose of a loose sand heap gives a reasonable indication of the internal angle of friction of a sand.

3.3 Bearing

3.3.1

All footings shall bear upon solid bottom in undisturbed material or upon fill which complies with 3.1.2(d). Such material is referred to in this Standard as firm bearing.

3.3.2

The minimum depths of footings below the cleared ground level shall be:

(a) 150 mm in firm weathered rock;

(b) 300 mm in other materials, except for expansive clays, subject to any special limitations noted on a certificate of suitability issued in terms of NZS 4431 in respect of the building site (see 3.1.2(d));

(c) Where expansive clays occur the foundations shall be specifically designed. Such design is outside the scope of this standard.

C3.3.2
"Cleared ground level" is used as the depth datum because this level is not usually altered by future landscaping, thus retaining the lateral support of the building.

3.4 Site drainage and flood avoidance

The site shall be located or built up such that under severe flood conditions (200 year event) water does not rise above the top of the concrete, stone or other such durable foundation layer. Determination of these levels is outside the scope of this Standard.

C3.4
Flood waters can destroy adobe or lightly stabilized earth wall materials that are inundated for more than short periods. This could lead to overall structural collapse. More care is needed in siting earth wall buildings than for conventional construction.

Some situations that require specific consideration are:

(a) Height above river or stream flood level;

(b) Flood paths on sloping ground;

(c) Adequate drainage to prevent overland flow accumulation;

(d) Height above maximum storm wave upwash combined with maximum likely water levels on lakes or sea.

3.5 Site preparation

3.5.1
Before a building is erected on any site all rubbish, noxious matter, and organic matter shall be removed from the area to be covered by the building.

In suspended floor construction, (but not in slab-on-ground construction) firm turf and close-cut grass may remain provided that for the purposes of complying with 3.3.2, cleared ground level shall be taken as the underside of soil containing organic matter.

3.5.2
Any subsoil drains severed during the excavation process shall be reinstated or diverted and the building area shall be permanently drained to ensure freedom from surface water in the subfloor space.

C3.5.2
Footings should be backfilled and compacted up to cleared ground level.

4 FOOTINGS

4.1 General

4.1.1
Every earth wall, whether loadbearing or non-loadbearing, shall be supported by a continuously reinforced concrete footing of the dimensions and reinforcement given in this section.

4.1.2
The footing shall be formed symmetrically about the centre line of the wall.

C4.1.2
If 4.1.2 cannot be satisfied because a wall is to be built up to a boundary or for any other reason, then it will be necessary for both the footing and the wall to be the subject of specific design. Such design is outside the scope of this Standard.

4.1.3
The footing shall have all soil bearing surfaces horizontal but may be stepped to accommodate variations in cleared ground level or variations in depth of formation level to provide a design bearing capacity as defined in 3.1.1.

4.2 Width of footing

4.2.1
The width of the footing shall not be less than 280 mm nor the width of the earth wall construction whichever is the greater.

4.2.2
The width of the footing shall not exceed 450 mm.

4.3 Depth of footing

The footing shall extend to at least the depths below cleared ground level and be on firm bearing as defined in 3.3, refer to figure 4.1.

4.4 Height of footing

4.4.1

The top of the footing at the underside of the earth wall shall be:

(a) A minimum of 225 mm above the finished exterior ground level;

(b) A minimum of 50 mm above the interior floor level during construction before weatherproofing of the roof;

(c) A maximum of 600 mm above the cleared ground level;

(d) A minimum of 150 mm above permanent paving.

Refer to figure 4.1.

C4.4.1
Footing walls exceeding 600 mm height above cleared ground level will require specific design as these are outside the limitations defined in 1.2.

The clearance above interior floor level of (b) is to avoid soaking of wall base by ponded water during construction.

4.4.2

The walls in wet areas of buildings shall be provided with a concrete footing which is a minimum of 50 mm above floor level.

C4.4.2
This requirement for wet areas of buildings, which include bathrooms, laundries and the like, are to avoid wall damage from spills or leaks.

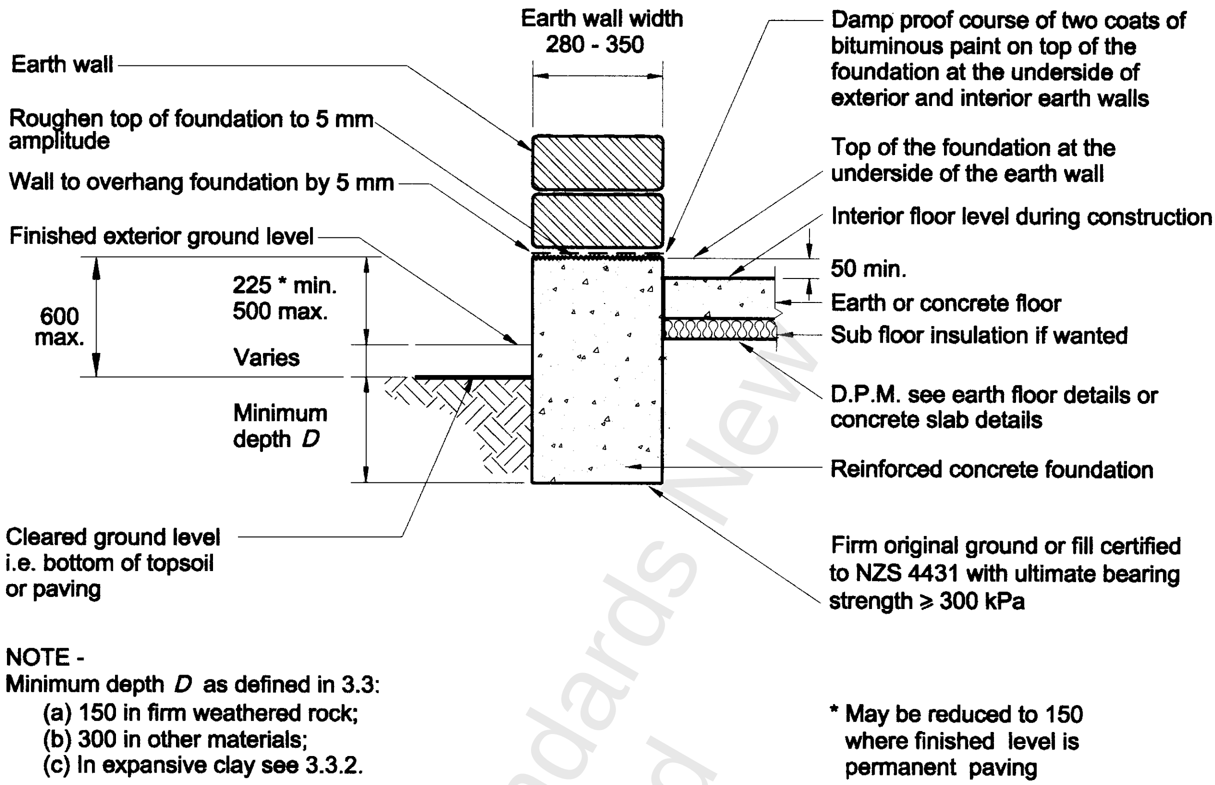


Figure 4.1 – Footing dimensions and general details

4.5 Reinforcement of footings

4.5.1 *Reinforcement of footings where earthquake zone factor ≤ 0.6*

4.5.1.1
Longitudinal reinforcement shall consist of one of:

(a) 4/D12 or 2/D16 bars for footings not exceeding 350 mm wide;

(b) 4/D16 bars for footings exceeding 350 mm wide;

(c) 3/D12 bars as provided for footing types E and G shown in figures 4.5 and 4.7;

(d) 3/D16 bars as provided for in figures 4.5 and 4.7.

Refer to figures 4.2 to 4.7.

4.5.1.2
Footing reinforcement shall be tied with R6 rectangular stirrups at 400 mm centres or R6 “L” stirrups at 400 mm centres as shown in figure 4.5 except where there is a concrete floor in which case the stirrups shall be D10 at 400 mm centres as shown in figures 4.6, 4.7 and 4.8. For foundations with an overall depth of less than 450 mm, the above spacings shall be 350 mm.

4.5.1.3
Reinforcement at intersections shall be tied together with D12 L bars top and bottom and lapped 40 bar diameters as shown in figure 4.4.

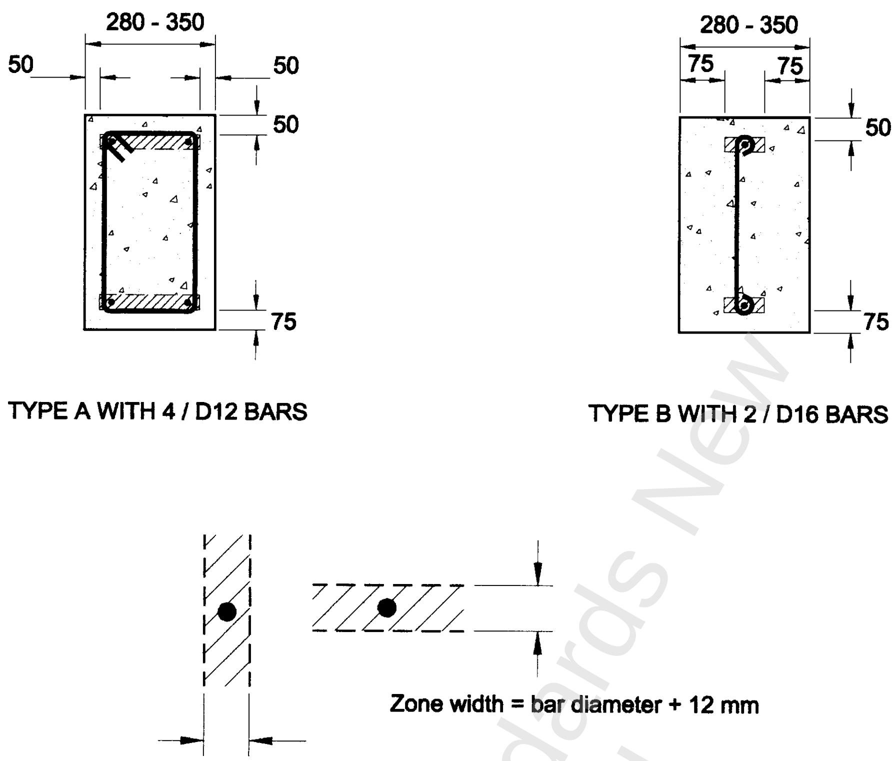


Figure 4.2 – Footing reinforcement where earthquake zone factor ≤ 0.6

4.5.2 *Reinforcement of footings where earthquake zone factor > 0.6*

4.5.2.1
Longitudinal reinforcement shall consist of:

(a) 3/D16 for foundation types E and G with fired brick facing, refer to figures 4.5 and 4.7;

(b) 4/D16 bars for all other footings.

Refer to figure 4.3.

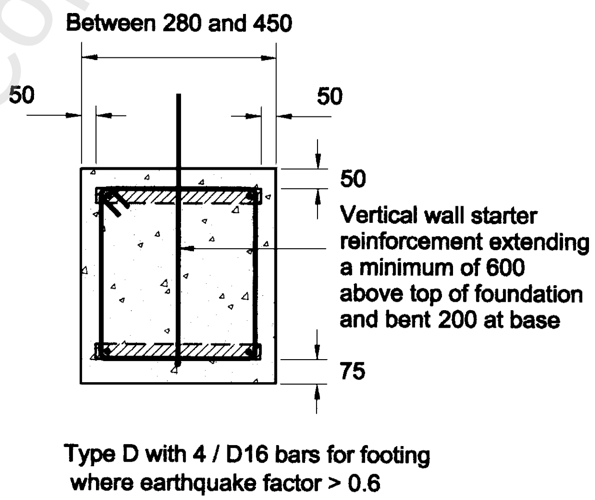


Figure 4.3 – Footing reinforcement where earthquake zone factor > 0.6

4.5.2.2
Footing reinforcement shall be tied with R10 stirrups at 400 mm centres.

Reinforcement at footing intersections shall be tied together with D16 L bars top and bottom and lapped 40 bar diameters as shown in figure 4.4.

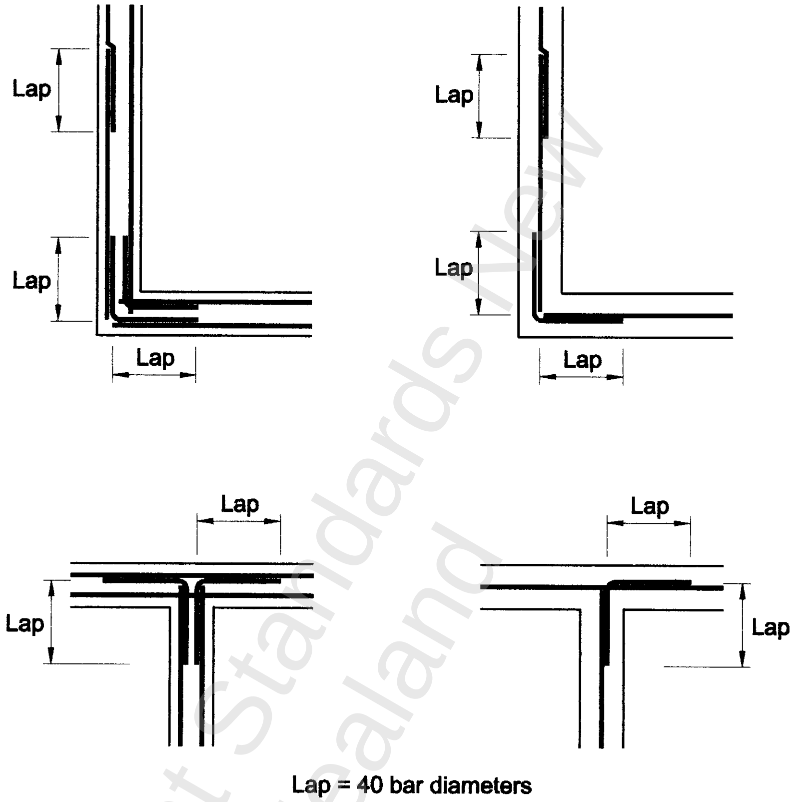


Figure 4.4 – Reinforcement at footing or bond beam intersections

4.6 Cover to reinforcement

The cover to reinforcement in the footing shall be:

(a) 75 mm to the bottom of the footing;

(b) 50 mm the sides of the footing;

(c) 50 mm minimum to the top of the footing.

Refer to figures 4.2 and 4.3.

4.7 Vertical wall starter reinforcement

4.7.1
Vertical wall starter reinforcement of the same diameter, type, spacing and location as the wall vertical reinforcement shall be provided in every footing for reinforced and partially reinforced earth walls so as to penetrate the wall to a distance of not less than 600 mm.

4.7.2
Vertical wall starter reinforcement shall be tied and anchored by the provision of at least one 90° bend around a tie bar the same size or larger than the wall starter contained in the bottom of the footing followed by a horizontal leg of 200 mm minimum.

4.8 Concrete slab-on-ground floors

4.8.1 *General*
Concrete floor slabs, where provided shall comply with the requirements of the following clauses.

4.8.2
The finished concrete floor level shall be a minimum of 175 mm above the adjoining finished exterior ground level or 100 mm above the finished level of adjoining permanent paving. Refer to figure 4.1.

C4.8.2
This provision is to limit splash back and avoid water ponding or damp soil build up against the base of a wall.

4.8.3 *Bearing*

4.8.3.1
Clause 4.3 (minimum depth of footings below cleared ground level) shall apply to the footing walls but not to the ground slab itself. For external walls, the depth shall be measured from the cleared ground level outside the footing wall and not from the cleared ground level beneath the ground slab. For internal walls the depth shall be measured from the cleared ground level beneath the floor slab. See figure 4.1.

4.8.3.2
The cleared ground level beneath the slab shall be such that:

(a) The granular fill material required by 4.8.4 shall be placed either on solid bottom or on firm fill which complies with 3.1.2(d);

(b) The thickness of granular fill shall be not less than 75 mm nor greater than 600 mm.

4.8.4 Granular fill
The granular base shall comply with the following requirements:

(a) It is placed and compacted in layers not exceeding 150 mm thick before compaction;

(b) Granular fill material shall be composed of rounded gravel, crushed rock and:

(i) Not more than 5 % shall pass a 2.2 mm sieve;

(ii) 100 % shall pass either:

(A) 19 mm sieve for any fill thickness; or

(B) 37.5 mm sieve for a fill thickness exceeding 100 mm.

4.8.5 *Vapour barriers*
The vapour barrier under the concrete slab shall comply with the requirements of NZS 3604.

4.8.6 *Thickness and reinforcement*
The thickness and reinforcement of concrete slabs shall comply with the requirements of NZS 3604.

4.8.7 *Support of loadbearing timber internal walls*
The support of loadbearing timber wall shall comply with the requirements of NZS 3604.

4.9 Damp proof course

4.9.1
A damp proof course shall be provided on the top of the footing at the underside of the earth wall.

The top of the concrete footing shall be roughened to 5 mm amplitude prior to the application of the damp proof course.

The damp proof course shall comprise 2 coats of bituminous paint for the full width of the earth wall or material which complies with AS/NZS 2904.

4.10 Splashback course

C4.10
A splashback back course of fired brick or poured concrete may be provided between the top of the concrete footing and underside of the earth wall to reduce the risk of erosion to the base of the wall particularly in exposed locations with driving rain or to protect the base of the wall during construction.

4.11 Footing construction details

4.11.1
Footing construction details for earth brick construction in accordance with this Standard shall be as shown on figures 4.1 to 4.7.

C4.11
Several alternative typical footing construction details for both footings with and without concrete floor slabs are shown on figures 4.5 to 4.7.

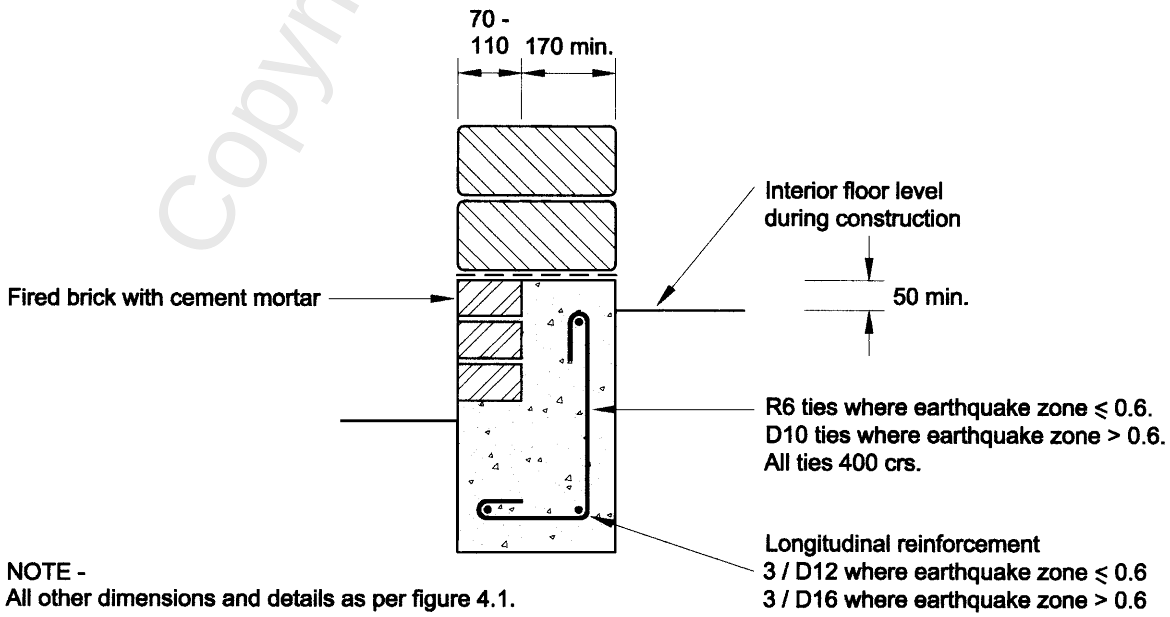


Figure 4.5 – Alternative strip footing type E with fired brick facing

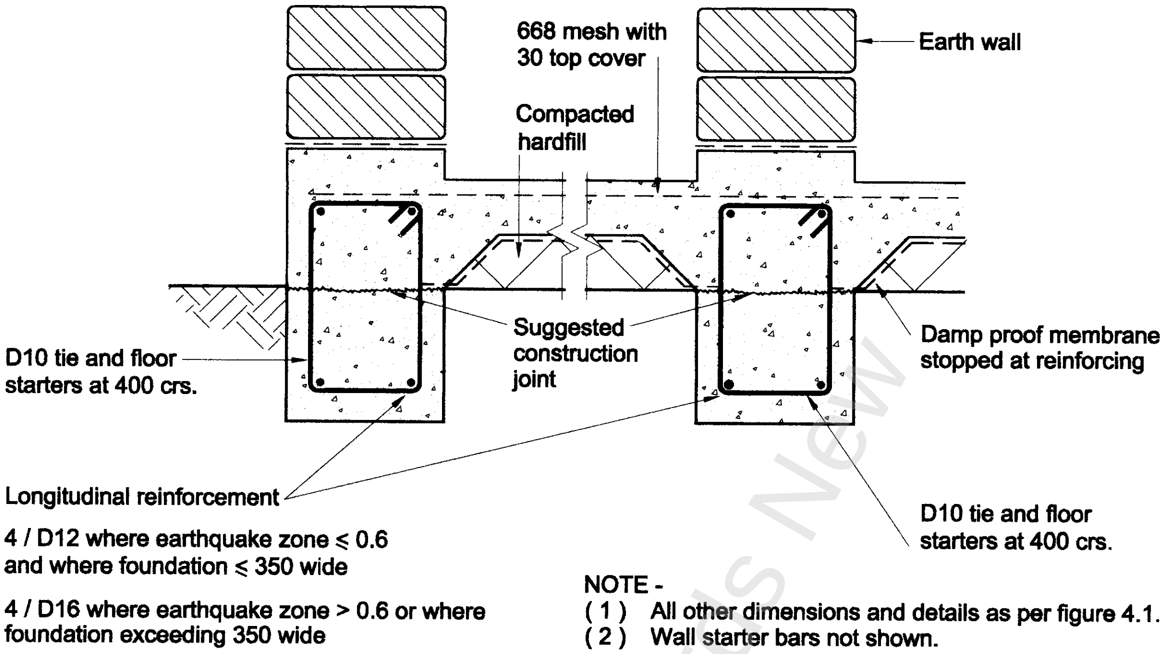


Figure 4.6 – Footing type F with concrete floor slab

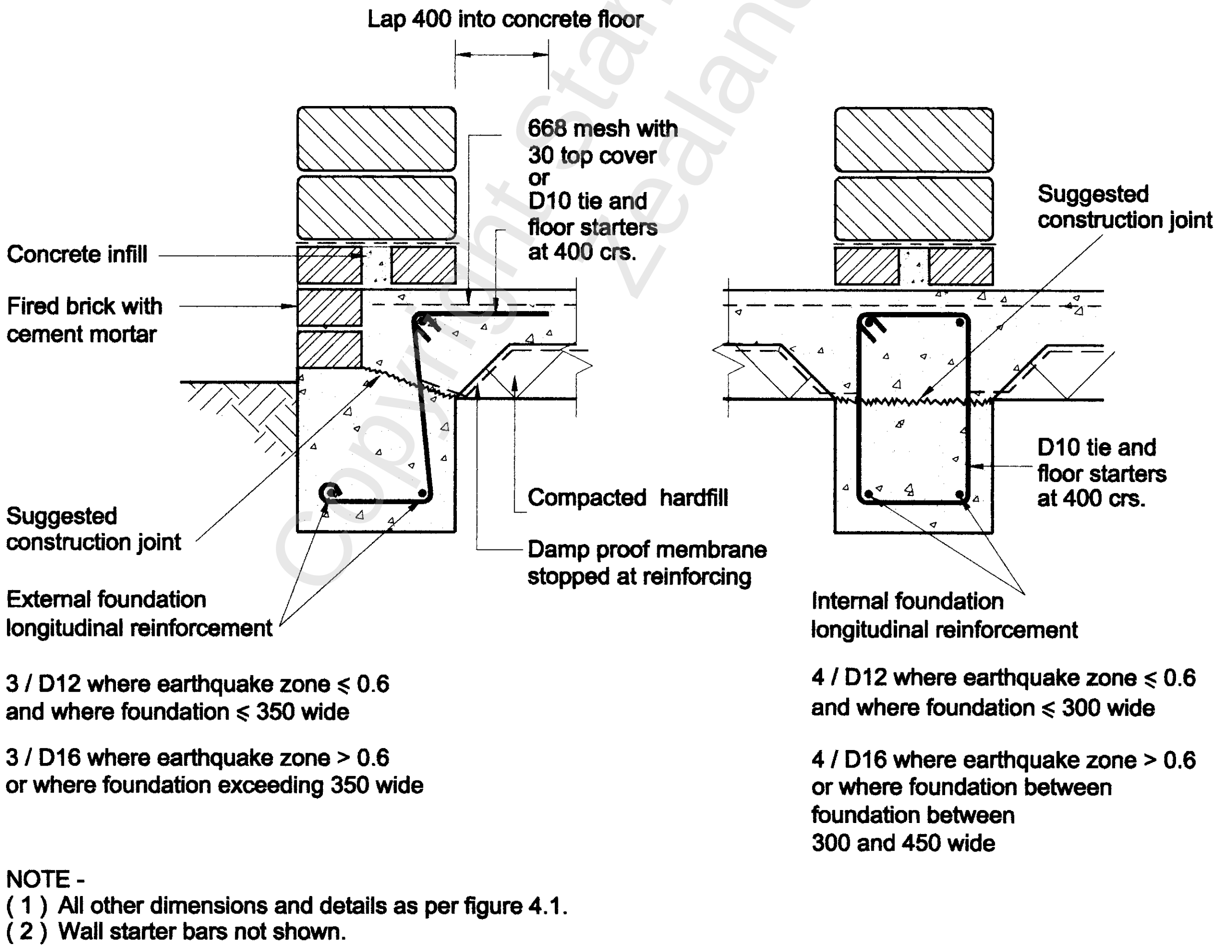
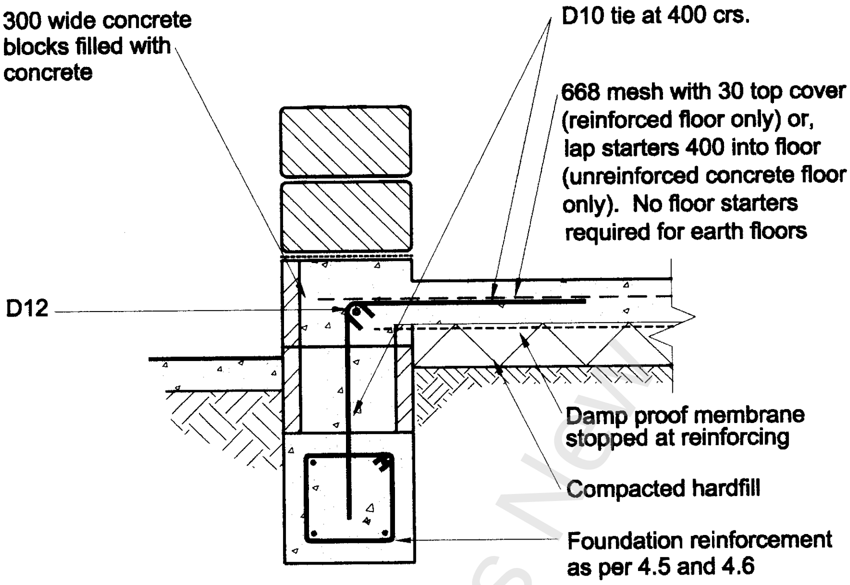


Figure 4.7 – Footing type G with concrete floor slab and fired brick facing



NOTE -
(1) All other dimensions and details as per figure 4.1.
(2) Wall starters not shown.

Figure 4.8 – Footing with concrete floor slab and concrete block facing

5 WALLS

5.1 General

5.1.1
The wall system of each storey shall consist of:

(a) A wall system of earth with or1 without loadbearing light timber framing walls to resist vertical loads complying with 5.2, combined with

(b) A wall system of earth to resist horizontal loads complying with 5.3, combined with

(c) Any other wall which is non-loadbearing shall be of light timber framing and shall not be taken into account for the purposes of 5.2 and 5.3.

5.1.2
Earth walls shall be reinforced in accordance with 5.4 and 5.8 where earthquake zone factor > 0.6.

Cinva brick walls shall be reinforced in all zones.

Where the earthquake zone factor, $Z \leq 0.6$, earth walls may be either reinforced, partially reinforced or unreinforced. Where reinforced, such walls shall be in accordance with 5.5 and 5.8. Where unreinforced, such walls shall be in accordance with 5.6. Where partially reinforced, such walls shall be in accordance with 5.7.

5.1.3
The thickness of earth walls shall be a minimum of 280 mm except for cinva brick walls which shall conform with section 11 of this Standard.

5.1.4
The maximum thickness of earth walls for earth buildings complying with this Standard shall be 350 mm exclusive of any surface finishes including plaster.

> ***C5.1.4***
> *Earth buildings with earth walls thicker than provided for in 5.1.4 are outside the scope of this Standard and will require specific design.*

5.1.5
Structural diaphragms complying with section 6 or bond beams complying with section 7 shall be provided at the top of all earth walls and at first floor and ceiling levels.

> ***C5.1.5***
> *Generally structural diaphragms are recommended in preference to bond beams.*

5.1.6
Openings on external walls shall be located a minimum of 900 mm from the outside edge of an external corner.

5.1.7
Earth wall panels between openings shall have a minimum length of 600 mm.

5.2 Wall systems to resist vertical loads

5.2.1
The wall system to resist vertical loads shall be such that all roof framing members and all floor framing members shall be directly supported by any of the following or any combination of them:

(a) Structural walls constructed of earth;

(b) Loadbearing timber framing in accordance with NZS 3604 which may be supported on earth walls;

(c) Timber lintels in accordance with NZS 3604 which may be supported on earth walls;

(d) Reinforced concrete or timber lintels complying with section 8;

(e) Another roof or floor framing member;

(f) Reinforced concrete footing walls and footings.

5.2.2
No earth walls within the scope of this Standard shall be supported on a timber structure, except for timber lintels in accordance with section 8.

5.2.3
Lintels shall be fixed to earth walls in accordance with section 8.

5.3 Earth wall systems to resist horizontal loads

5.3.1 *General*
All earth buildings shall be braced by earth bracing walls in each of the 2 principal directions of the building, at 90° to each other, to resist horizontal wind and earthquake loads.

> ***C5.3.1***
> *Figure 5.1 is a chart summarizing the method for determining the bracing demand for a building.*
>
> *Figure 5.2 is a chart summarizing the method for determining the bracing capacity of walls.*

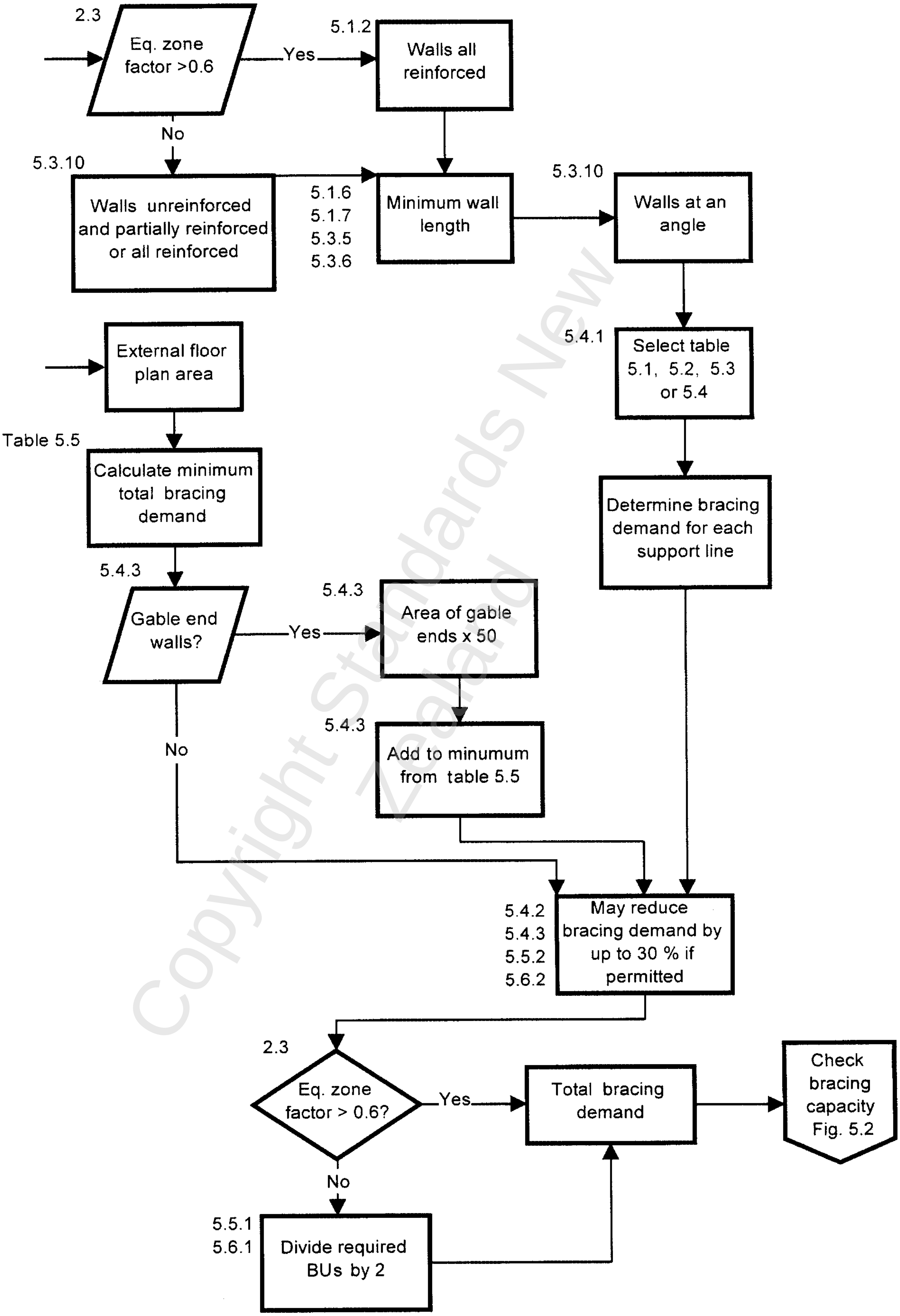


Figure 5.1 – Determination of bracing demand

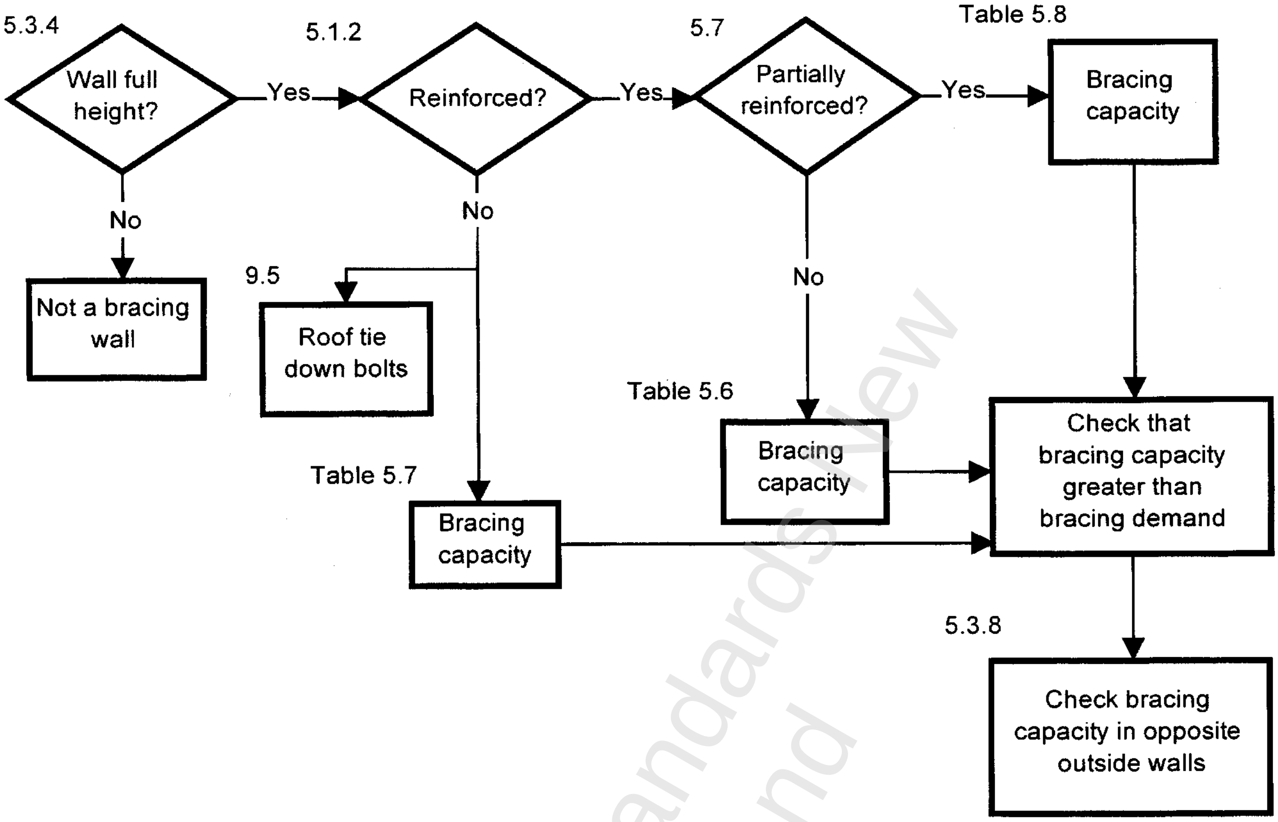


Figure 5.2 – Determination of bracing capacity

5.3.2
For earth buildings within the scope of this standard, the requirements for walls to be able to resist wind loads will in all cases be met or exceeded by the provisions required to resist earthquake loads.

5.3.3
The centrelines of parallel bracing lines shall be not more than 6 m apart. Refer to figure 5.3.

5.3.4
The earth walls of a building shall be subdivided into panels of various lengths as determined by 5.3.6.

C5.3.4
The maximum lengths of panels in long walls without openings are controlled by the maximum spacing of control joints specified in section 10.

5.3.5
Bracing walls shall be those full height panels with a minimum height of 1.8 m, a minimum length of 1.2 m for walls up to 2.4 m high, a minimum length of 1.5 m for walls up to 3.0 m high and a minimum length of 1.8 m for walls up to 3.3 m high and with no openings within the panel between the footing and top plate or bond beam. For the effective height of raking or gable end walls refer to 5.3.12.

5.3.6
The length of a bracing wall shall be the horizontal length along the wall between wall ends, openings, corners or control joints.

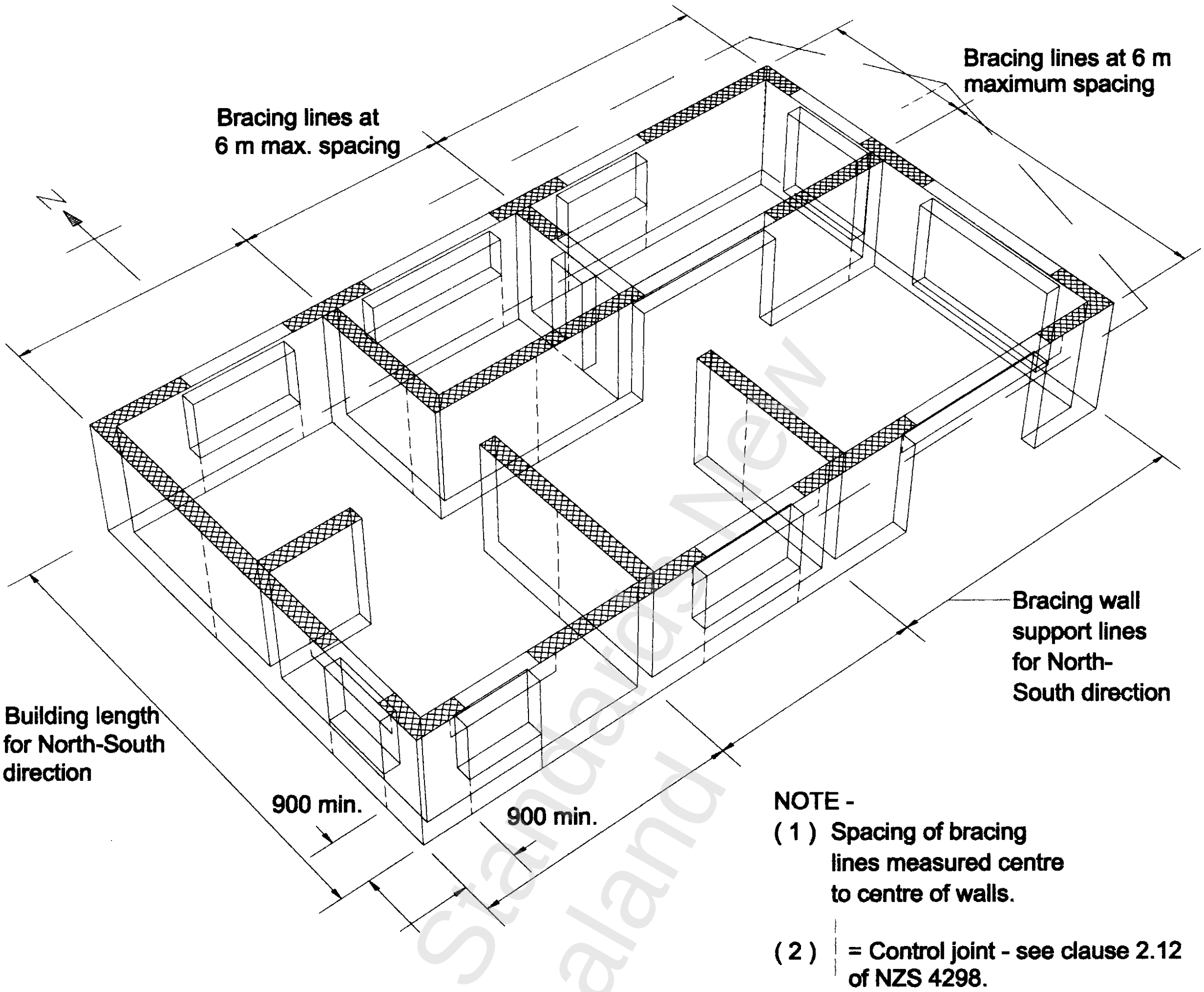


Figure 5.3 – Bracing line support system and openings at external corners

5.3.7

Subject to the requirements of 5.4, 5.5 and 5.6, wall bracing elements shall as far as is practicable be located at the corners of external walls and evenly throughout the buildings.

> ***C5.3.7***
> *The horizontal torsional resistance of buildings to resist earthquake and wind forces, are best served by wall bracing elements placed uniformly around a structure. The most effective locations for wall bracing are those extremities of the floor plan such as at external corners.*

5.3.8

The bracing capacity in each of the outside walls in each direction shall be such that the bracing capacity in one outside wall is not less than 50 % of the total of the bracing capacity in the opposite, parallel outside wall.

5.3.9

Bracing walls may be a maximum of 1 m either side of the bracing wall support line and contribute to the total bracing capacity for that support line.

> ***C5.3.9***
> *The bracing line chosen is to represent the combined line of action of all walls considered to act on that line and bracing walls may be a maximum of 1 m either side of the bracing wall support line.*

5.3.10
Where bracing walls are at the following angles to the bracing wall support line they may contribute to the total bracing capacity of that support line as follows:

(a) 30º to one direction and 60º in the other direction, 0.87 and 0.5 times the bracing capacity of the bracing wall;

(b) 45º to both directions, 0.7 times the bracing capacity of the bracing wall;

(c) The factors for other angles shall be obtained by specific design and is outside the scope of this Standard.

5.3.11
A bracing line shall consist either of all reinforced panels or all unreinforced panels and partially reinforced.

5.3.12
The effective height of a raking wall or gable end wall shall be taken as its average height.

5.3.13
Top storey timber wall bracing shall be as determined by NZS 3604.

5.3.14
Reinforced rammed earth walls may be designed and built without horizontal reinforcing by spacing vertical D12 steel bars as per table 5.10, and by following all other relevant sections of this standard.

5.4 Bracing demand for reinforced earth walls where earthquake zone factor > 0.6

5.4.1
The bracing demand for various building types, building lengths, and bracing wall support line spacings shall be as shown in the following tables:

(a) Table 5.1 for single storey earth walls and light roof;

(b) Table 5.2 for single storey earth walls and heavy roof;

(c) Table 5.3 for lower storey earth walls and timber part second storey and light roof;

(d) Table 5.4 for lower storey earth walls and timber second storey and light roof.

C5.4.1
For reinforced earth walls with limited ductility 20 bracing units are equivalent to 1 kN lateral force at the ultimate limit state at the top plate level with assumed construction of ground floor earth walls, timber first floor, timber walled part storey in the roof space not exceeding 50 % of the ground floor or timber second storey and a light or heavy roof.

For walls nominally 300 mm thick the values from tables 5.1 to 5.4 for 280 mm walls will apply.

Table 5.1 – Bracing demand for bracing support lines for
- **single storey earth walls**
- **light roof, and**
- **earthquake zone factor > 0.6**

Wall thickness and wall or storey height	Building length in direction of bracing walls (m)	Bracing demand (Bracing Units)					
		Exterior walls			Interior walls		
		Support line spacing (m)			Support line spacing (m)		
		3.0	4.5	6.0	3.0	4.5	6.0
280 thick walls 2400 high	6	310	370	430	420	540	660
	9	465	555	645	630	810	990
	12	620	740	860	840	1080	1320
	15	775	925	1075	1050	1350	1650
	21	1086	1295	1505	1470	1890	2310
280 thick walls 2750 high	6	355	424	493	481	619	756
	9	533	636	739	722	928	1134
	12	711	848	985	962	1237	1512
	15	888	1060	1232	1203	1546	1890
	21	1243	1484	1724	1684	2165	2646
350 thick walls 2400 high	6	388	463	537	525	675	825
	9	581	694	806	787	1012	1237
	12	775	925	1075	1050	1350	1649
	15	969	1156	1344	1312	1687	2062
	21	1357	1619	1881	1837	2362	2886
350 thick walls 2750 high	6	444	530	616	601	773	945
	9	666	795	923	902	1159	1417
	12	888	1060	1231	1203	1546	1889
	15	1110	1324	1539	1503	1932	2362
	21	1554	1854	2155	2105	2705	3306

Table 5.2 – Bracing demand for bracing support lines for
- **single storey earth walls**
- **heavy roof, and**
- **earthquake zone factor > 0.6**

Wall thickness and wall or storey height	**Building length in direction of bracing walls** (m)	**Bracing demand (Bracing Units)**					
		Exterior walls			**Interior walls**		
		Support line spacing (m)			**Support line spacing** (m)		
		3.0	4.5	6.0	3.0	4.5	6.0
280 thick walls 2400 high	6	330	400	470	460	599	739
	9	495	600	705	690	899	1109
	12	660	800	939	919	1199	1478
	15	825	1000	1174	1149	1499	1848
	21	1155	1399	1644	1609	2098	2587
280 thick walls 2750 high	6	378	458	538	527	687	847
	9	567	687	807	790	1030	1270
	12	756	916	1076	1053	1373	1693
	15	945	1145	1345	1316	1717	2117
	21	1323	1603	1883	1843	2403	2963
350 thick walls 2400 high	6	412	500	587	574	749	924
	9	619	749	880	862	1124	1386
	12	825	999	1174	1149	1498	1847
	15	1031	1249	1467	1436	1873	2309
	21	1443	1749	2054	2011	2622	3233
350 thick walls 2750 high	6	472	572	672	658	858	1058
	9	708	859	1009	987	1287	1587
	12	945	1145	1345	1316	1716	2116
	15	1181	1431	1681	1645	2145	2645
	21	1653	2003	2353	2303	3003	3703

Table 5.3 – Bracing demand for bracing support lines for
- **single storey earth walls**
- **timber part storey**
- **light roof, and**
- **earthquake zone factor > 0.6**

Wall thickness and wall or storey height	Building length in direction of bracing walls (m)	Bracing demand (Bracing Units) – Exterior walls – Support line spacing (m) 3.0	4.5	6.0	Interior walls – Support line spacing (m) 3.0	4.5	6.0
280 thick walls 2400 high	6	351	428	504	503	656	809
	9	527	642	757	754	983	1213
	12	703	856	1009	1005	1311	1617
	15	879	1070	1261	1257	1639	2021
	21	1230	1498	1765	1759	2295	2830
280 thick walls 2750 high	6	403	490	578	576	751	926
	9	604	735	867	864	1126	1389
	12	805	980	1156	1151	1502	1852
	15	1006	1225	1444	1439	1877	2315
	21	1409	1716	2022	2015	2628	3242
350 thick walls 2400 high	6	439	535	630	628	819	1010
	9	659	802	945	942	1229	1516
	12	878	1069	1261	1256	1639	2021
	15	1098	1337	1576	1570	2048	2526
	21	1537	1872	2206	2198	2867	3536
350 thick walls 2750 high	6	503	613	722	719	938	1157
	9	755	919	1083	1079	1408	1736
	12	1006	1225	1444	1439	1877	2315
	15	1258	1531	1805	1799	2346	2894
	21	1761	2144	2527	2518	3285	4051

Table 5.4 – Bracing demand for bracing support lines for
- **single storey earth walls**
- **timber second storey**
- **light roof, and**
- **earthquake zone factor > 0.6**

Wall thickness and wall or storey height	Building length in direction of bracing walls (m)	Bracing demand (Bracing Units)					
		Exterior walls			Interior walls		
		Support line spacing (m)			Support line spacing (m)		
		3.0	4.5	6.0	3.0	4.5	6.0
280 thick walls 2400 high	6	393	486	579	585	771	957
	9	589	729	868	878	1157	1436
	12	785	971	1157	1170	1542	1914
	15	982	1214	1447	1463	1928	2393
	21	1375	1700	2025	2048	2699	3350
280 thick walls 2750 high	6	450	556	663	670	883	1096
	9	675	835	994	1005	1325	1645
	12	900	1113	1326	1341	1767	2193
	15	1125	1391	1657	1676	2208	2741
	21	1574	1947	2320	2346	3092	3837
350 thick walls 2400 high	6	491	607	723	731	964	1196
	9	736	910	1085	1097	1446	1794
	12	982	1214	1446	1463	1927	2392
	15	1227	1517	1808	1828	2409	2990
	21	1718	2124	2531	2560	3373	4187
350 thick walls 2750 high	6	562	695	828	838	1104	1370
	9	843	1043	1243	1257	1656	2055
	12	1124	1391	1657	1675	2208	2740
	15	1405	1738	2071	2094	2760	3425
	21	1968	2433	2899	2932	3864	4796

5.4.2 Buildings without earth gable end walls

The total bracing capacity of the building in each direction shall comply with the minimum number per square metre shown in table 5.5 for buildings without earth gable walls. The total bracing demand at any support line as shown in tables 5.1 to 5.4 shall be reduced by up to 30 % provided the total bracing capacity of the building in each direction complies with the minimum number per m^2 shown in table 5.5 for buildings without earth gable walls.

C5.4.2

The wall bracing capacity is able to be reduced by up to 30 % allowing for the conservative assumption of walls at 3 m spacings in the calculation of wall bracing demand for each support line.

5.4.3 Buildings with earth gable end walls

The total bracing capacity of the building in each direction shall comply with the minimum number per square metre shown in table 5.5 plus the total face area of earth gable walls above the nominal building height multiplied by 50 for buildings with earth gable walls. The bracing demand at any support line as shown in tables 5.1 to 5.4 shall be reduced by up to 30 % provided the total bracing capacity of the building in each direction complies with the minimum number per m^2 shown in table 5.5 plus the total face area of earth gable walls above the nominal building height multiplied by 50 for buildings with earth gable walls.

Table 5.5 – Minimum bracing demand per square metre for earthquake zone factor > 0.6

		Bracing units required per m^2 of external floor plan area of building					
	Earth wall thickness (mm)	**2400 mm wall or storey height**			**2750 mm wall or storey height**		
Support line spacing (m)		3	4.5	6	3	4.5	6
Single storey earth walls and light roof	280 350	25 30	21 26	20 24	28 34	24 29	22 27
Single storey earth walls and heavy roof	280 350	28 33	25 29	23 27	31 37	27 32	25 30
Lower storey earth, timber part second storey and light roof	280 350	34 40	31 35	29 33	37 43	33 38	31 35
Lower storey earth, timber second storey and light roof	280 350	43 48	39 43	37 41	46 52	41 46	39 44

5.4.4

The bracing capacity of reinforced earth bracing walls shall be as shown in table 5.6. Refer to 5.3.12 for the height of raking or gable end walls.

Table 5.6 – Bracing capacity of reinforced earth walls

Wall length (*L*) (m)	Wall heights (m)			
	2.4	2.7	3.0	3.3
	Bracing units provided			
1.2	262	NA	NA	NA
1.5	347	309	278	NA
1.8	432	384	346	314
2.1	517	459	413	376
2.4	601	535	481	437
2.7	686	610	549	499
3.0	771	685	617	561
>3.0	130+210xL	60+205xL	40+190xL	50+170xL

NOTE – Maximum wall heights are limited by 1.2.

5.5 Bracing demand for reinforced earth walls where earthquake zone factor ≤ 0.6

5.5.1

The bracing demand for various building types, building lengths and bracing wall support line spacings shall be 50 % of those shown in tables 5.1 to 5.4.

5.5.2

The total bracing capacity of the building in each direction shall comply with the minimum number per square metre in accordance with 5.4.2 and 5.4.3 divided by 2. The bracing demand at any support line shall be reduced by up to 30 % provided the total bracing capacity of the building in each direction complies with the minimum number of bracing units per square metre in accordance with 5.4.2 and 5.4.3 divided by 2.

5.5.3

The bracing capacity of reinforced earth bracing walls shall be as shown in table 5.6.

5.6 Bracing demand for unreinforced earth walls where earthquake zone factor ≤ 0.6

5.6.1

The bracing demand for various building types, building lengths and bracing wall support line spacings shall be 50 % of those shown in tables 5.1 to 5.4.

5.6.2

The total bracing capacity of the building in each direction shall comply with the minimum number per square metre in accordance with 5.4.2 and 5.4.3 divided by 2. The bracing demand at any support line shall be reduced by up to 30 % provided the total bracing capacity of the building in each direction complies with the minimum number per square metre in accordance with 5.4.2 and 5.4.3 divided by 2.

5.6.3

The bracing capacity of unreinforced earth bracing walls shall be as shown in table 5.7.

C5.6.3

For unreinforced earth walls with elastic response, 12 bracing units are equivalent to 1 kN lateral force at the ultimate limit state at the top plate level.

Table 5.7 – Bracing capacity of unreinforced earth walls

Wall length (L) (m)	Wall heights up to 3.3 m maximum Bracing units provided
280 mm thick wall	
1.5	45
1.8	65
2.1	90
2.4	115
2.7	145
3.0	180
>3.0	20 x L^2
350 mm thick wall	
1.5	55
1.8	80
2.1	110
2.4	145
2.7	185
3.0	225
>3.0	25 x L^2

5.7 Partially reinforced walls

5.7.1
Partially reinforced walls shall only be used where the earthquake zone factor $Z \leq 0.6$.

5.7.2
Partially reinforced earth walls shall have one D12 vertical reinforcing bar at each end of bracing walls at a distance of 150 mm to 200 mm from the ends of the bracing walls as shown in figure 5.4.

5.7.3
Partially reinforced earth walls need not contain horizontal reinforcing.

5.7.4
The bracing capacity provided by partially reinforced walls shall be as given by table 5.8.

Table 5.8 – Bracing capacity of partially reinforced earth walls

Wall length (*L*) (m)	**Wall heights** (m)			
	2.4	**2.7**	**3.0**	**3.3**
	Bracing units provided			
1.2	157	NA	NA	NA
1.5	208	185	167	NA
1.8	259	230	208	188
2.1	310	275	248	226
2.4	361	321	289	262
2.7	412	366	329	299
3.0	463	411	370	337
>3.0	78 + 126 x *L*	36 + 123 x *L*	24 + 114 x *L*	30 + 102 x *L*

NOTE – Maximum wall heights are limited by 1.2.

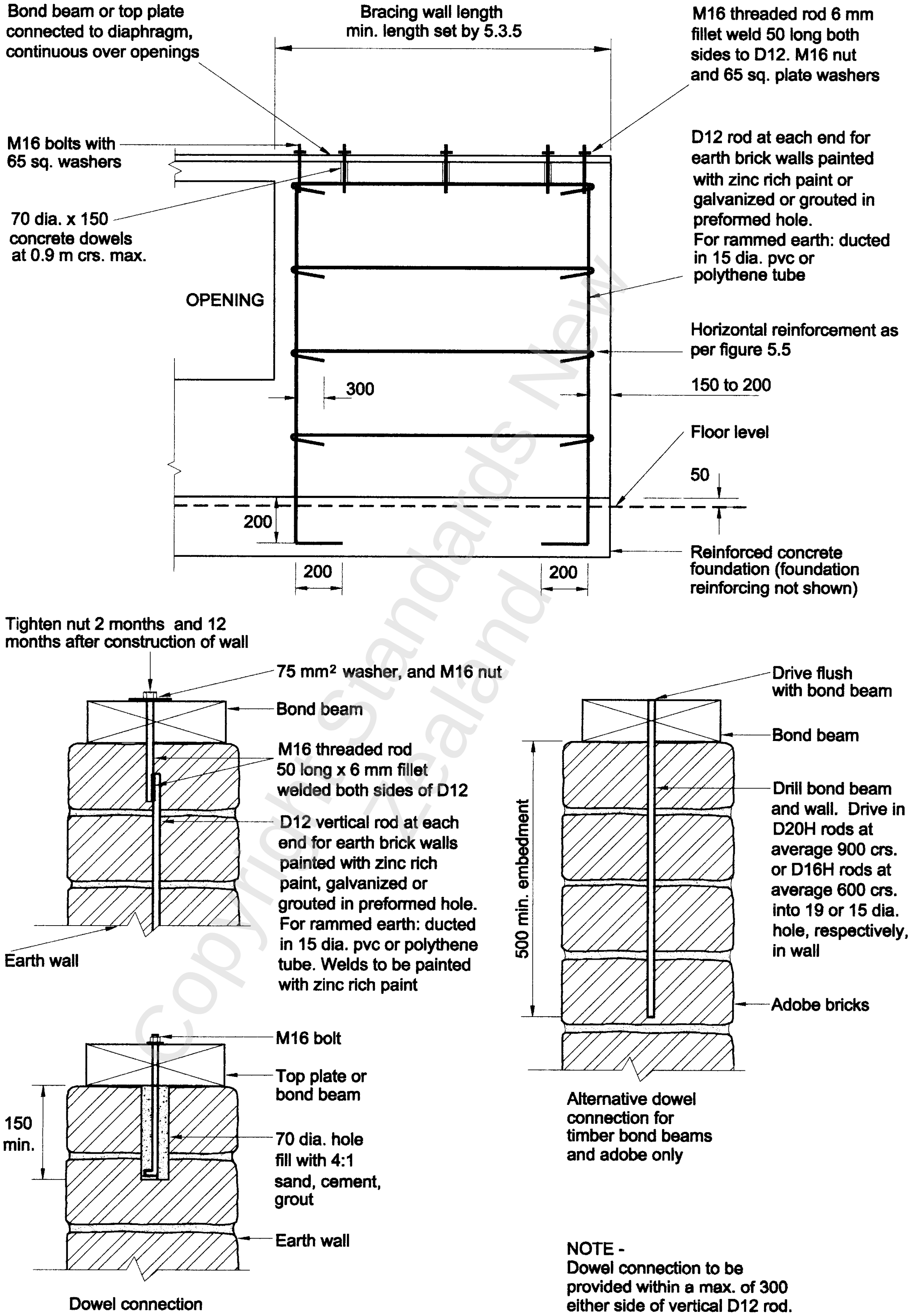


Figure 5.4 – Reinforcing and dowels for reinforced and partially reinforced earth walls

5.8 Reinforcement of earth walls 280 to 350 mm thick

5.8.1
Reinforced earth walls shall have one D12 vertical reinforcing bar at each end of bracing walls at a distance of 150 mm to 200 mm from the ends of the bracing wall as shown in figure 5.4.

5.8.2
Except as provided by 5.8.4, all reinforced adobe, rammed earth and pressed brick walls shall have vertical D12 reinforcing bars at the average and maximum spacings shown in table 5.9.

C5.8.2
Vertical reinforcing provided under 5.8.1 shall be included within the requirements of 5.8.2.

Table 5.9 – Spacing of vertical D12 reinforcement in earth walls

Height of wall (m)	**Average spacing** (m)	**Maximum spacing** (m)
2.4	1.65	2.10
2.7	1.35	1.80
3.0	1.05	1.50
3.3	0.75	1.20

5.8.3
Except as provided by 5.8.4, all reinforced earth walls 280 to 350 mm thick shall have horizontal reinforcement which shall comprise one of the following alternatives:

(a) Type A – 5.3 mm diameter wire cut from 665 steel mesh reinforcing with 100 mm cross wires, at 450 mm centres in mortar joints as shown in figure 5.5; or

(b) Type B – Polypropylene geotechnical material such as polypropylene biaxial geogrid with square apertures 25 to 50 mm wide and with a quality control strength of 40 kN/m determined in accordance with BS 6906, cut into 200 mm wide strips at 450 centres in mortar joints as shown in figure 5.5. A 6 x 200 mm HDPE bodkin or 6 mm diameter minimum galvanized steel rod, 200 mm long threaded through the geogrid shall anchor the geogrid to the vertical reinforcing. The geogrid shall be pulled tight and fixed in place prior to being covered by earth wall material; or

(c) Type C – D12 bars at maximum 900 centres as shown in figure 5.4, 5.6 or 5.7; or

(d) As shown in figure 5.7 for reinforced rammed earth walls with concrete columns.

C5.8.3 (c)
The geogrid may be tightened by use of a wider bodkin or larger diameter rod.

5.8.4
As an alternative to the provisions of 5.8.2 and 5.8.3, rammed earth walls may be constructed with no horizontal reinforcement embedded in the earth wall but with vertical D12 reinforcement provided in accordance with table 5.10.

Table 5.10 – Spacing of vertical D12 reinforcement in rammed earth walls without horizontal reinforcement

Height of wall (m)	**Average spacing** (m)	**Maximum spacing** (m)
2.4	1.15	1.50
2.7	0.95	1.20
3.0	0.70	0.90
3.3	0.50	0.60

5.8.5
Each horizontal reinforcing member shall be in a single continuous length without laps between ends of bracing walls. Joints in horizontal reinforcing shall be located at vertical D12 rods at ends of bracing walls. A minimum overlap of 300 mm with a bodkin or 6 mm diameter rod either side of the vertical D12 rod shall be provided for joints in Type B reinforcing.

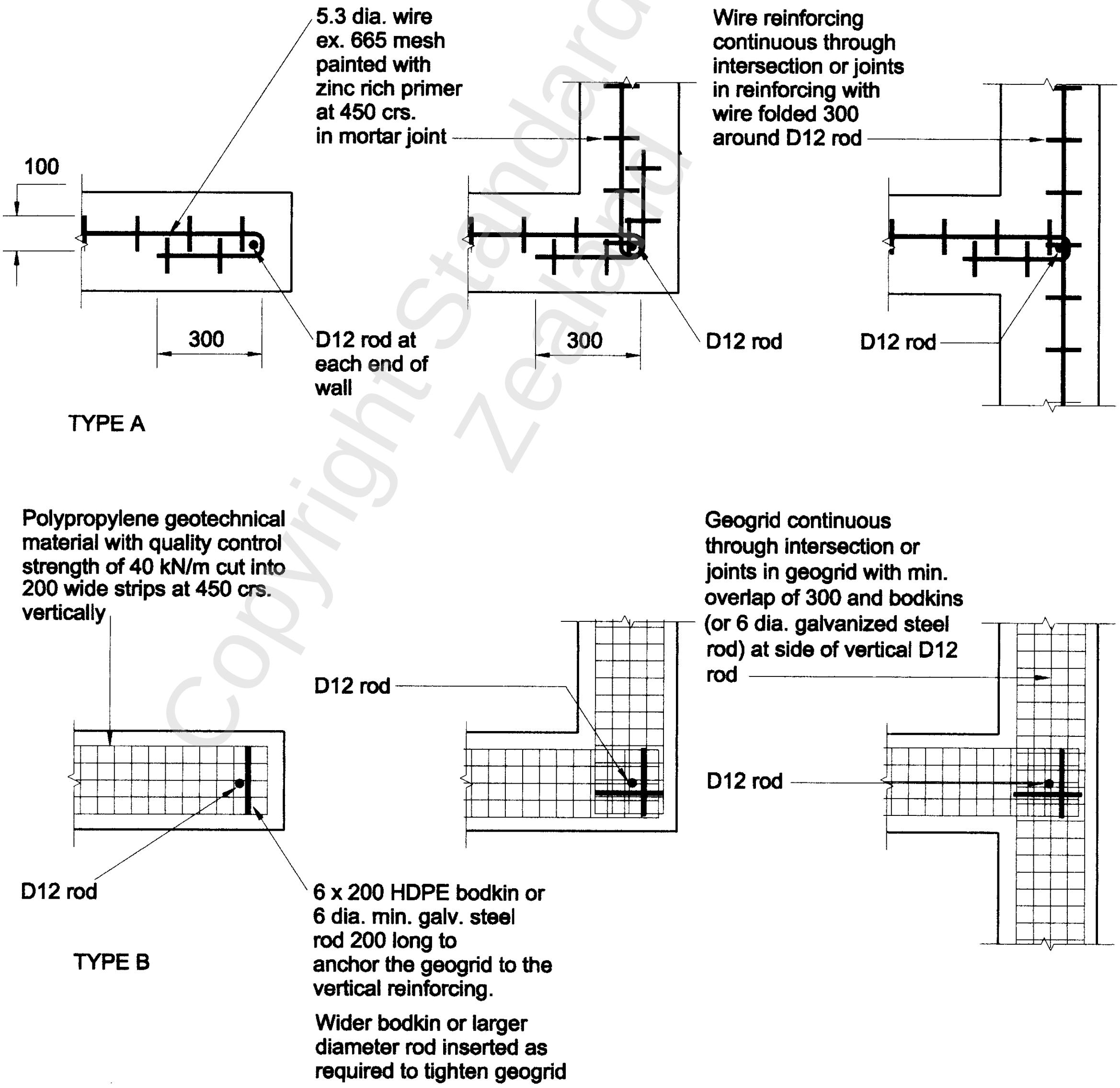
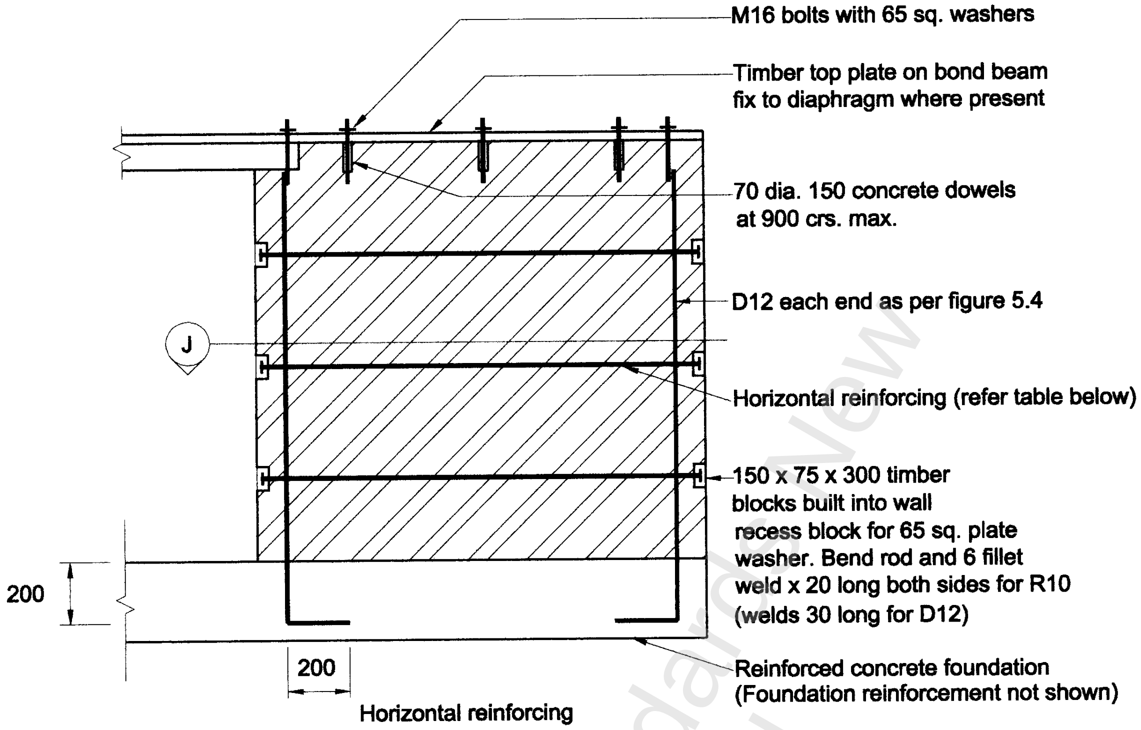
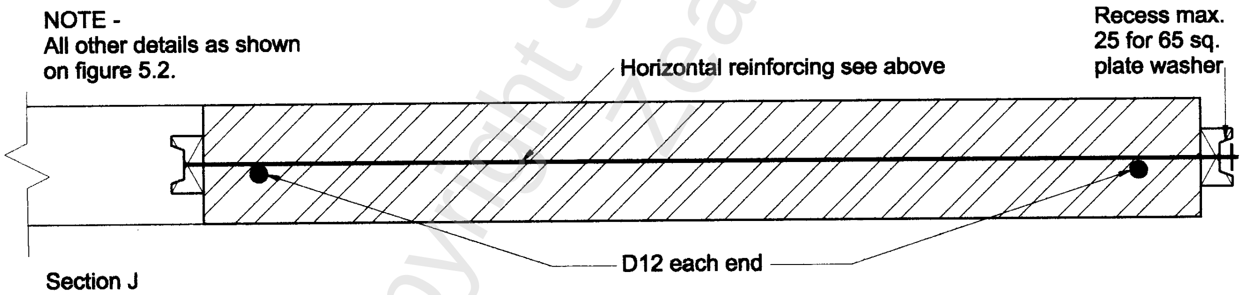


Figure 5.5 – Horizontal reinforcement for reinforced earth walls, Types A and B



Horizontal reinforcing

Bracing wall length	**Horizontal reinforcing**
1.8 - 3.0 m	R10 AT 600 crs or D12 AT 900 crs
1.2 - 1.8 m	R10 AT 600 crs



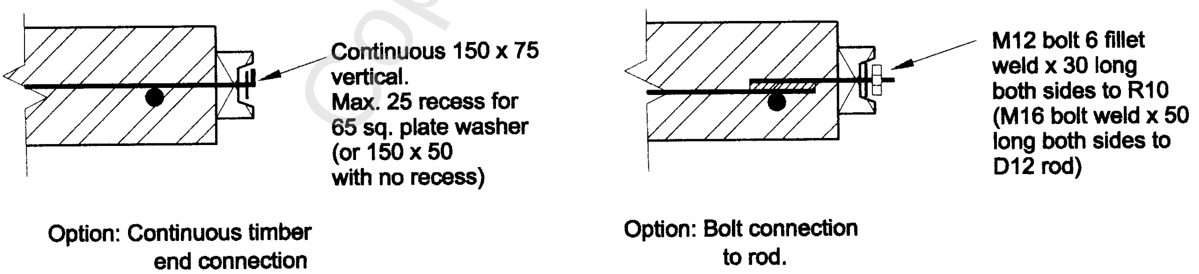
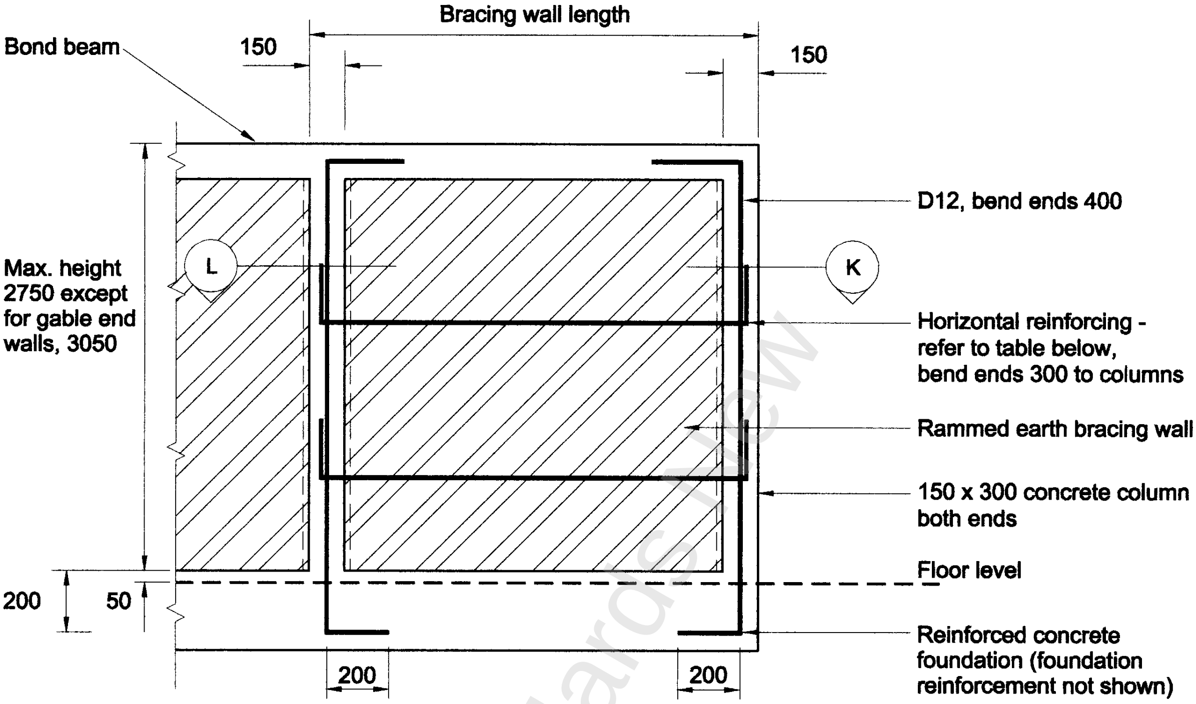


Figure 5.6 – Horizontal reinforcement for reinforced earth walls, Type C



HORIZONTAL REINFORCING

Bracing wall length	Horizontal reinforcing
1.8 - 3.0 m	R10 at 800 crs or D12 at 800 crs
1.2 - 1.8 m	R10 at 600 crs

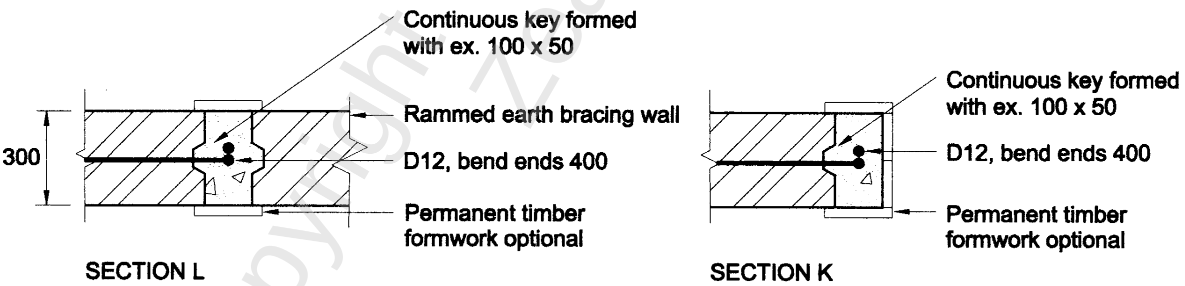


Figure 5.7 – Reinforced rammed earth walls with concrete columns

5.9 Reinforcement of rammed earth walls, 280 to 350 mm thick

5.9.1

Reinforced rammed earth walls shall be constructed in accordance with 5.8 and as shown on figure 5.4 with a D12 vertical reinforcing rod ducted within a 15 mm diameter PVC or polythene tube or as shown in figure 5.7 for walls with a concrete column on both sides of the rammed earth panel.

5.9.2

All reinforced rammed earth walls shall have horizontal reinforcement as provided for in 5.8.3.

5.9.3
For rammed earth walls with concrete columns the horizontal reinforcement shall be as shown in figure 5.8 at corners and ends of short return walls.

5.9.4
For rammed earth walls with concrete columns horizontal reinforcement comprising one R10 bar shall be provided under window openings as shown in figure 5.9.

5.9.5
Concrete columns between or at the ends of rammed earth panels shall not be poured until at least 7 days after the most recent panel has been rammed.

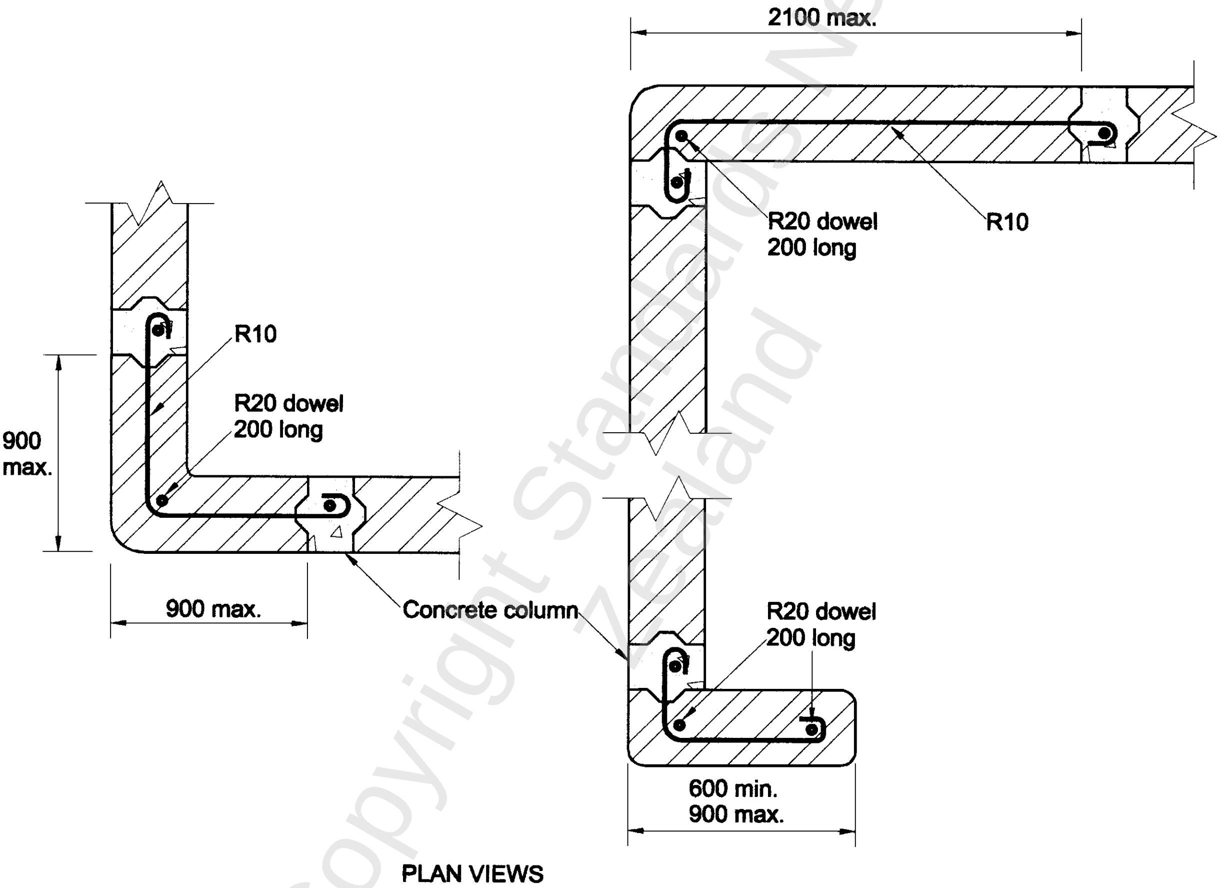
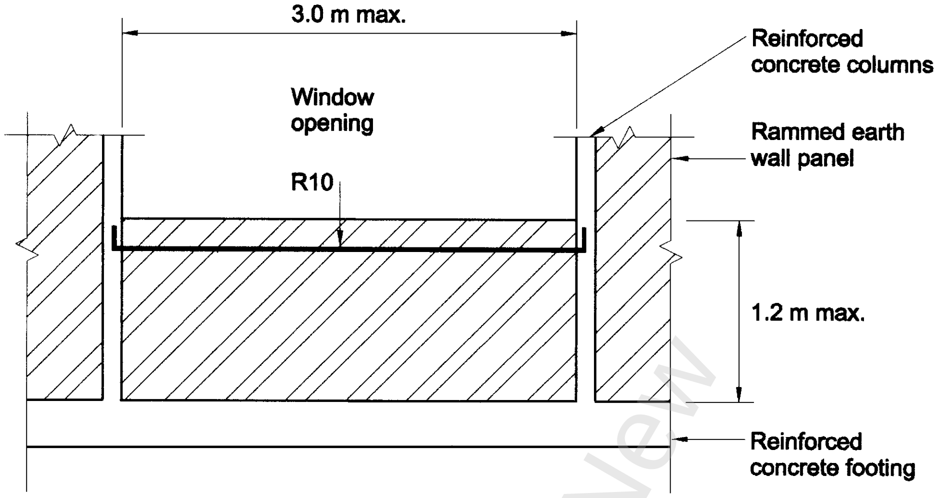


Figure 5.8 – Reinforcement of reinforced rammed earth walls with concrete columns at corners and short return walls



NOTE - The R10 reinforcing can be either in the rammed earth or incorporated into a poured concrete window sill.

Figure 5.9 – Reinforcement of reinforced rammed earth walls with concrete columns under window openings

5.10 Earth walls without structural diaphragms

5.10.1
Where it is not possible to connect earth walls to a structural roof, all walls shall be laterally supported at the top by a bond beam connected to return walls as shown on figure 5.10. All walls supporting a first floor or a heavy roof shall be connected to a diaphragm. Earth walls without structural diaphragms shall be used only for single storey construction with a light roof.

5.10.2
Bond beams without a structural diaphragm shall be reinforced concrete where earthquake zone factor > 0.6, in accordance with section 7.

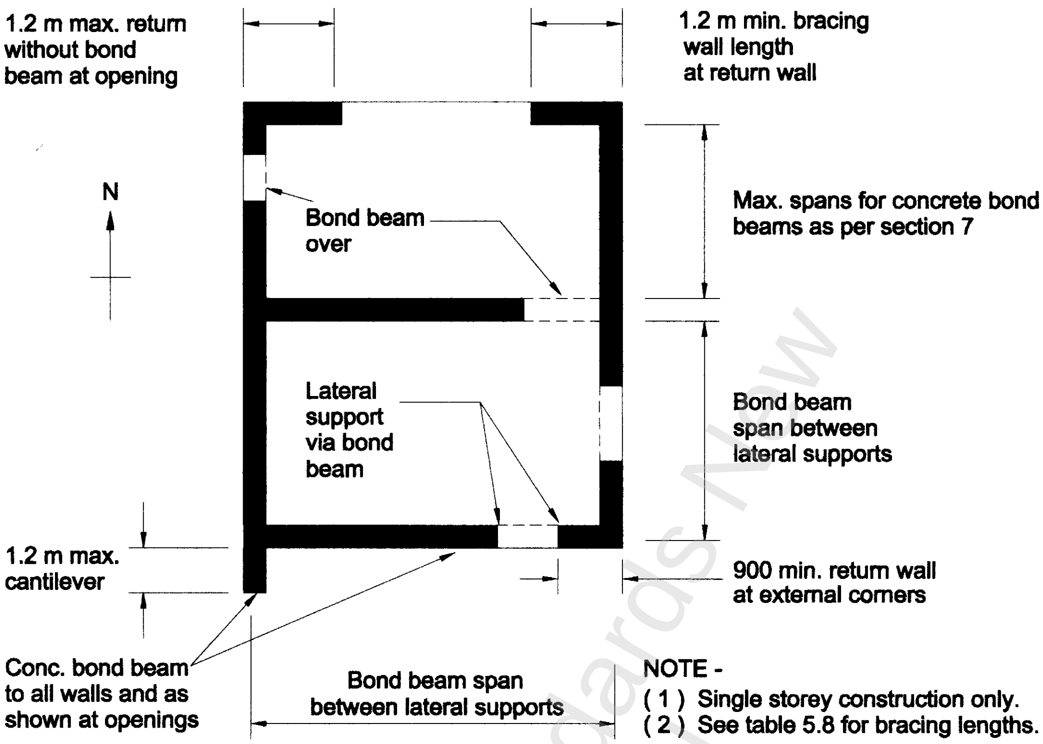
> ***C5.10.2***
> *Timber bond beams without a structural diaphragm may be used where earthquake zone factor > 0.6 if specifically designed. Such timber bond beams are outside the scope of this Standard.*

5.10.3
Timber bond beams without a structural diaphragm in accordance with section 7 may be used only where earthquake zone factor ≤ 0.6. Timber bond beams with a structural diaphragm shall be in accordance with section 6. Timber bond beams at timber gable end walls above earth walls shall be in accordance with 7.9.

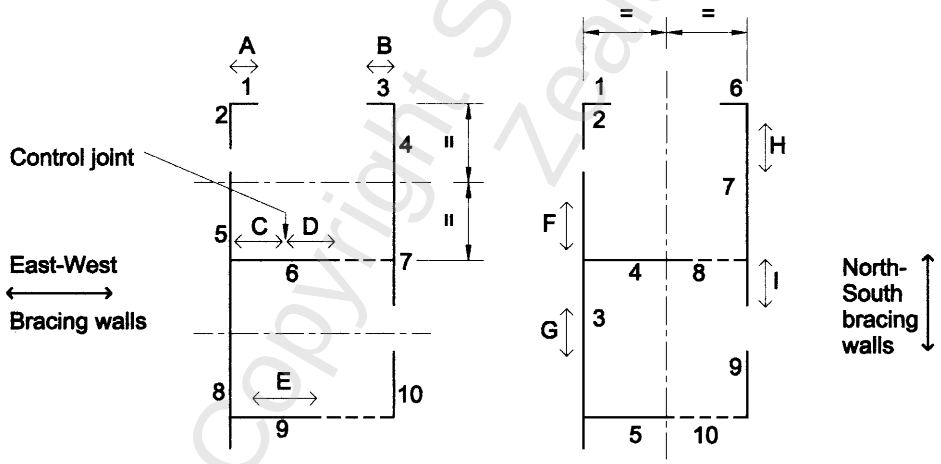
5.10.4
Return walls shall be provided to provide lateral restraint to bond beams. Such return walls shall contain earth bracing walls in accordance with 5.3 to 5.9.

5.10.5
The maximum length of a bond beam spanning between supporting return walls shall be 6.0 m. The bond beam shall be constructed in accordance with section 7 and as shown in figures 7.1, 7.2 and 7.3.

5.10.6
The maximum distance that a non-continuous concrete bond beam may extend past a return wall shall be 1.2 m as shown in figure 5.10.



TYPICAL EARTH WALL LAYOUT



Supported wall length	To bracing walls
1+2	A
3+4	B
5+6+7	C+D
8+9+10	E

Supported wall length	To bracing walls
1+2+3+4+5	F+G
6+7+8+9+10	H+I

ALLOCATION OF SUPPORTED WALL LENGTH
TO BRACING WALLS AT RETURN WALLS

Figure 5.10 – Layout of earth walls with concrete bond beams and without a structural diaphragm

5.10.7
Timber bond beams without structural diaphragms shall be continuous between return walls.

5.10.8
In addition to the requirements of 5.10.4, return bracing walls shall be provided as shown in table 5.11 and figure 5.10 for the total lengths of laterally supported wall with bond beam only and without a structural diaphragm.

Table 5.11 – Length of return walls for bond beam supported walls

Laterally supported wall length (m)	**Minimum return bracing wall length** (m)
4.5	1.2
6.0	1.5
7.5	1.8
9.0	2.1
10.5	2.25
12.0	2.4

5.11 Connection between walls and top plates or bond beams

Unreinforced, partially reinforced and reinforced earth walls shall be connected to bond beams and top plates by dowels as shown in figure 5.4. These dowels shall be in addition to hold down bolts required by 9.5.

> ***C5.11***
> *Dowels prevent bond beams or wall plates from sliding sideways from the walls under lateral loads.*

6 STRUCTURAL DIAPHRAGMS

6.1 General

6.1.1
All structural diaphragms supporting earth walls against horizontal loads shall be constructed in accordance with this section.

6.1.2
Structural diaphragms complying with 6.2 and 6.3 shall in addition be constructed as follows:

(a) The diaphragm shall be square or rectangular and its length shall not exceed twice its width, both length and width being measured between supporting walls;

(b) Diagonal sarking or sheet materials shall cover the entire area of the diaphragm. Sheet materials shall be laid in a running bond pattern and be continuous across adjacent diaphragms.

(c) The minimum sheet size shall be 1800 mm x 900 mm except where the building dimensions prevent the use of a complete sheet;

(d) Each sheet shall be fastened along each edge to boundary members with nails at 150 mm centres and shall also be fastened to every intermediate framing member at 300 mm centres. Joints in sheet material shall be made over supports. 100 mm x 50 mm timbers fixed between joists with their top surfaces set to a common level shall be provided as necessary for this purpose. Refer to figure 6.1.

(e) Fastenings shall be not less than 10 mm from sheet edges.

C6.1.2

This clause requires more stringent requirements for structural diaphragms supporting earth walls than NZS 3604. Structural diaphragms supporting timber walls may however be in accordance with NZS 3604.

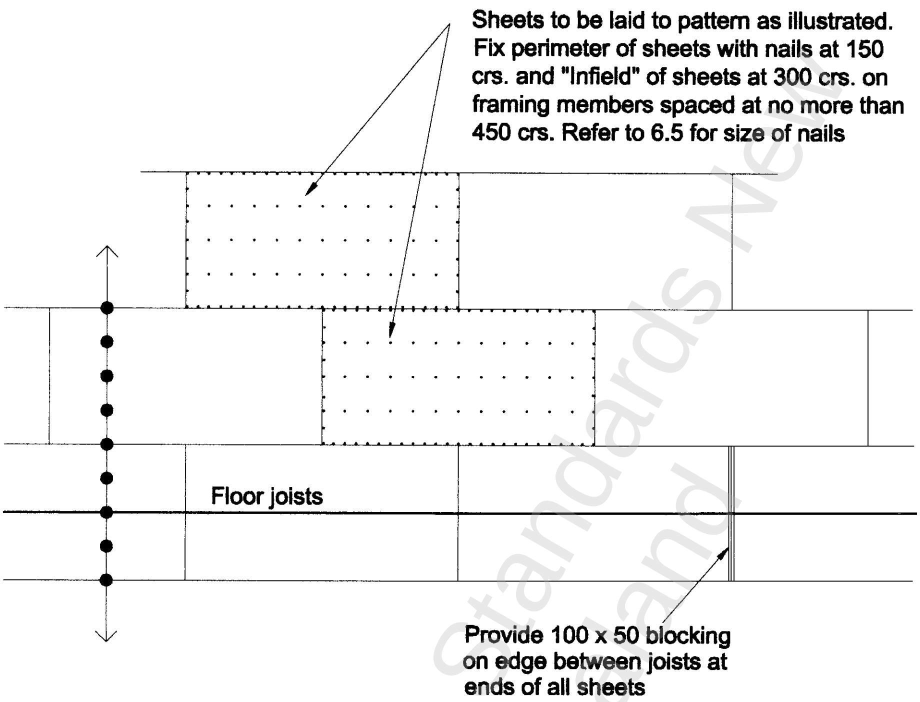


Figure 6.1 – Sheet sarking diaphragm

6.1.3

Rafter, joist and floor sizes and details shall be in accordance with NZS 3604 unless noted otherwise in this Standard.

6.1.4

Rafters and joists shall be solid blocked at all supports and earth walls and ridge lines. Rafters and joists shall be solid blocked in accordance with NZS 3604.

6.1.5

Floor or ceiling joists and rafter splices at supports, shall be lapped and nailed or nail plate connected to give a 2 kN axial tension capacity. This includes rafter ridge connections on roofs.

6.2 Ceiling and roof diaphragms

Ceiling and roof diaphragms at the tops of earth walls shall not be steeper than 25° to the horizontal and shall be constructed of diagonal sarking complying with 6.4 or sheet sarking complying with 6.5.

6.3 Floor diaphragms

Floor diaphragms at the tops of earth walls shall be constructed of diagonal strip flooring complying with 6.4 or sheet flooring complying with 6.6.

6.4 Diagonal sarking

Diaphragms constructed using diagonal sarking shall consist of ex 150 mm x 25 mm or ex 100 mm x 25 mm boards of minimum finished thickness of 18 mm that are:

(a) Inclined at not less than 40o nor more than 50o to the floor joist, ceiling joist or ridge line;

(b) Laid in straight parallel lines fitted closely together;

(c) Fixed to each joist, truss or rafter that they cross;

(d) Have end joints butted over rafters or joists with end joints in adjacent boards staggered;

(e) Fixed with 2/60 x 2.8 mm nails at each joist or rafter spaced at maximum 900 mm centres;

(f) Fixed with 2/60 x 2.8 mm nails at ends;

(g) Laid to cover the entire area of the diaphragm except for penetrations not exceeding 500 mm square or 550 mm diameter with a total area of 1.0 m2 or except for openings in accordance with 6.8;

(h) The edge members to which the sarking is fixed shall be continuous between return walls;

(j) As an alternative to 60 x 2.8 nails, 51 mm long, 7 gauge screws may be used.

6.5 Sheet sarking

Diaphragms constructed using sheet sarking shall:

(a) Be either:

(i) Plywood not less than 7.5 mm thick three-ply;

Nail fixed with 60 x 2.8 mm nails at 150 mm centres into framing member at sheet edges;

Nail fixed infield of sheets with 60 x 2.8 mm nails at 300 centres on framing members spaced at no more than 450 centres (see figure 6.1); or

(ii) High density internal ceiling plaster board lining not less than 9.5 mm thick and having a density not less than 880 kg per cubic metre and having a NZS 3604 rating in bracing units when fixed in place of not less than 100 Bracing Units per metre of element.

(b) Be fixed directly to rafters, ceiling battens, joists or trusses;

(c) Cover the entire area of the diaphragm except for openings in accordance with 6.8;

(d) The edge members to which the sheet material is fixed shall be continuous between return walls.

(e) As an alternative to 60 x 2.8 nails, 51 mm long, 7 gauge screws may be used.

Refer to figure 6.1.

6.6 Sheet flooring

Diaphragms constructed using sheet flooring shall be:

(a) Plywood not less than 18 mm in thickness; or

(b) Any other wood based product not less than 17 mm thick having a density of not less than 600 kg per m^3

and be nail fixed with 90 x 3.55 mm nails at 150 mm centres on framing members at sheet edges and infield of sheets spaced at 300 centres on framing members spaced at no more than 600 centres.

6.7 Connections of diaphragms to earth walls

6.7.1
All floor diaphragms shall be provided with boundary joists continuous between return walls and of dimensions not less than attached joists.

6.7.2
Diaphragms shall be connected to the bond beam or top plate at the top of the earth wall as shown in figures 6.2, 6.3 and 6.4.

6.7.3
Nail on plates shall be provided to connect the rafter blocking to the timber bond beam or top plate in accordance with table 6.1 and figures 6.2, 6.3, 6.4 and 6.5.

Table 6.1 – Connection of structural diaphragm to timber bond beam

Building location	Spacing of nail on plates (mm)
Where earthquake zone factor ≤ 0.6	1800 maximum
Where earthquake zone factor > 0.6	900 maximum

Refer to figure 6.3 for details of nail on plates.

6.8 Openings in diaphragms

6.8.1
Continuous boundary members shall be provided to all sides of openings in diaphragms and shall be not less than the rafters or joists of the diaphragm construction.

6.8.2
The dimensions of any single opening in a diaphragm in each of the 2 principal directions at right angles shall not exceed the following percentages of the respective parallel overall dimension of the diaphragm:

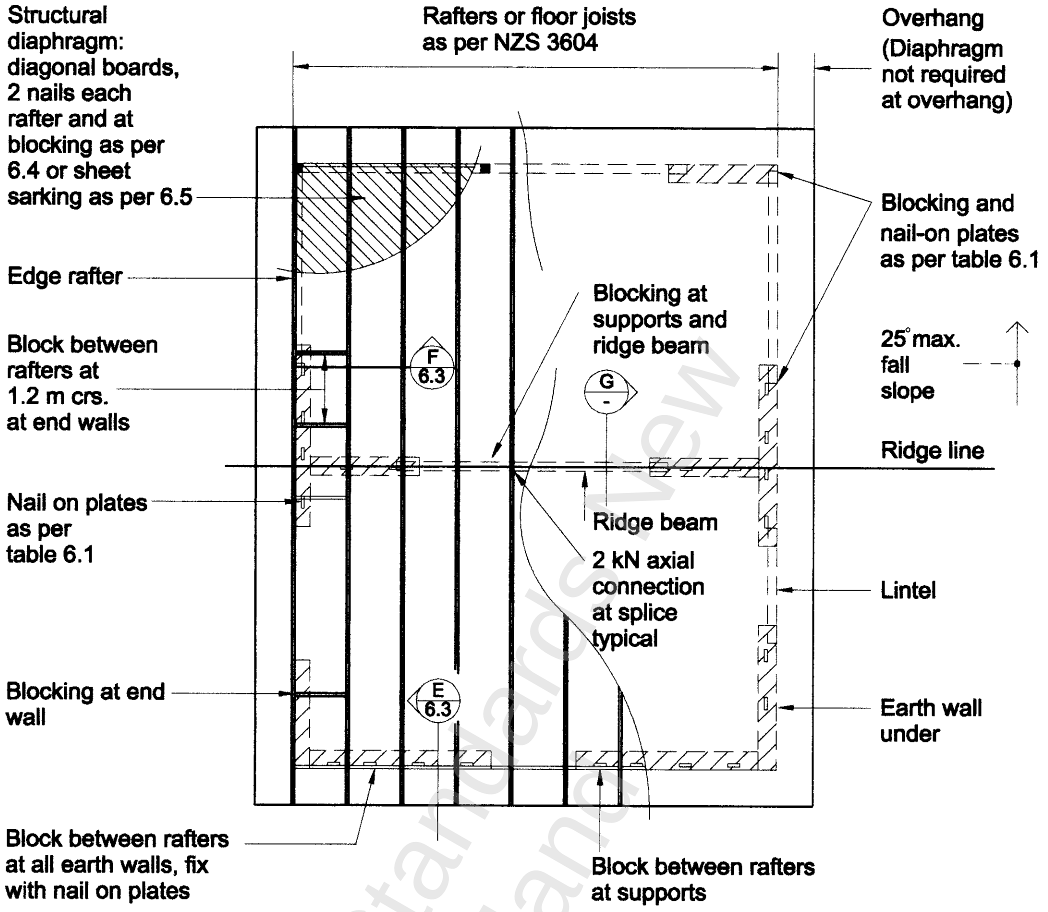
(a) Where the opening is located wholly within the middle half area of the diaphragm as defined in figure 6.5 .... 40 %

(b) Where the opening is located other than wholly within the middle half area of the diaphragm .... 20 %

In addition the sum of the areas of all openings in a diaphragm shall not exceed the following percentages of the total area of the diaphragm (inclusive of openings):

(i) Where all the openings are located wholly within the middle half area of the diaphragm .... 16 %

(ii) Where any opening is located other than wholly within the middle half area of the diaphragm .... 4 %



PLAN OF TYPICAL ROOF DIAPHRAGM

NOTE -
(1) Details similar at floor diaphragm.
(2) Floor joists blocked at midspan for spans over 3.6 m.

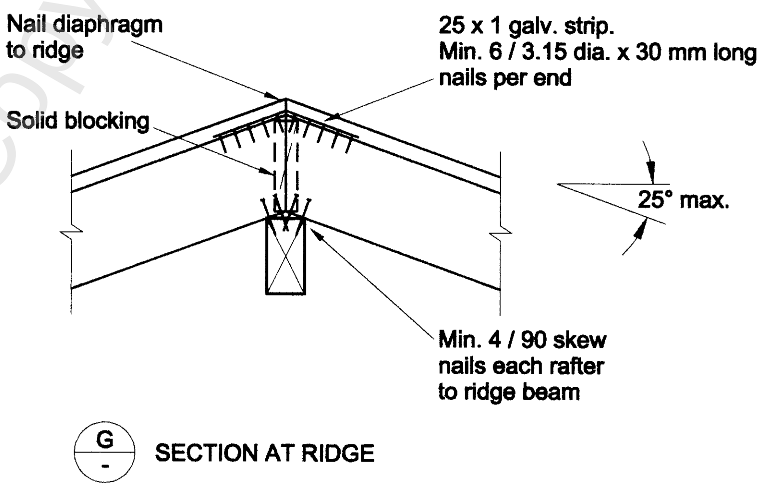
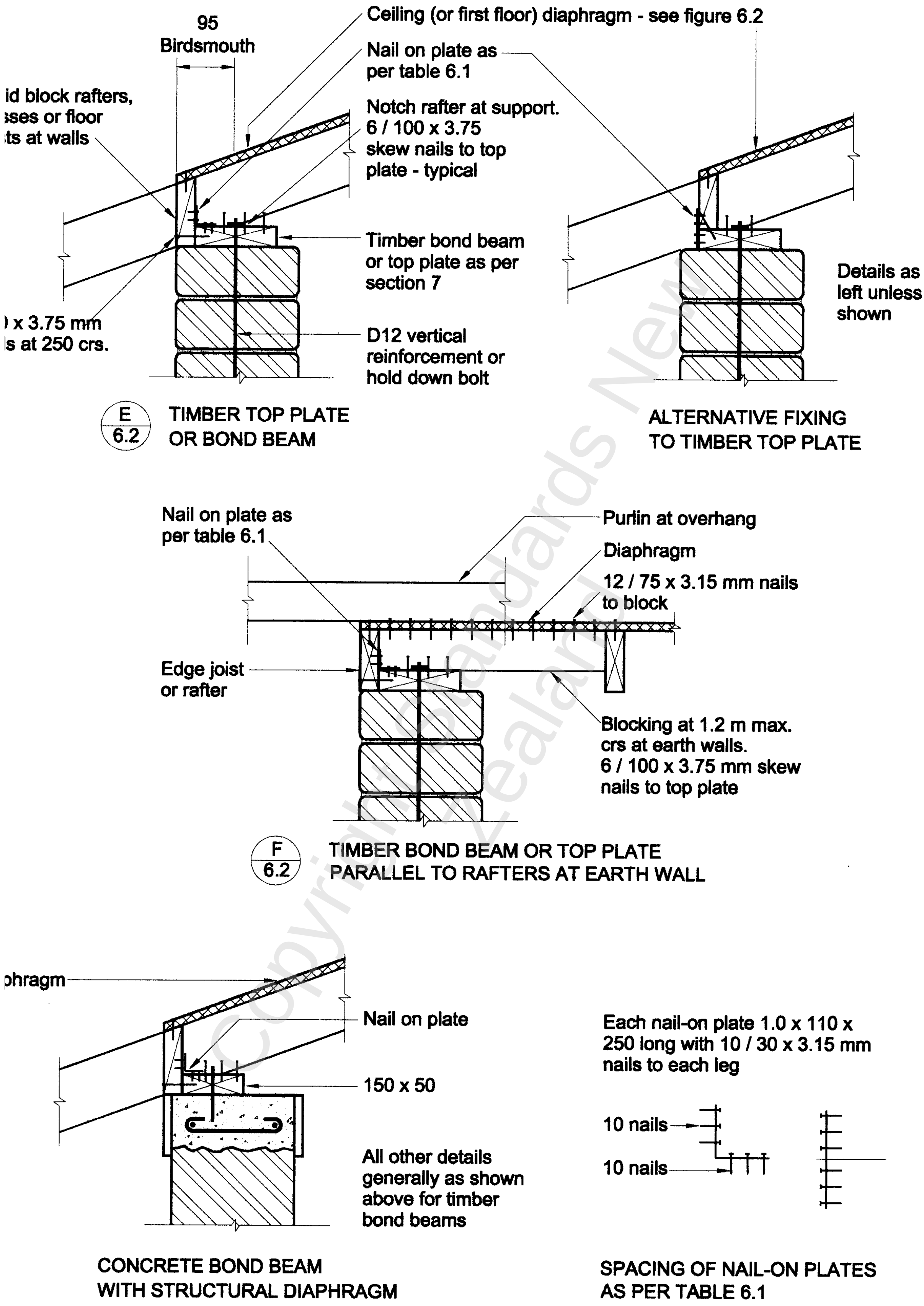


Figure 6.2 – Diaphragm fixing details



NOTE – These details apply to diaphragms with rafters, trusses and floor joists.

Figure 6.3 – Connection of diaphragms to walls

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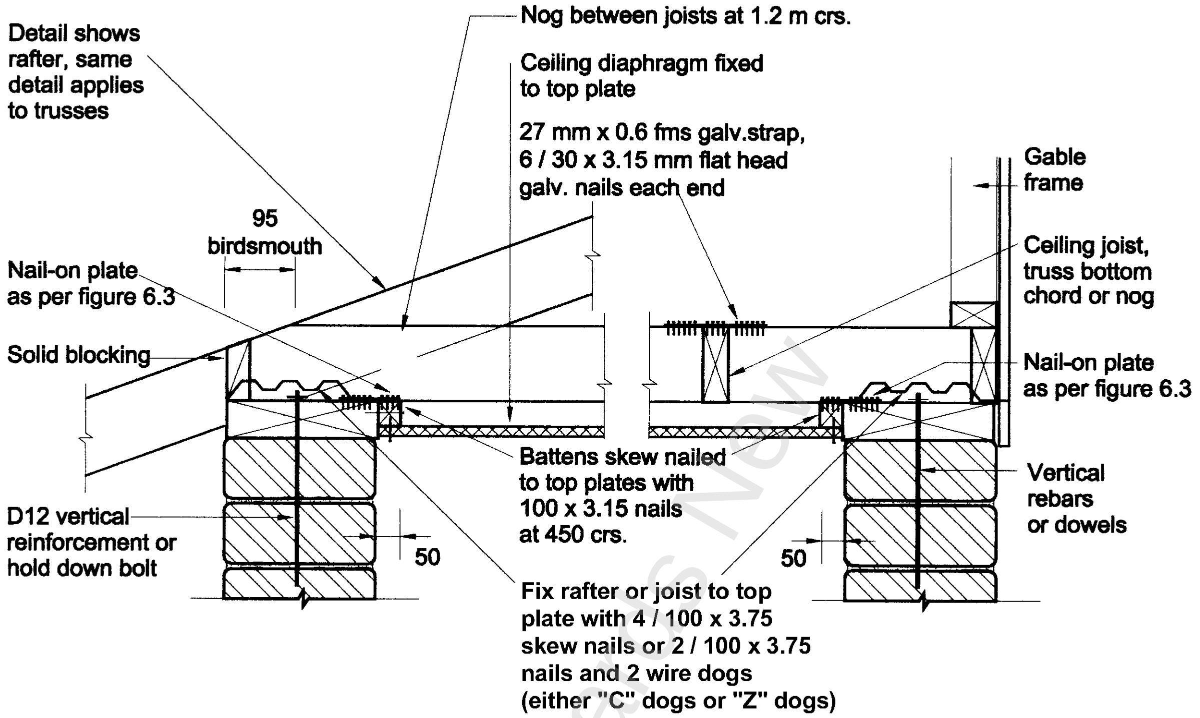

TIMBER GABLE WALL

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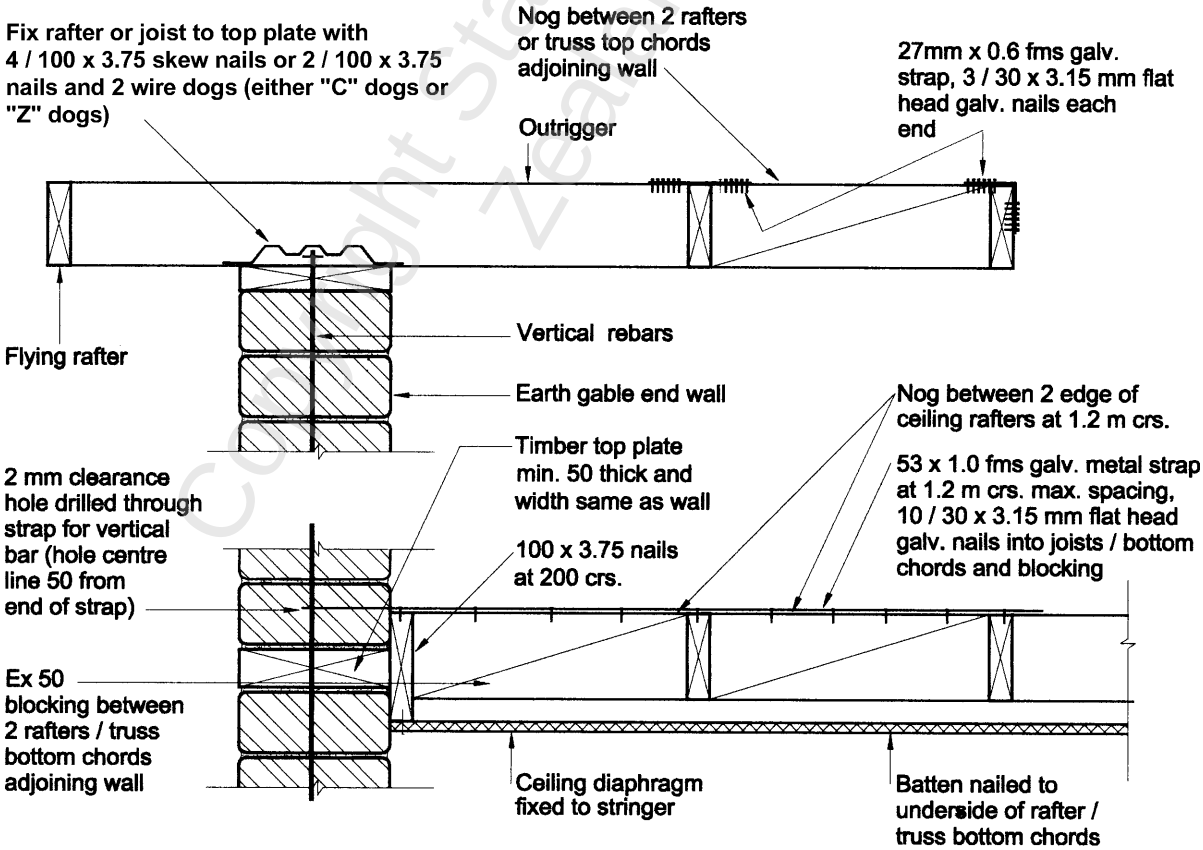


EARTH GABLE WALL

Figure 6.4 – Connection of ceiling diaphragms to earth walls for battened joists or trusses

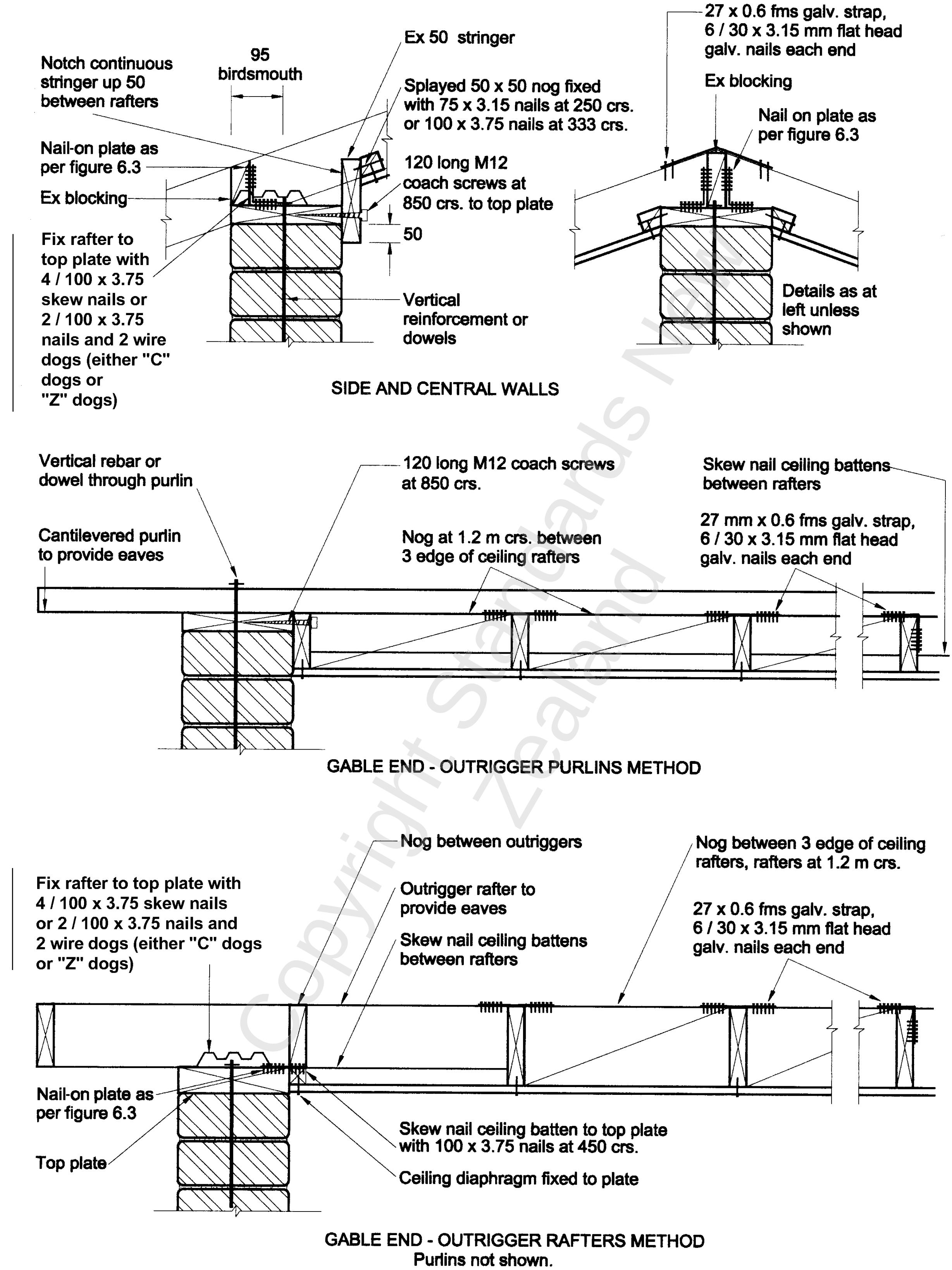


Figure 6.5 – Connection of ceiling diaphragms to earth walls for sloping ceilings on underside of rafters

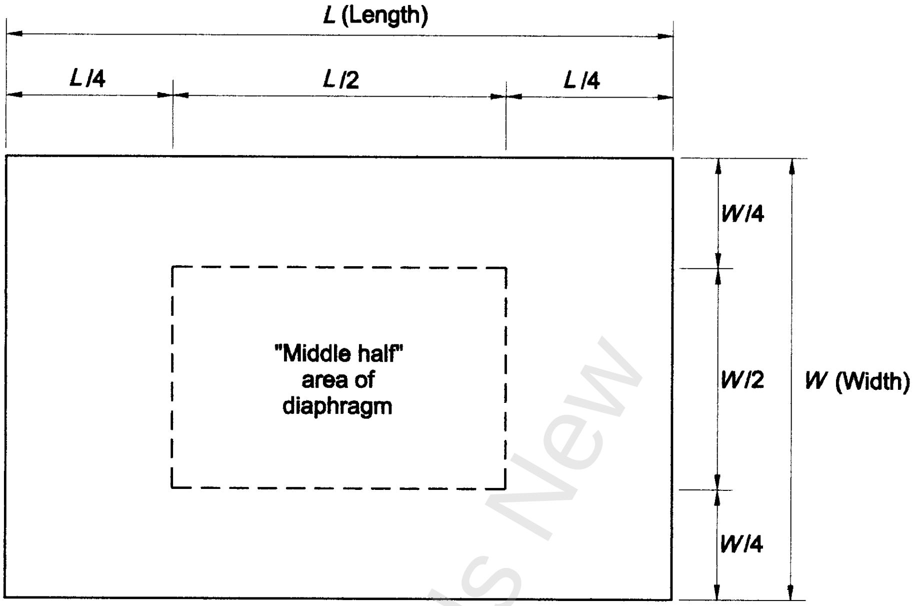


Figure 6.6 – Location of openings in diaphragm

7 BOND BEAMS

7.1 General

7.1.1
Bond beams shall be provided at the top of all earth walls in order to:

(a) Assist in supporting lateral loads between adjacent transverse structural walls;

(b) Provide anchorage of floor and roof members;

(c) Tie the earth walls together.

7.1.2
The maximum height of earth walls between the footing and bond beam is specified in 1.2(c).

7.1.3
Timber bond beams shall not be less than 70 % of the width of the wall to which they are attached.

7.1.4
The connection of the bond beam to the wall shall be as shown in figure 5.4.

7.2 Bond beams with structural diaphragms

7.2.1 *Where earthquake zone factor ≤ 0.6*
Timber or concrete bond beams shall be provided at the top of earth walls as shown in table 7.1.

Table 7.1 – Bond beams with structural diaphragms where earthquake zone factor ≤ 0.6

Bond beam type and minimum size	Earth wall application	Maximum spacing between transverse bracing walls
Timber 200 x 50 mm	All types	6.0 m
Concrete Type A – 200 x 100 with 2/D12 and R6 ties at 400 centres	All types	6.0 m

NOTE – Timber bond beams may need to be wider to comply with 7.1.3.

7.2.2 *Where earthquake zone factor > 0.6*

Timber or concrete bond beams shall be provided at the top of earth walls as shown in table 7.2.

Table 7.2 – Bond beams with structural diaphragms where earthquake zone factor > 0.6

Bond beam type and minimum size	Earth wall construction type	Maximum spacing between transverse bracing walls
Timber		
200 x 75 mm	All types	6.0 m
250 x 50	All types	6.0 m
Concrete Type A 200 x 100 with 2/D12 and R6 ties at 400 centres	All types	6.0 m
Type E 250 x 175 with 2/D16 and R6 ties at 400 centres	All types	6.0 m

NOTE – Timber bond beams may need to be wider to comply with 7.1.3.

7.2.3

The connection of the bond beam to the wall and structural diaphragm shall be as shown in figures 6.3 and 6.4.

7.3 Bond beams without structural diaphragms

7.3.1 *Where earthquake zone factor ≤ 0.6*

Timber or concrete bond beams shall be provided at the top of earth walls as shown in table 7.3.

Table 7.3 – Bond beams without structural diaphragms where earthquake zone factor ≤ 0.6

Bond beam type and minimum size (mm)	Earth wall application	Maximum spacing between transverse bracing walls (m)	
		Light roof	Heavy roof
Timber			
200 x 50	Single storey for all types	3.0	2.7
200 x 75	Single storey for all types	3.8	3.4
200 x 100	Single storey for all types	4.5	3.9
250 x 50	Single storey for all types	4.0	3.5
250 x 75	Single storey for all types	4.8	4.2
250 x 100	Single storey for all types	5.4	4.8
300 x 50	Single storey for all types	4.8	4.2
300 x 75	Single storey for all types	5.7	5.1
300 x 100	Single storey for all types	6.0	6.0
Concrete			
Type A 200 x 100 with 2/D12	Single storey for all types	3.0	2.7
Type B 250 x 100 with 2/D12	Single storey for all types	3.6	3.3
Type C 250 x 100 with 2/D16	Single storey for all types	4.8	4.2
Type D 250 x 150 with 2/D16	Single storey for all types	4.8	4.2
Type E 250 x 175 with 2/D16	Single storey for all types	5.4	4.8
Type F 250 x 175 with 2/D20	Single storey for all types	6.0	6.0

NOTE –
(1) All ties to concrete bond beams without structural diaphragms shall be R6 at 200 centres.
(2) Timber bond beams may need to be wider to comply with 7.1.3.

7.3.2 *Where earthquake zone factor > 0.6*
Concrete bond beams shall be provided at the top of earth walls as shown in table 7.4.

C7.3.2
Refer to 5.10 regarding timber bond beams without structural diaphragms.

Table 7.4 – Bond beams without structural diaphragms where earthquake zone factor > 0.6

Bond beam type and minimum size (mm)	**Earth wall application**	**Maximum spacing between transverse bracing walls** (m)	
		Light roof	**Heavy roof**
Concrete			
Type D 250 x 150 with 2/D16	Single storey for all types	4.2	3.6
Type E 250 x 175 with 2/D16	Single storey for all types	4.5	4.2
Type F 250 x 175 with 2/D20	Single storey for all types	5.7	5.1

NOTE – All ties to concrete bond beams shall be R6 at 200 centres.

7.4 Intersection of timber bond beams

7.4.1 *Intersections and joints between timber bond beams*
Intersections and joints between timber bond beams shall be fixed as shown in:

(a) Figure 7.1 for timber bond beams with structural diaphragms;

(b) Figure 7.2 for timber bond beams without structural diaphragms.

7.4.2
For timber bond beams without structural diaphragms, joints in the bond beam shall be only at the corners and intersections of walls.

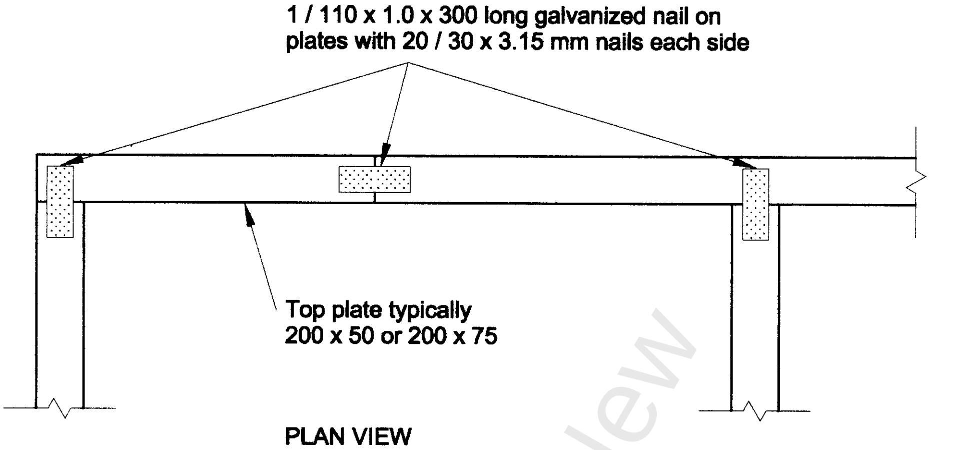


Figure 7.1 – Connection of timber bond beams or top plates with structural diaphragms (plan)

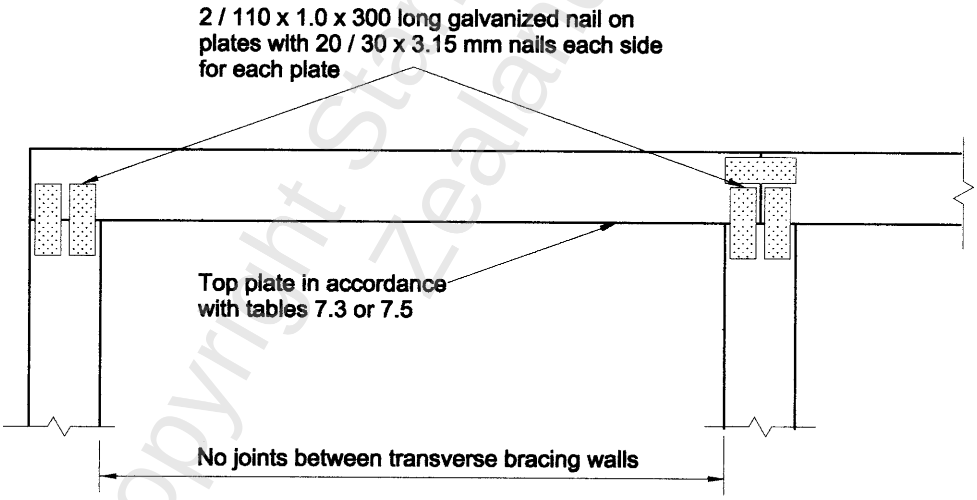


Figure 7.2 – Connection of timber bond beams or top plates without structural diaphragms (plan)

7.5 Laps in reinforcement of concrete bond beams

Laps in reinforcement of concrete bond beams shall be 40 times the bar diameter as shown in figure 4.4.

7.6 Size of reinforcement of concrete bond beams

The size and reinforcement of concrete bond beams shall be as shown in figure 7.3. Concrete cover to steel reinforcement and concrete strength shall be in accordance with 2.7.

Where there is a structural diaphragm, the R6 ties in concrete bond beams shall be at 400 mm centres.

Where there is no structural diaphragm, the R6 ties in concrete bond beams shall be at 200 mm centres.

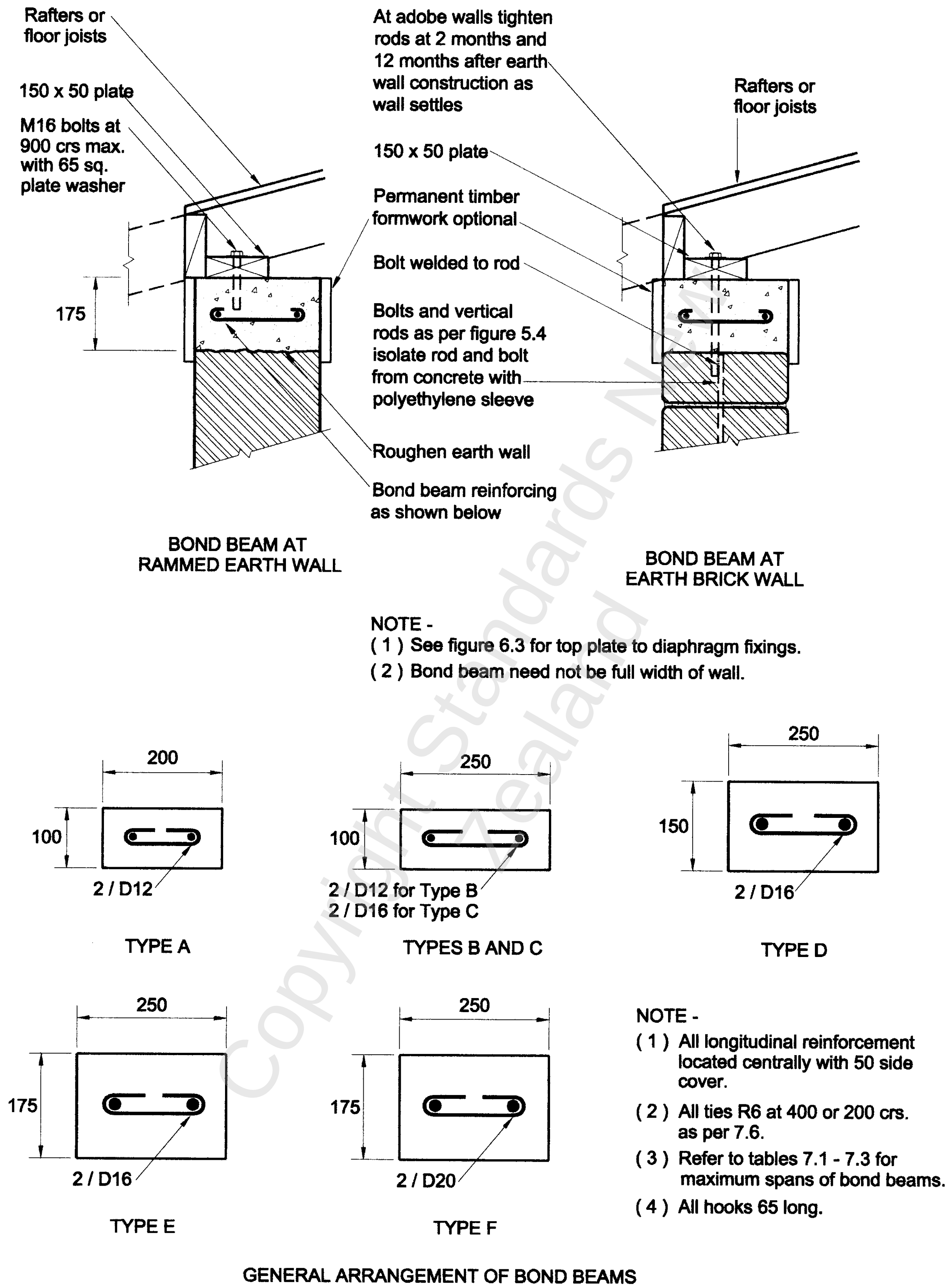


Figure 7.3 – Concrete bond beams

7.7 Intersection of concrete bond beams

Reinforcement at concrete bond beam intersections shall be tied together with D16 L bars lapped 40 bar diameters as shown in figure 4.4.

7.8 Gable shaped walls

A raking bond beam shall be provided to top of every gable shaped wall and shall be connected to and be continuous with other adjoining bond beams. The size of the raking bond beam shall be determined in accordance with 7.2 to 7.3.

7.9 Timber gable end walls above earth walls

7.9.1 *Where earthquake zone factor > 0.6*

Where the earthquake zone factor > 0.6 and for single storey buildings with timber gable ends above earth walls as shown in figure 1.1(b) one of the following shall be provided:

(a) A timber bond beam with a flat ceiling diaphragm in accordance with section 6, or

(b) A concrete bond beam in accordance with 7.3, or

(c) A timber bond beam between the earth wall and the timber gable ends and with a roof diaphragm in accordance with section 6 not steeper than 25o and as shown in figure 7.4 and table 7.5.

7.9.2 *Where earthquake zone factor ≤ 0.6*

Where the earthquake zone factor (0.6 and for single storey buildings with timber gable ends above earth walls as shown in figure 1.1(b) one of the following shall be provided:

(a) A timber bond beam with a flat ceiling diaphragm in accordance with section 6, or

(b) A concrete or timber bond beam without a structural diaphragm in accordance with 7.3, or

(c) A timber bond beam between the earth wall and the timber gable ends and with a roof diaphragm in accordance with section 6 not steeper than 25o and as shown in figure 7.4 and table 7.5.

7.9.3 *Intersections and joints between timber bond beams*

Intersections and joints between timber bond beams between timber gable ends and earth walls shall be as shown in figure 7.2. There shall be no joints between transverse bracing walls.

Table 7.5 – Timber bond beams at timber gable end walls above earth walls

Bond beam minimum size (mm)	**Maximum spacing between transverse bracing walls** (m)
200 x 50	3.0
200 x 75	3.6
200 x 100	4.3
250 x 50	3.8
250 x 75	4.6
250 x 100	5.4
300 x 50	4.5
300 x 75	5.5
300 x 100	6.0

NOTE – Bond beams may need to be wider to comply with 7.1.3.

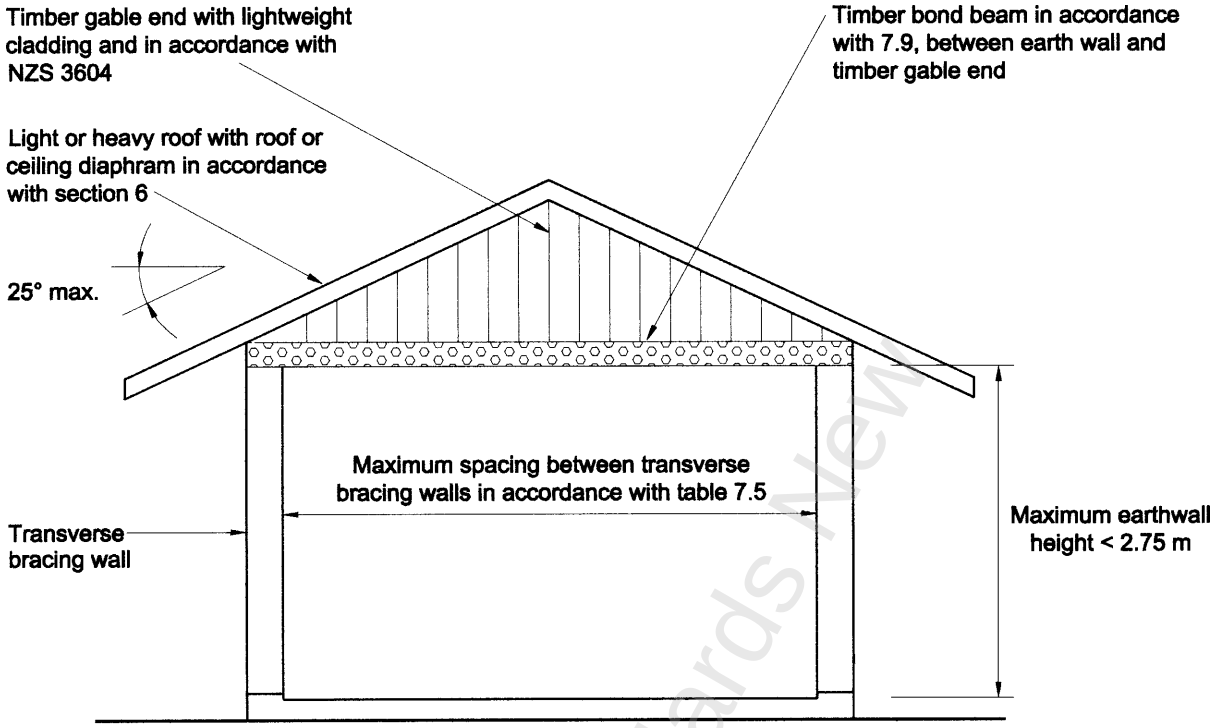


Figure 7.4 – Timber bond beam for timber gable end walls above earth walls

8 LINTELS

8.1 General

Lintels shall be used over all openings and shall be constructed of timber in accordance with 8.2 or of concrete in accordance with 8.3.

> ***C8.1***
> *The lintel details provided in this section make provision for the drying shrinkage of earth walls.*

8.2 Timber lintels

8.2.1

Timber lintels shall be seated a minimum of 300 mm on the earth wall on either side of the opening as shown in figure 8.1. Timber lintels narrower than the wall width shall bear on a 50 minimum thickness timber block the same width as the wall as shown in figure 8.1. For splayed reveals greater than 100 mm there is to be a 300 mm bearing at the widest part of the opening.

> ***C8.2.1***
> *Solid timber lintels or box beams the full width of the wall may bear directly on the earth wall. See figure 9.3 for explanation of "splayed reveals".*

8.2.2

Timber lintels supporting timber framed walls, floor and roof above shall be in accordance with NZS 3604 and as shown in figure 8.1.

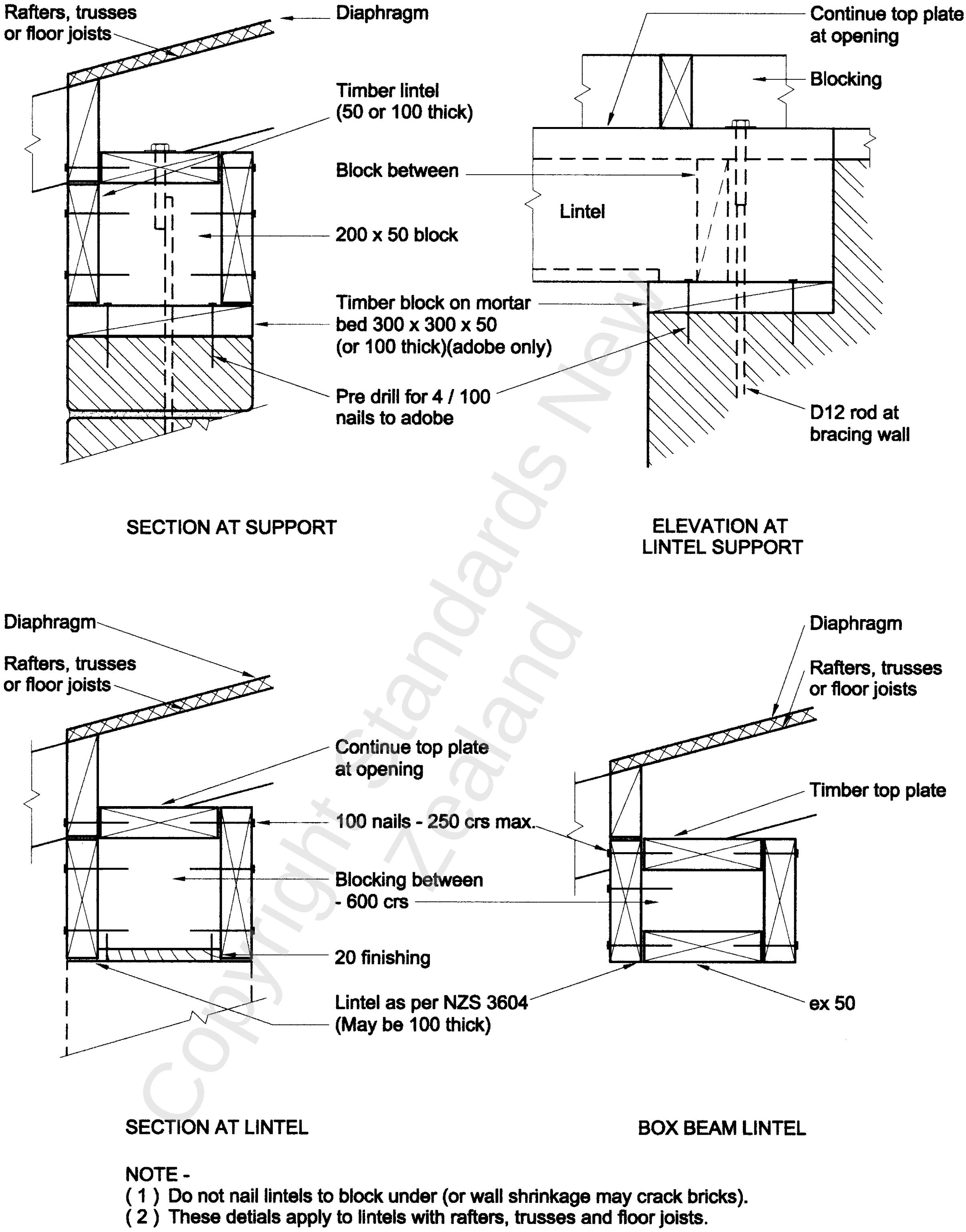


Figure 8.1 – Timber lintels supporting timber framing above

8.2.3
Timber lintels supporting earth walls at gable end walls and roof loads only shall be as shown on figure 8.2. Timber lintels shall be supported at mid span during and for one month after construction of the wall above.

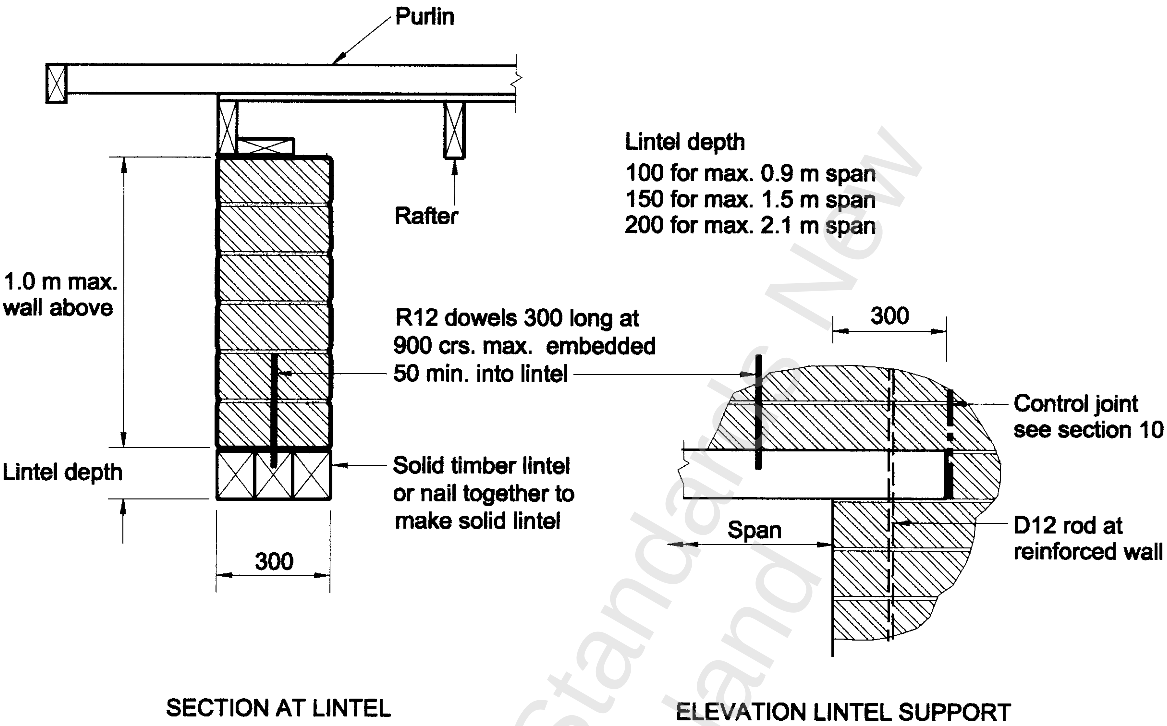


Figure 8.2 – Timber lintels supporting earth walls at gable ends

8.2.4
Timber lintels supporting both earth walls and first floor loads shall be specifically designed. Such lintels are outside the scope of this Standard.

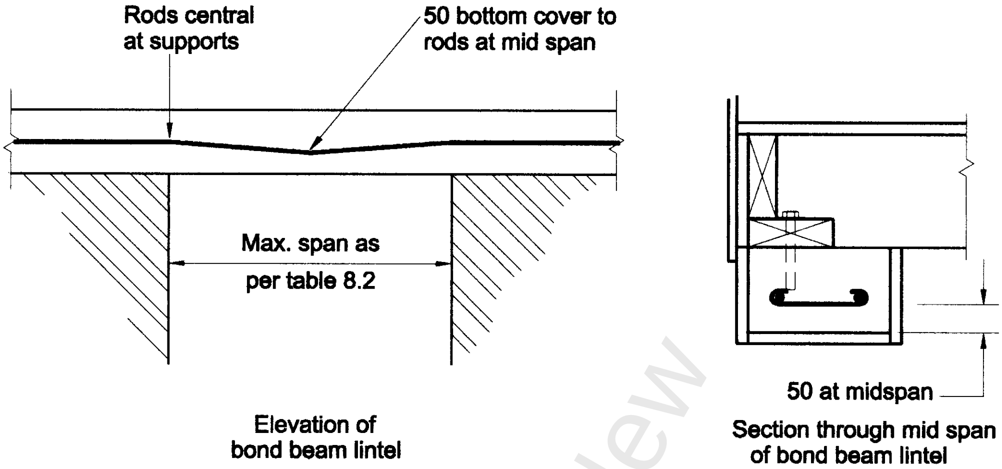
8.3 Concrete lintels

8.3.1 *Concrete lintels*
Concrete lintels shall be continuous with the concrete bond beam on either side of the opening.

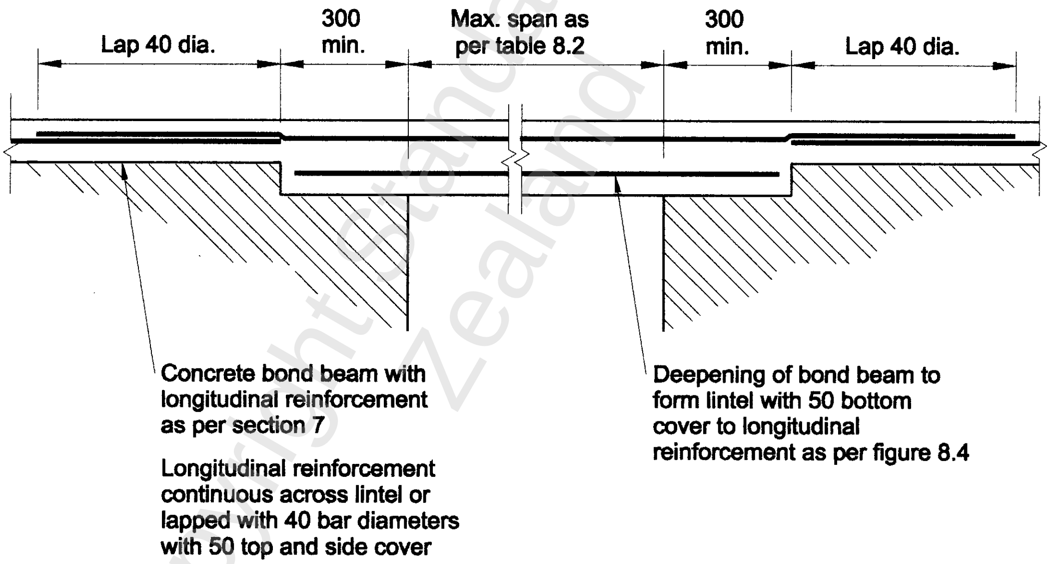
8.3.2
Where required the deepening of the concrete bond beam for the concrete lintel shall be as shown in figure 8.5.

8.3.3
Concrete cover to steel reinforcement and concrete strength shall be in accordance with 2.7.

8.3.4
Sizes, reinforcement and maximum spans of lintels supporting timber framed walls, floor and roof above shall be in accordance with tables 8.1and 8.2 according to the snow load and figures 8.3, and 8.4. The different load cases of table 8.2 are shown in figure 8.5.



GENERAL ARRANGEMENT OF CONCRETE LINTELS WHERE BOND BEAM DOES NOT REQUIRE DEEPENING
(Types A1, B1, C1, D1, E1, AND F1)



GENERAL ARRANGEMENT OF CONCRETE LINTELS WHERE BOND BEAM REQUIRES DEEPENING
(Types A2, B2, C2, D2, E2, AND F2)

Figure 8.3 – Concrete lintel general arrangement

Table 8.1 – Concrete lintel details

Type	Width	Depth	Longitudinal reinforcement
A1	200	100	2/D12
A2	200	200	4D/12
B1	250	100	2/D12
B2	250	200	4/D12
C1	250	100	2/D16
C2	250	200	4/D16
D1	250	150	2/D16
D2	250	200	4/D16
E1	300	175	2/D16
E2	300	250	4/D16
F1	300	175	2/D20
F2	300	250	4/D20

Table 8.2 – Concrete lintels with 0.0, 0.5 or 1.0 kPa snow loads

Type	Maximum span (m)								
	No snow load			Snow load < 0.5 kPa			Snow load < 1.0 kPa		
	Load case 1	Load case 2	Load case 3	Load case 1	Load case 2	Load case 3	Load case 1	Load case 2	Load case 3
A1	1.2	1.2	NA	1.2	0.9	NA	0.9	0.9	NA
A2	2.7	2.1	1.5	2.4	2.1	1.8	2.1	1.8	1.5
B1	1.2	1.2	NA	1.2	0.9	NA	0.9	0.9	NA
B2	2.7	2.1	1.8	2.4	2.1	1.8	2.1	1.8	1.5
C1	1.5	1.2	NA	1.2	1.2	NA	1.2	0.9	NA
C2	3.0	3.0	2.4	3.0	2.7	2.4	2.7	2.4	2.1
D1	2.7	2.4	NA	2.4	2.1	NA	2.1	1.8	NA
D2	3.0	3.0	3.0	3.0	3.0	2.7	3.0	2.7	2.4
E1	3.0	2.7	NA	2.7	2.4	NA	2.4	2.1	NA
E2	3.0	3.0	2.7	3.0	3.0	2.7	3.0	2.7	2.4
F1	3.0	3.0	NA	3.0	3.0	NA	2.7	2.4	NA
F2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0

Load cases:

1. Light roof only or light roof and walls only, figures 8.5(A) or (B).
2. Heavy roof only or heavy roof and walls only, figures 8.5(A) or (B).
3. Light roof and walls and timber floor or walls and timber floor only, figures 8.5(C), (D) or (E).
4. Specific design is required where a lintel supporting a roof has a loaded dimension of greater than 6.0 m, that is, when the supported roof member spans divided by 2 plus the eaves overhang is greater than 6.0 m.

Amd 1 Dec '99

NA – Not applicable.

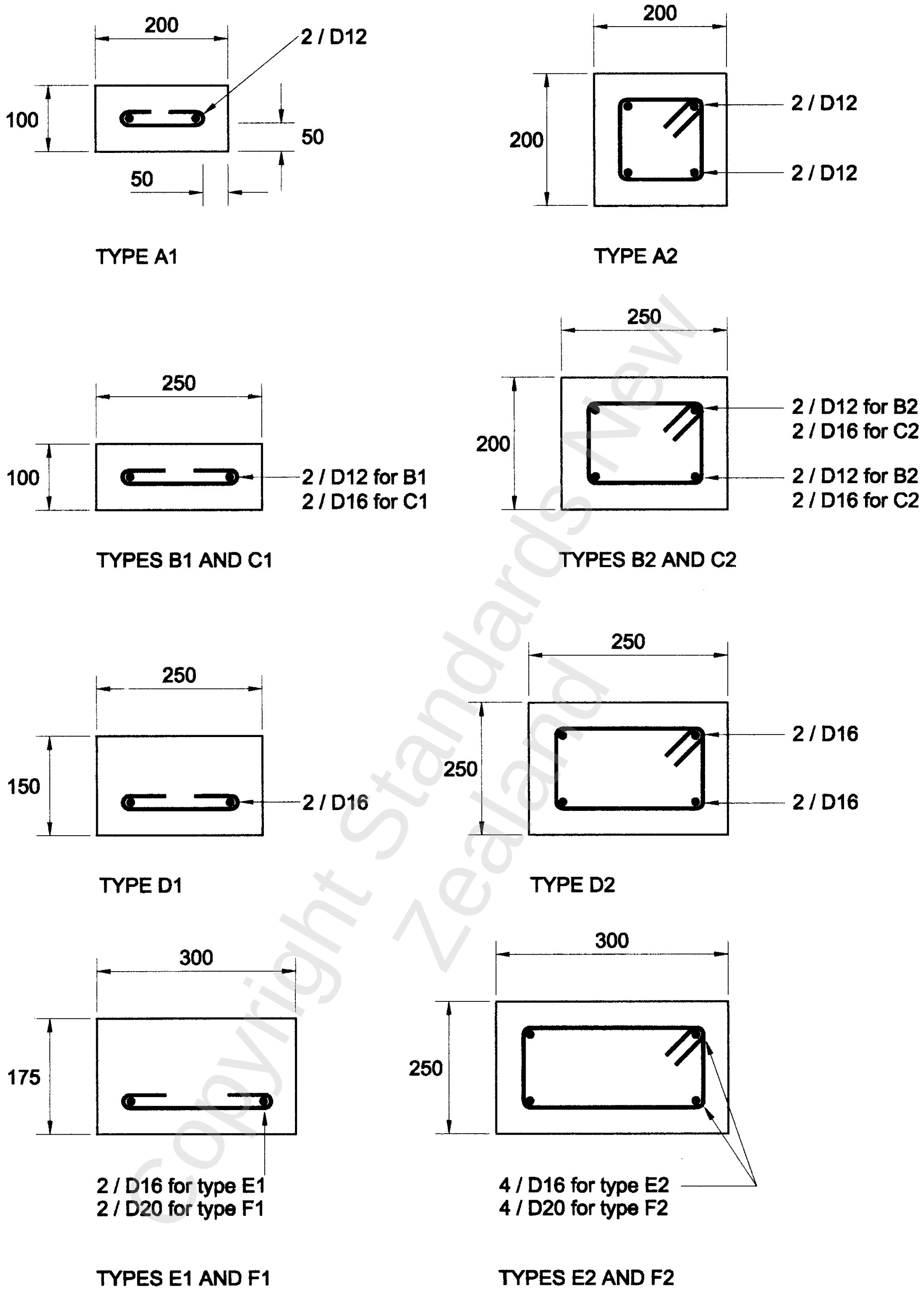
8.3.6
Concrete lintels supporting earth walls shall be specifically designed. Such lintels are outside the scope of this Standard.

8.3.7
Where a concrete lintel is combined with a concrete bond beam and with a structural diaphragm, the bond beam reinforcement may be included in the area of the lintel reinforcement provided that the area of the lintel reinforcement exceeds the minimum area of the bond beam reinforcement.

8.3.8
Where a concrete lintel is combined with a concrete bond beam without a structural diaphragm, the reinforcement of the lintel shall be either:

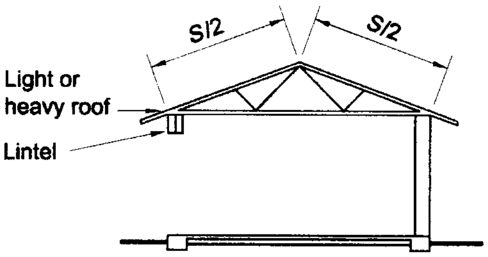
(a) The maximum amount required by either the lintel or bond beam where the total length of the lintel lies within the middle two thirds of the bond beam span; or

(b) The summation of the reinforcement required by the bond beam and lintel where the lintel or any part of it is located outside the middle two thirds of the bond beam span. Refer to figure 8.6.

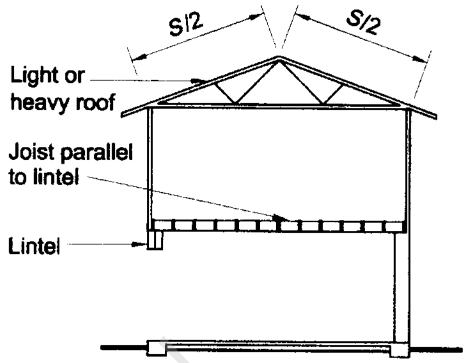


NOTE -
(1) 50 cover to longitudinal reinforcing.
(2) All ties R6 at 200 crs. for A1 - F1 & 100 crs for A2 - F2.
(3) Refer to table 8.2 for maximum spans.
(4) All hooks 65 long.

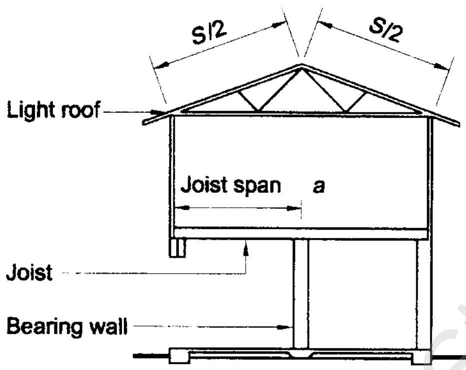
Figure 8.4 – Concrete lintel sizes and reinforcement



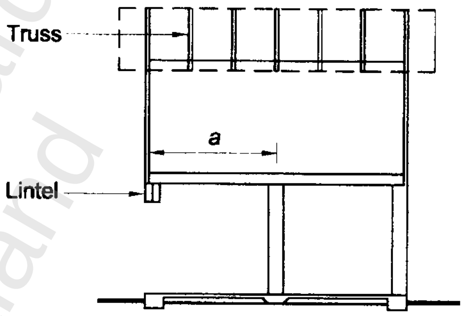
(A) LINTEL SUPPORTS ROOF
(*S* FOR ROOF)



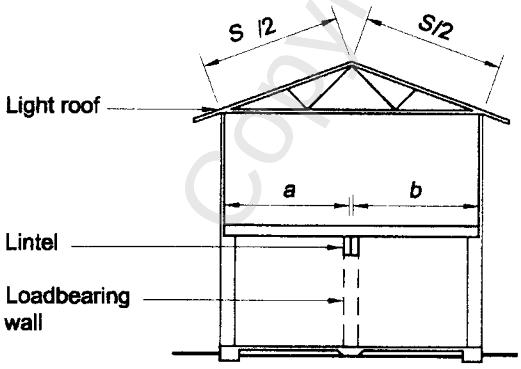
(B) LINTEL SUPPORTS ROOF AND WALLS
(*S* FOR ROOF)



(C) LINTEL SUPPORTS ROOF,
FLOOR JOISTS AND WALLS
(GREATER OF *S* FOR JOIST SPAN *a*)



(D) LINTEL SUPPORTS WALL AND FLOOR
(TRUSS PARALLEL TO LINTEL)
(SPAN OF JOIST *a*)

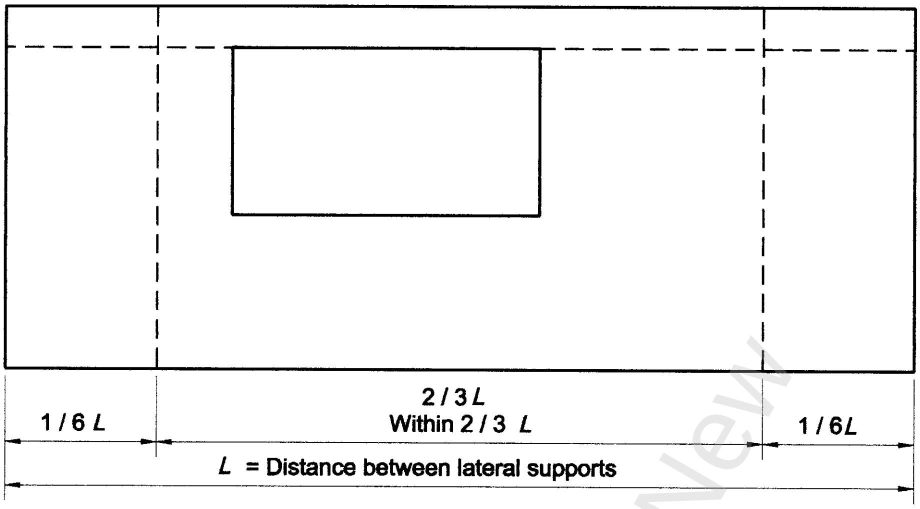


(E) LINTEL SUPPORTS FLOOR ONLY
(SPANS OF JOISTS *a* AND *b*)

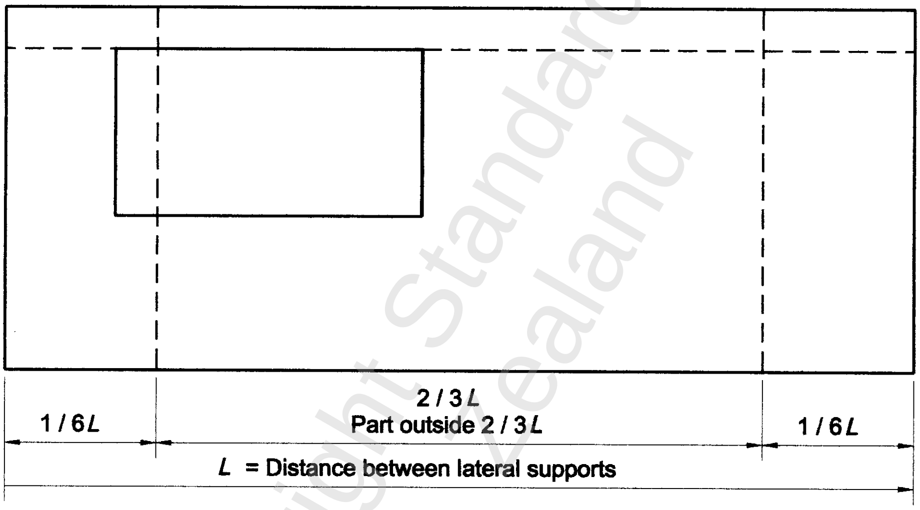
NOTE -
$S \leqslant 12.0$ m
$a \leqslant 6.0$ m
$b \leqslant 6.0$ m

Load case	Figure	Roof
1.	A & B	Light roof
2.	A & B	Heavy roof
3.	C,D & E	Light roof

Figure 8.5 – Load cases for concrete lintels



Whole of lintel within middle 2/3 of bond beam span



Part of lintel outside middle 2/3 of bond beam span

Figure 8.6 – Concrete lintel within and outside middle 2/3 of bond beam span

8.3.9
The reinforcement of the lintel shall extend to at least 900 mm either side of the opening as shown in figure 8.3. Where the lintel contains 4 longitudinal bars, this clause applies to the upper 2 bars only.

8.3.10
Laps for joining lintel and bond beam reinforcement shall be 600 mm.

8.3.11
No laps in reinforcement shall be within 300 mm of the opening.

9 WALL OPENINGS AND FIXINGS

9.1 Anchoring of joinery frames to walls

Windows and door frames shall be anchored securely to the earth wall. Details of anchor devices for anchoring door and window frames are shown in figure 9.1.

Joinery may be fixed to earth walls by screw or nail fixing to wooden inserts as per figure 9.1 or by masonry nail or non-expanding masonry screws to rammed earth or pressed brick walls.

C9.1

The drawing note "20 dia. hole for D12 vertical reinforcing rod (if required)" relates to the accommodation of wall reinforcing and is not a requirement for additional reinforcing for the frame fixing.

Anchor devices may be installed after construction but the most secure and economic devices are generally installed as the wall is being constructed.

Alternatively a rough frame may be built into the wall as it is being constructed and the "finished" frame fixed to this frame after the completion of wall and door construction although care must be taken to ensure that all necessary shrinkage can take place without "hang-up" on the rough frame. One method is to leave a gap of approximately 50 mm between the bottom of the rough frame and the concrete foundation.

9.2 Door and window details

Details are shown in figures 9.2 to 9.4. Vertical settlement occurs in earth walls and is to be provided for to prevent hang up and jamming of doors and windows.

C9.2

The detailing of doors and windows in earth walls requires special consideration when compared to conventional timber and masonry construction. The earth walls are thicker, surface of the earth wall less uniform and the wall material more fragile.

The major enemy of earth walls is water and careful attention to flashing and water control details is essential.

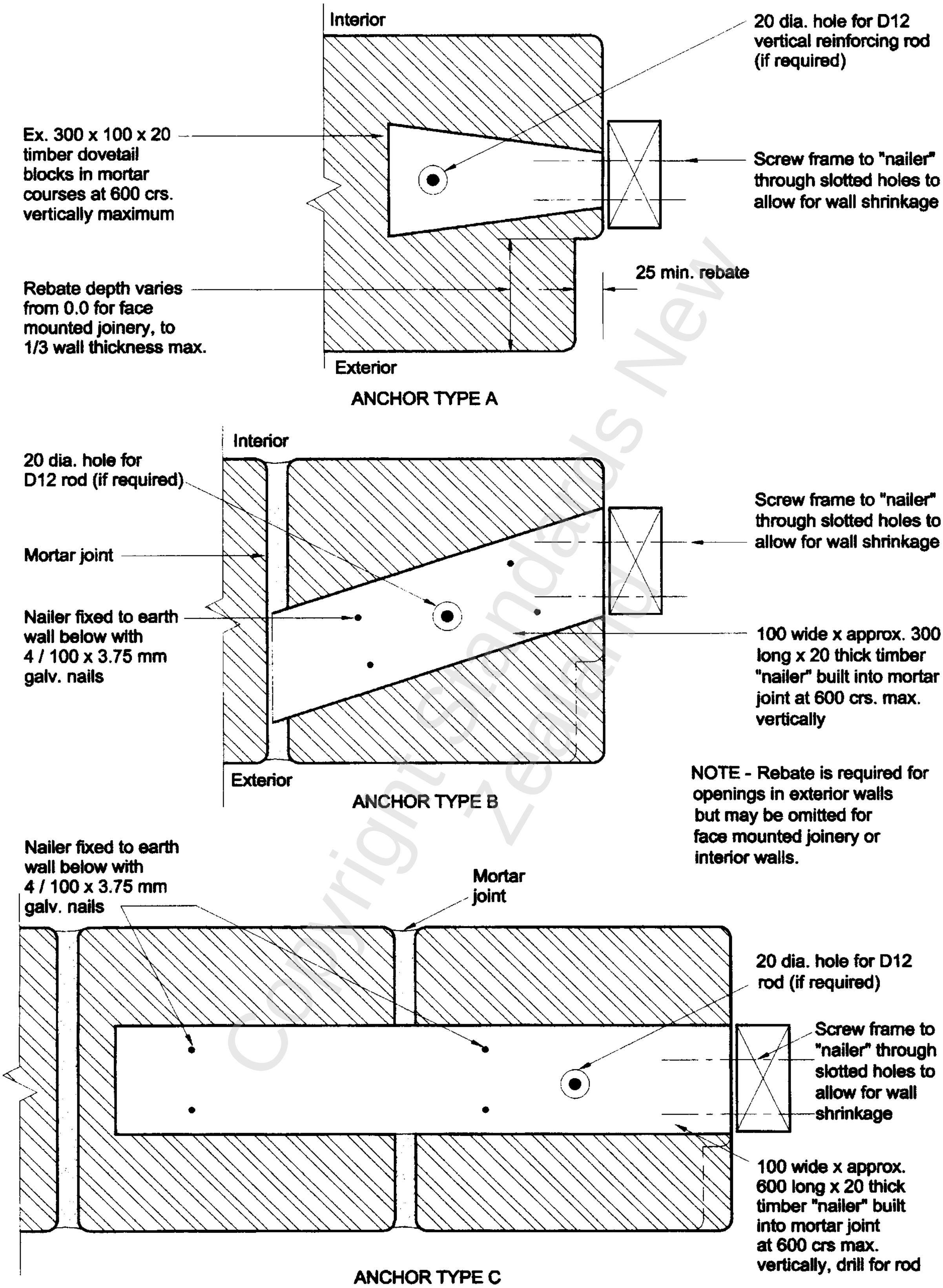
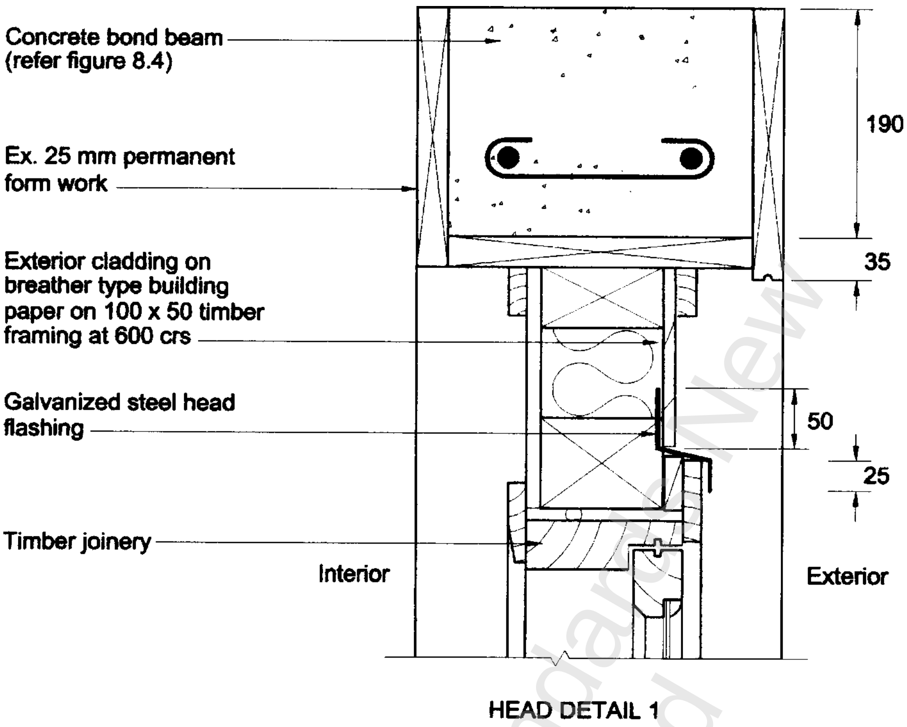


Figure 9.1 – Anchors for door, window and timber partition frames for earth walls



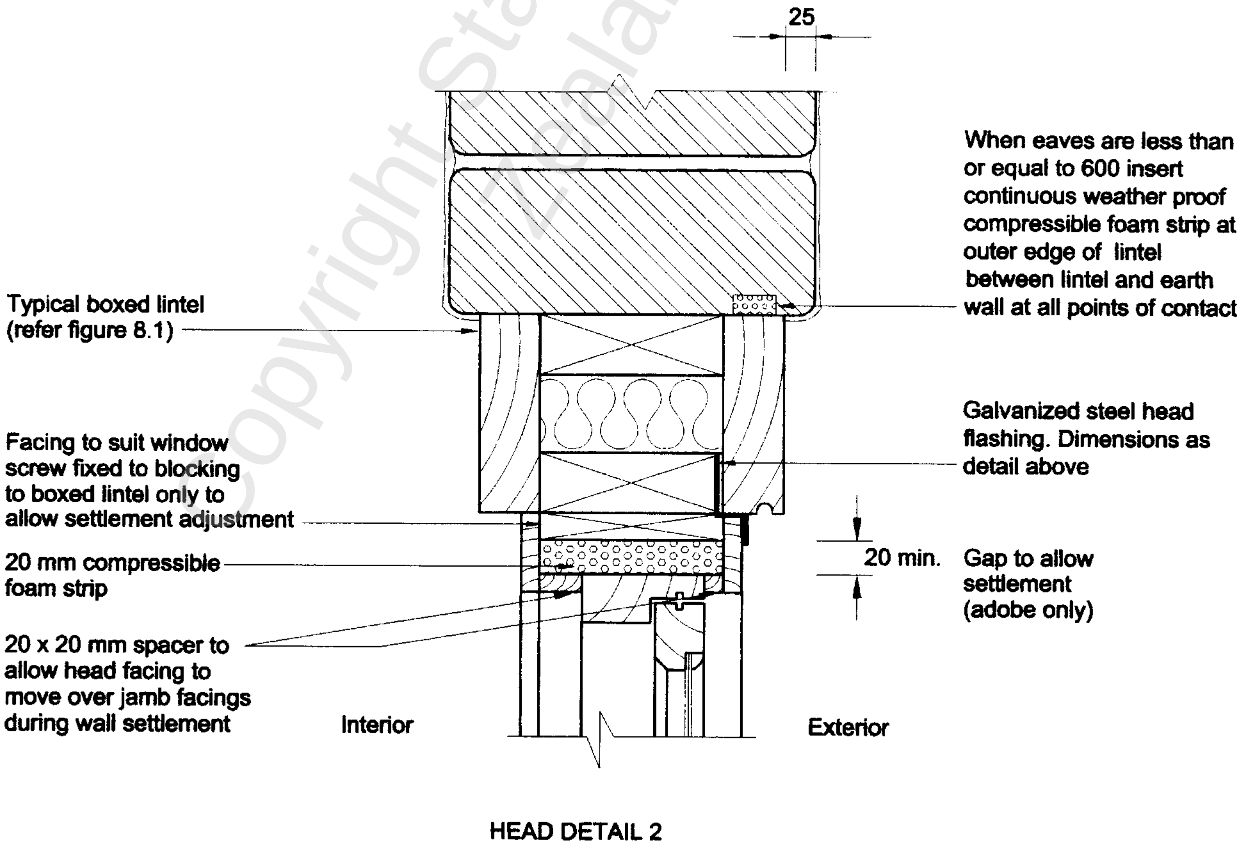
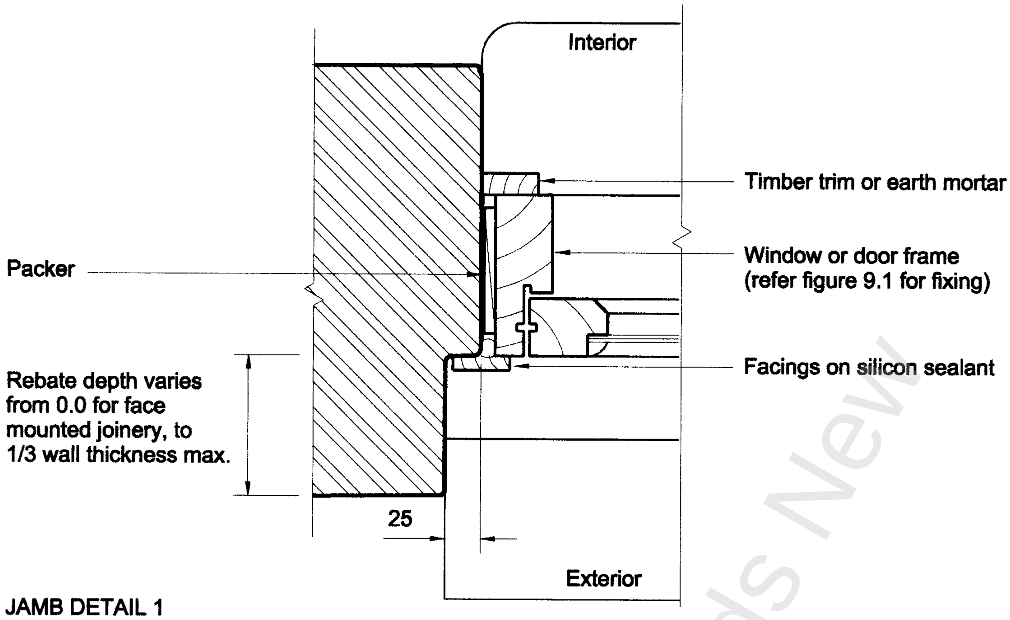
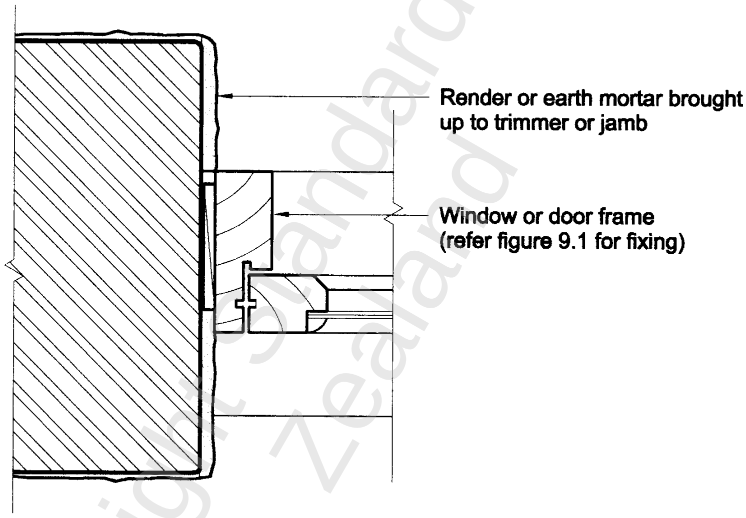


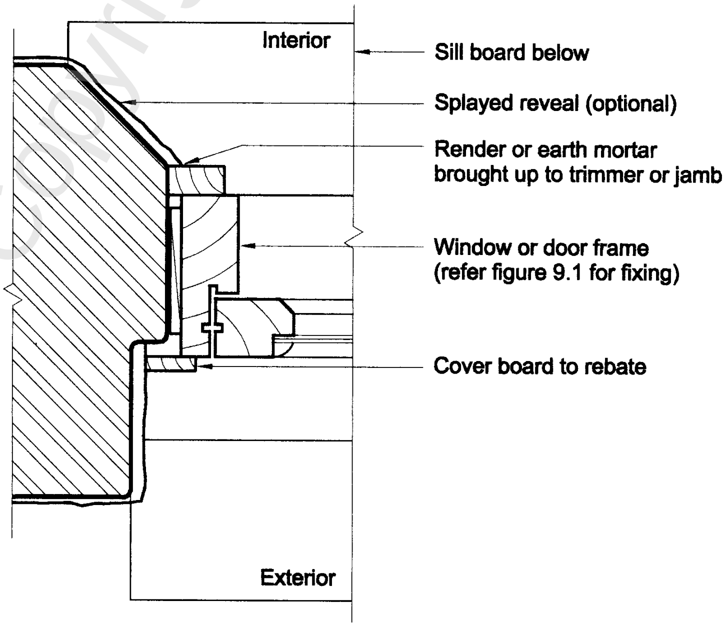
Figure 9.2 – Window head details



JAMB DETAIL 1

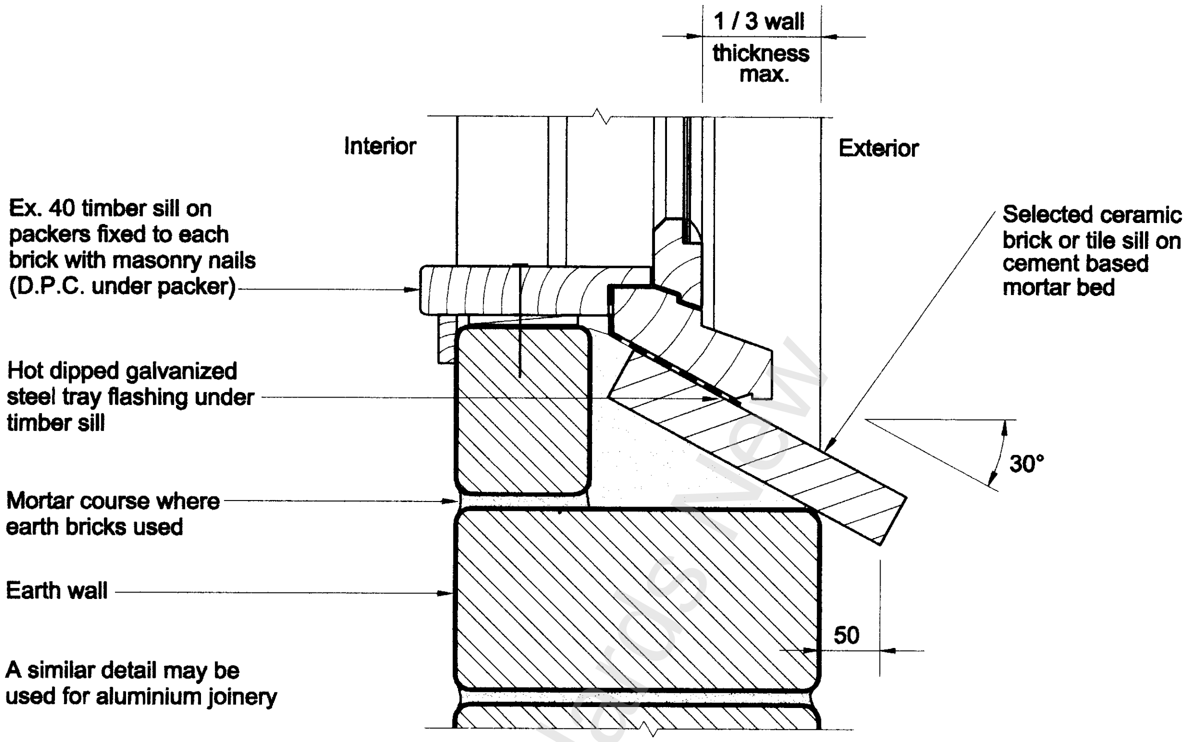


JAMB DETAIL 2
(For interior wall only)

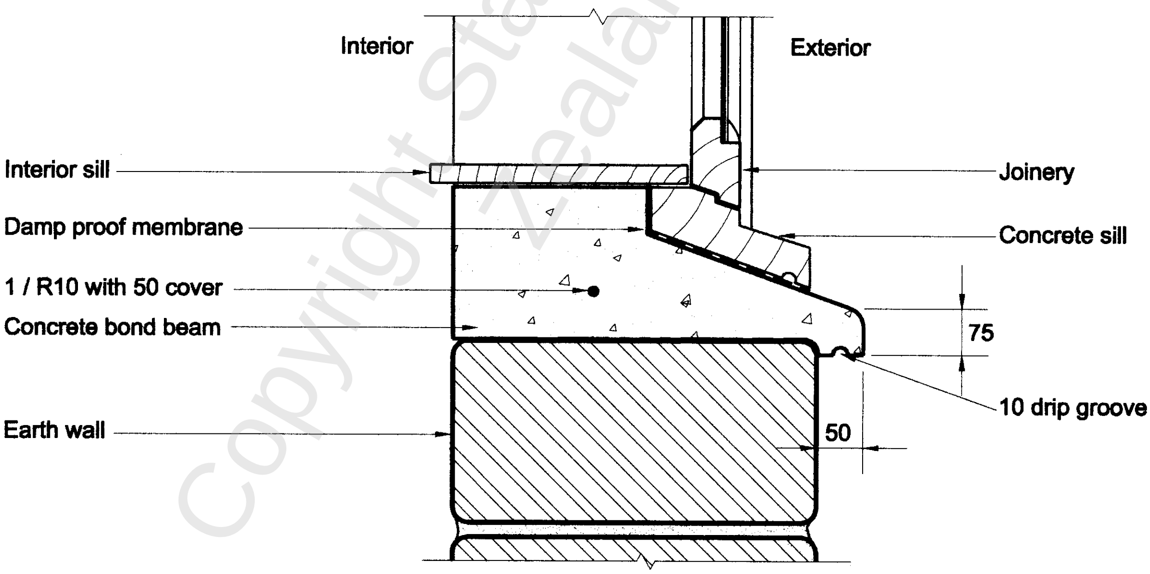


JAMB DETAIL 3

Figure 9.3 – Window jamb details



(A) TIMBER WINDOW SILL DETAIL TYPE S1 WITH BRICK OR TILE SILL



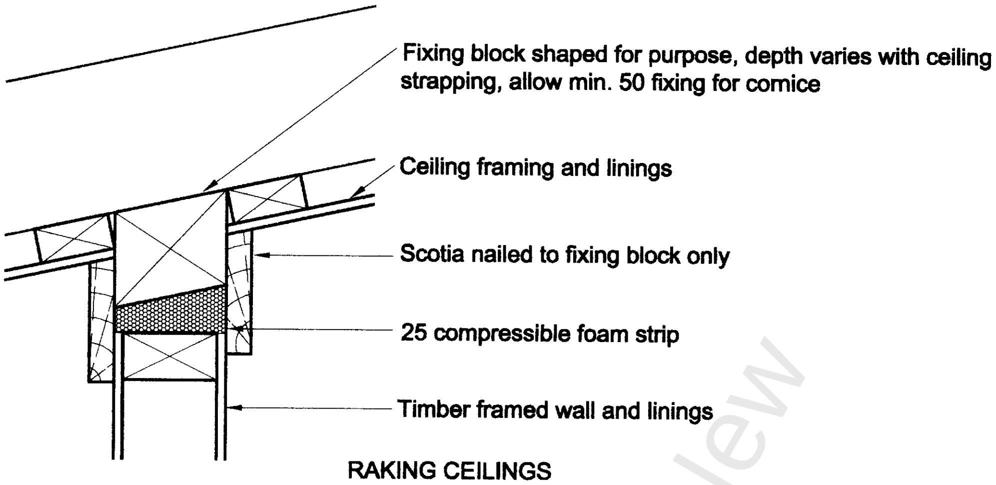
(B) WINDOW SILL DETAIL TYPE S2 WITH CONCRETE SILL

Figure 9.4 – Window sill details

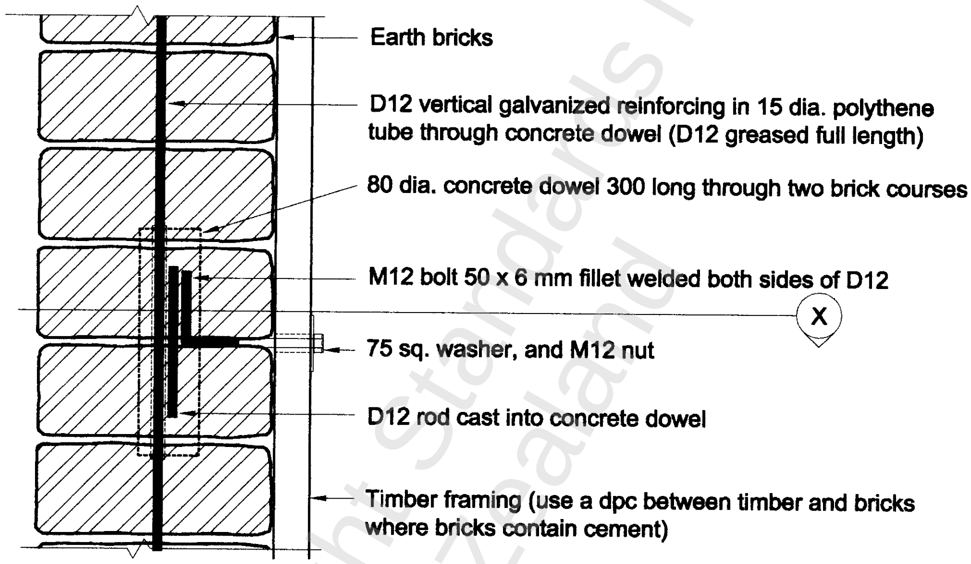
9.3 Fixings for timber framed walls

Fixings for timber framed walls shall allow for settlement of the earth wall. Details are shown in figure 9.5.

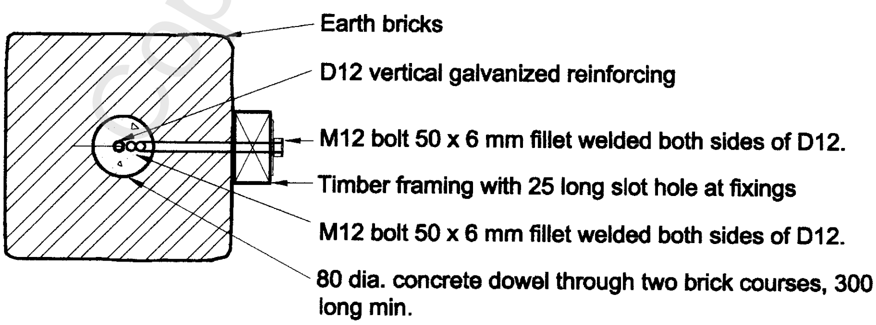
The vertical studs of the timber framed wall may be fixed to the earth wall as shown in figure 9.6 or with anchors in accordance with figure 9.1 or with three 12 mm diameter coach bolts through the end stud of the timber framed wall with a durable timber block set into the outside of the earth wall at top, mid-height and bottom. The top detail of figure 9.5 shall be used only for a non-loadbearing wall.



RAKING CEILINGS



FRAMING CONNECTION SECTION
FOR ADOBE ONLY



FRAMING CONNECTION PLAN SECTION 'x'
FOR ADOBE ONLY

Figure 9.5 – Fixing of timber framed walls to allow for adobe earth wall vertical shrinkage

9.4 Arches

9.4.1
Earth bricks may be used to form arches over doors and windows as shown in figure 9.6.

C9.4.1
The bricks making up the arch may be specially shaped or may be parallel sided, however parallel sided bricks may present difficulties in achieving mortar joint thickness within the allowable range.

Arches in rammed earth or poured earth are subject to specific design to eliminate their tendency to crack.

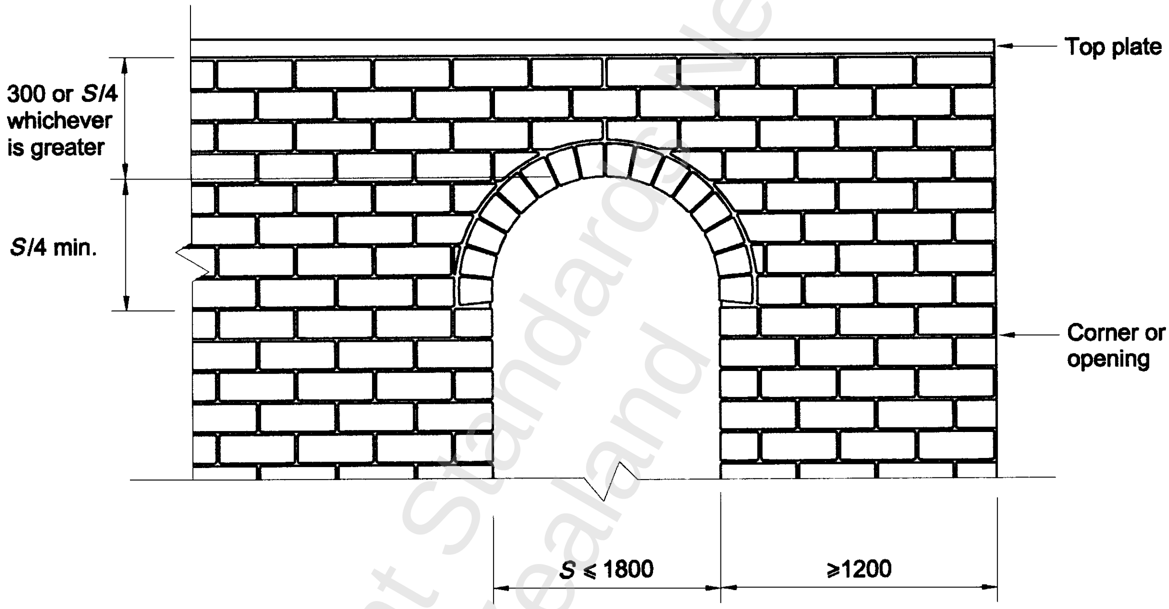


Figure 9.6 – Arch at door or window opening

9.4.2
The maximum span of openings with arches shall be 1800 mm.

9.4.3
The height of the earth wall above the underside of the arch and below the bond beam at the top of the wall shall be a minimum of one quarter of the span of the opening or 300 mm, whichever is the greater.

9.4.4
The side of the arched opening shall be a minimum of 1200 mm from any other opening or external corner.

9.5 Roof tie down bolts

9.5.1
Roof tie down bolts shall be provided for unreinforced earth walls where the earthquake zone factor ≤ 0.6.

C9.5.1
In reinforced earth walls and partially reinforced earth walls roof tie downs are provided by the vertical reinforcement and additional tie down reinforcement is not required.

9.5.2

Roof tie down bolts shall be 12 mm diameter mild steel rods threaded at the top and anchored to a 8 mm thick 200 mm long by 100 mm wide mild steel plate embedded in the earth wall as shown in figure 9.7. These tie down bolts are in addition to dowels required by 5.11.

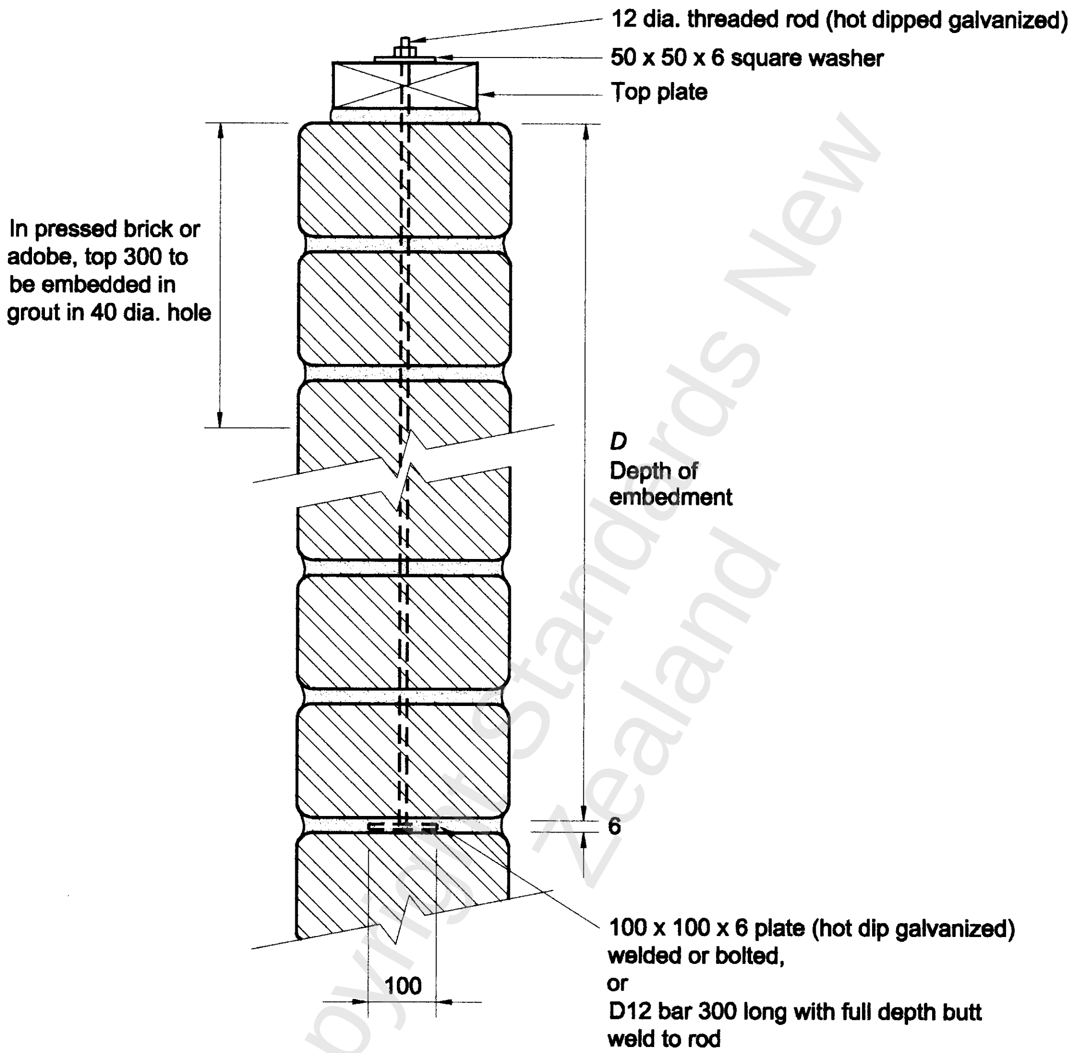


Figure 9.7 – Roof tie down detail

9.5.3

The depth of embedment in the walls, *D*, shall be as shown in table 9.1.

Table 9.1 – Depth of embedment (*D*) of roof tie down bolts

Building wind zone	Depth of embedment (*D*) (mm)	
	Light roof	**Heavy roof**
L and M	500	Not needed
H	900	Not needed
VH	1200	600

NOTE –
(1) Bolts at 1200 mm maximum centres.
(2) Wall thickness 280 to 350 mm.
(3) Maximum span between walls – 7 m.
(4) 12 mm diameter tie bolts with 50 x 50 x 6 mm square washer (see figure 9.7).
(5) Maximum cantilevered eaves width 1200 mm.
(6) Maximum width for veranda roof with tied down posts at outer edge, 2400 mm.

C9.5.3
For greater maximum span or greater eaves width than those listed, specific design will be required.

9.6 Flashings

Flashings, sills or other protrusions from the external face of a wall with earth wall below shall be detailed so as to prevent the concentrated flow of water over earth wall material.

10 CONTROL JOINTS

10.1 General

10.1.1
Vertical control joints shall be provided in all earth walls except unstabilized adobe in accordance with NZS 4298.

C10.1.1
Control joints are optional for unstabilized adobe walls.

10.1.2
Bond beams which support diaphragms or otherwise provide lateral supports to walls shall be continuous through control joints. Lintels and their supports shall also be continuous through control joints.

10.1.3
Horizontal reinforcement other than in bond beams and lintels shall not be continuous at control joints.

10.1.4
Reinforced earth walls and partially reinforced earth walls shall contain a reinforcing rod immediately either side of the control joint.

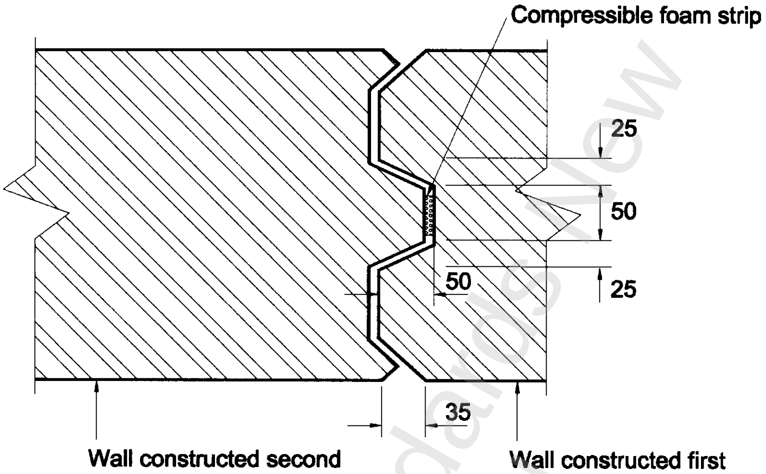
10.2 Control joints for rammed earth walls

Control joints for rammed earth walls shall be in accordance with figure 10.1.

Mechanical keys shall be formed at each control joint and 25 x 25 mm acrylic adhesive impregnated poly foam strip shall be fixed as shown in figure 10.1 for the full height of the wall. The foam strip shall extend 100 mm along the floor slab to ensure a complete seal of the bottom of the construction joint.

Horizontal construction joints for rammed earth, where there is a break in the construction sequence of more than 24 hours shall be in accordance with figure 10.2.

C10.2
A "V" joint as shown in figures 10.1 and 10.2 may be formed on both wall faces as shown.



NOTE - Key former ex 100 x 50, (can be ex 150 x 50).

Figure 10.1 – Control joint for rammed earth walls

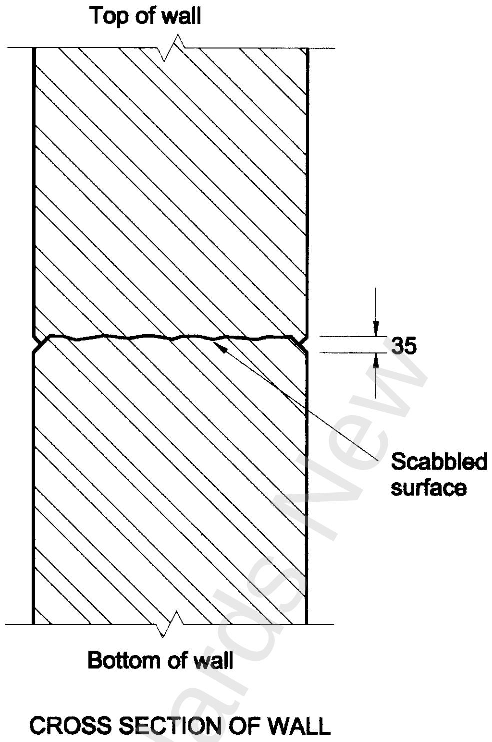


Figure 10.2 – Horizontal construction joint for rammed earth walls

10.3 Control joints for adobe and pressed brick walls

Control joints for adobe and pressed brick walls shall be full height continuous vertical mortar joint in accordance with figure 10.3.

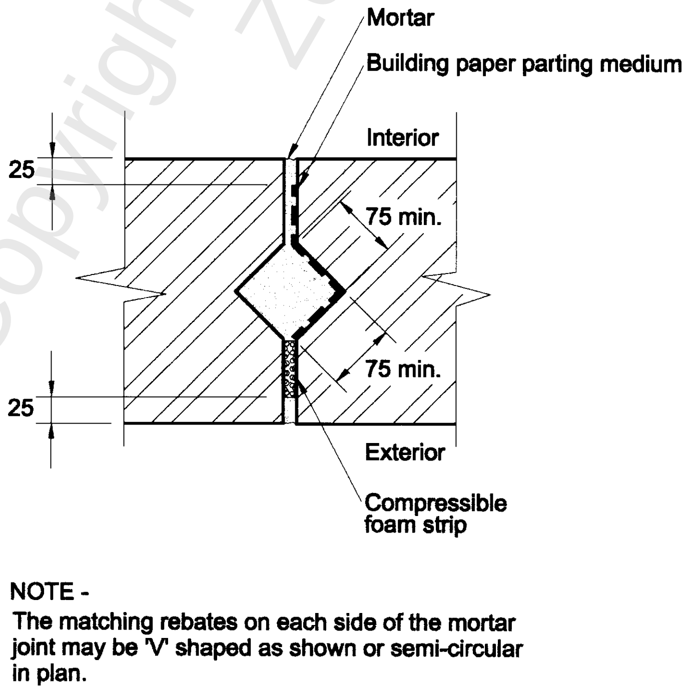


Figure 10.3 – Control joint for adobe and pressed brick

11 CINVA BRICKS

11.1 Scope

11.1.1
Buildings within the scope of this Standard which are constructed from cinva bricks shall comply with the additional provisions contained within this section.

11.1.2
Cinva bricks shall comply with the provisions of NZS 4298.

11.1.3
Exterior walls constructed from a single layer of cinva bricks shall have additional insulation to provide the minimum R values required by NZS 4218. This additional insulation is outside the scope of this Standard.

C11.1.3
The 140 mm thickness of cinva bricks acting alone does not provide sufficient thermal insulation to comply with Clauses E3 and H1 of the New Zealand Building Code and additional insulation is required.

11.2 Foundations

11.2.1
Clause 4.1.2 is to be replaced by the provision that the external wall face may be flush with the external footing face.

11.2.2
Clause 4.2.1 is to be replaced by the provision that the width of the footing shall be not less than 250 mm.

11.2.3
Footing details shall be in accordance with figure 11.1.

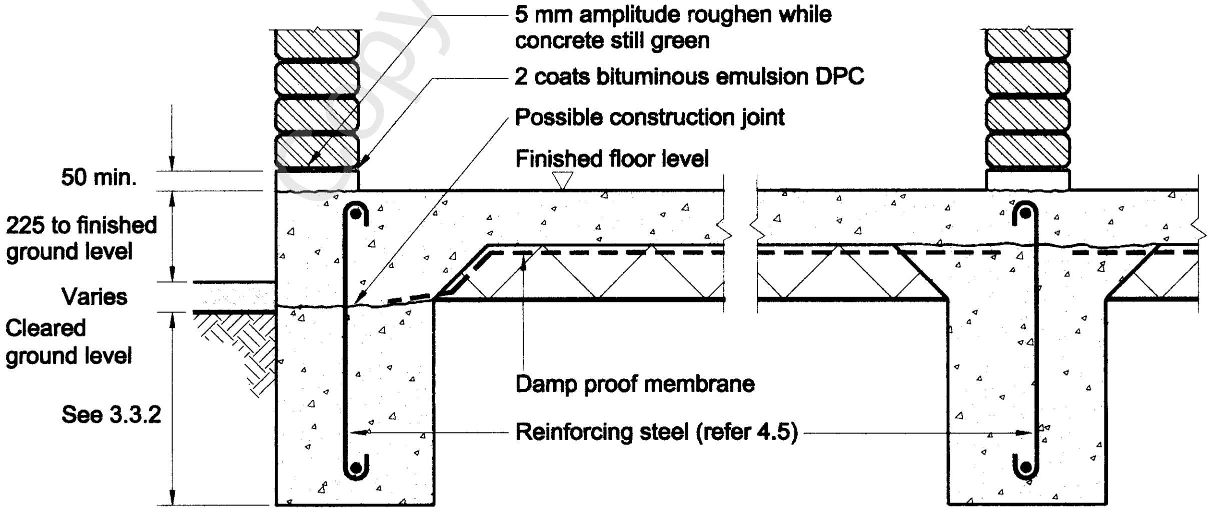


Figure 11.1 – Cinva brick wall footings

11.3 Bracing walls

11.3.1
The bracing demand shall be the values from tables 5.1 to 5.4 for 280 mm walls multiplied by 1.1.

11.3.2
In place of the provisions of table 5.5, the total bracing capacity in the building in each direction shall be at least:

(a) For single storey earth walls and light or heavy roof : 28 bracing units per square metre of floor area;

(b) For single storey earth walls with timber first floor and timber walled part storey in the roof space not exceeding 50 % of the ground floor and a light roof or with a full second storey with light cladding and a light roof : 45 bracing units per square metre of ground floor area.

11.3.3
The bracing capacity of cinva brick walls shall be those given by table 5.6 for 350 thick walls.

11.4 Wall reinforcing

11.4.1 *Vertical reinforcing*

11.4.1.1
Cinva brick walls shall have one D12 vertical reinforcing rod at each end of bracing walls at a distance of 75 to 230 mm from the ends of the bracing wall as shown in figure 5.4.

11.4.1.2
Vertical reinforcing by D12 bars shall be as given by table 11.1.

Table 11.1 – Maximum spacing of vertical reinforcement in cinva brick walls

Height of wall (m)	**Spacing** (m)
2.4	1.2
2.7	0.9
3.0	0.6
3.3	0.6

NOTE –

(1) Height of wall is measured between bottom of floor and underside of timber wall plate.

(2) For determining wall heights/bar spacings in raking walls, the wall shall be divided into 1.2 m panels and the average wall height for that panel and determine the bar spacing.

11.4.2 *Horizontal reinforcing*
Clause 5.8.3 shall apply with the following modifications.

(a) All horizontal steel shall be hot dip galvanized or alternatively it may be protected with 3 coats zinc-rich primer;

(b) Type A reinforcing shall not be used;

(c) Type B reinforcing shall not be used;

(d) Type C reinforcing shall have a 150 mm turn-down at the ends of the bar;

(e) Type D R10 reinforcing at 600 centres shown in figure 11.2 may be used.

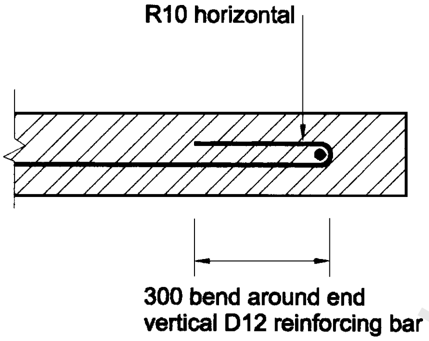


Figure 11.2 – Type D horizontal reinforcing (cinva brick only)

11.5 Cinva brick walls without structural diaphragms

For cinva brick walls without structural diaphragms 5.10 shall apply except that 5.10.5 shall be replaced by the following:

The maximum length of a bond beam spanning between supporting return walls shall be 5.0 m measured centre-line-to-centre-line of the walls. The bond beam shall be constructed in accordance with section 7 and as shown in figure 7.1, 7.2 and 7.3.

11.6 Structural diaphragms

Section 6 shall apply with the following modifications.

(a) All timber diaphragm top plates shall be 150 x 50;

(b) Immediately beneath the timber top plates shall be a channel bond beam or a raking concrete 150 wide x 100 minimum height concrete bond beam containing a D12 longitudinal bar.

11.7 Concrete bond beams

The provisions of 7.5 to 7.8 shall apply with the following additional clause.

11.7.1

Concrete bond beams shall be as shown in figure 11.3 below.

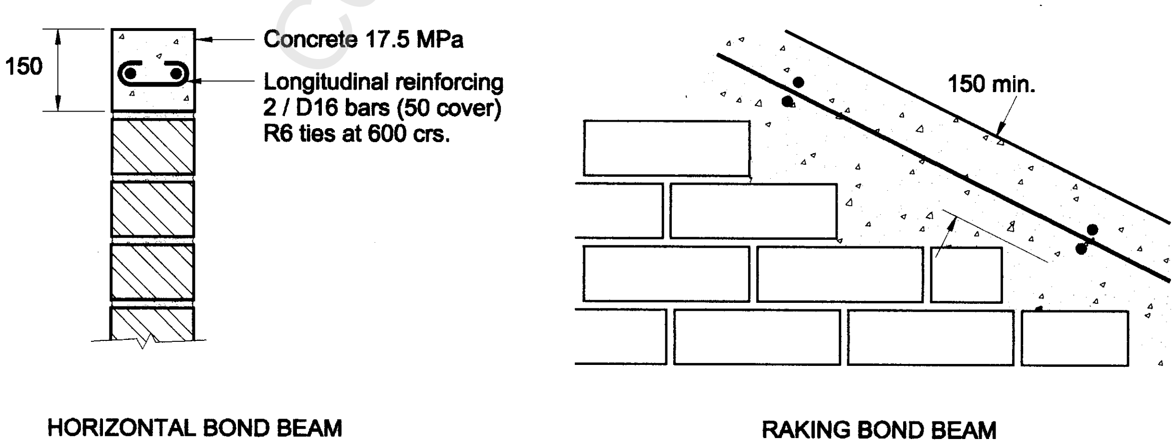


Figure 11.3 – Cinva brick walls – concrete bond beams

11.8 Lintels

11.8.1
Clause 8.1 is replaced by the following:

Lintels shall be used over all openings and shall be constructed of timber in accordance with 11.8.3, of concrete or concrete masonry in accordance with 11.8.4, or cinva bricks in accordance with 11.8.5.

11.8.2 *Gable ends*

11.8.2.1
Gable walls shall be no higher than 3.3 m.

11.8.2.2
For the purposes of 11.8.3 and 11.8.5, lintels in gable walls shall be deemed to support a roof span, *S*, of 8.0 m of heavy roof.

11.8.2.3
Rafters shall run perpendicular to the ridge line.

C11.8.2.3
Gable end walls which support rafters running parallel to the ridge area are outside the scope of this Standard.

11.8.3 *Timber lintels*

11.8.3.1
The maximum height of cinva brick wall supported by a timber lintel shall be a single course consisting of a reinforced cinva channel bond beam.

C11.8.3.1
Timber infill framing with light cladding may be used in any gap between the lintel and the underside of the bond beam.

11.8.3.2
Timber lintel sizes shall be in accordance with NZS 3604 with the following modifications:

(a) For lintels of 0.9 to 2.1 m span, the allowable lintel span given in NZS 3604 for each timber size shall be reduced by 70 mm;

(b) For lintels of greater than 2.1 m span and up to 3.6 m span, the allowable lintel span given in NZS 3604 for each timber size shall be reduced by 120 mm.

11.8.4 *Concrete or concrete masonry lintels*
Concrete or concrete masonry lintels shall be in accordance with NZS 4229.

11.8.5 *Cinva brick lintels*
Reinforced cinva brick lintels shall be as shown in figure 11.4, and shall have the spans shown in table 11.2. They shall support roofs only.

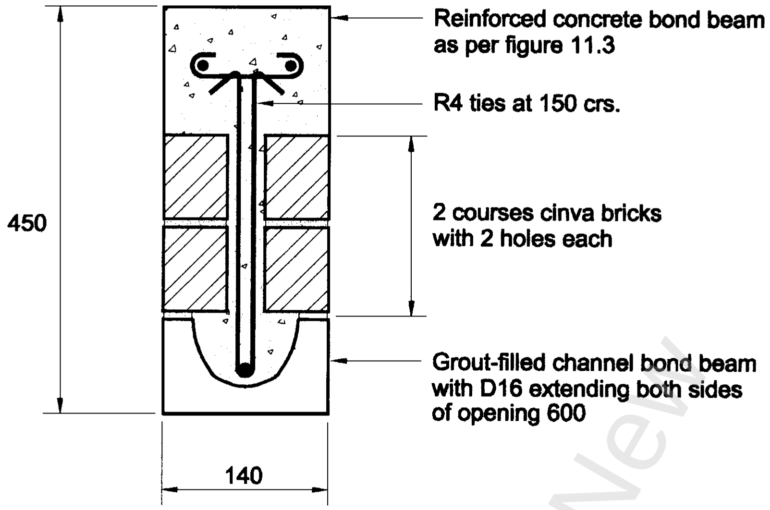


Figure 11.4 – Cinva brick lintels

Table 11.2 – Cinva brick lintels clear opening spans

Distance *S* (m)	8.0		12.0	
Basic snow load (kPa)	0.5	1.0	0.5	1.0
Roof type	**Maximum clear span** (m)			
Light	4.5	3.6	3.9	3.3
Heavy	3.9	3.3	3.3	2.7

NOTE –
(1) Refer to figure 8.5(A) for load case and definition of *S*.
(2) Specific design is required where a lintel supporting a roof has a loaded dimension of greater than 6.0 m, that is, when the supported roof member spans divided by 2 plus the eaves overhang is greater than 6.0 m. Amd 1 Dec '99

11.9 Wall openings and fixings

The provisions of section 9 are to be complied with in addition to the following provisions.

11.9.1

Timber top plates shall be fixed to cinva brick walls by either:

(a) M12 bolts set not less than 75 mm into the concrete and projecting sufficiently to allow for a washer and a fully-threaded nut above the timber;

(b) R10 steel dowels bent at least 90° set not less than 75 mm into the concrete and projecting sufficiently to allow for not less than a 75 mm length of the dowel to be clinched over the timber.

Such fixings shall be located not more than 300 mm from the end of the timber at corners of walls and not more than 1.4 m centres along the wall for M12 bolts and 900 mm centres for R10 dowels provided that each length of plate shall be fixed with not less than 2 such fixings.

11.9.2

Window and door frames may be fixed using 100 x 4.0 mm galvanized nails.

11.9.3

Where a timber top plate is not used the detail shown in figure 11.5 may be used for fixing rafters to a concrete bond beam.

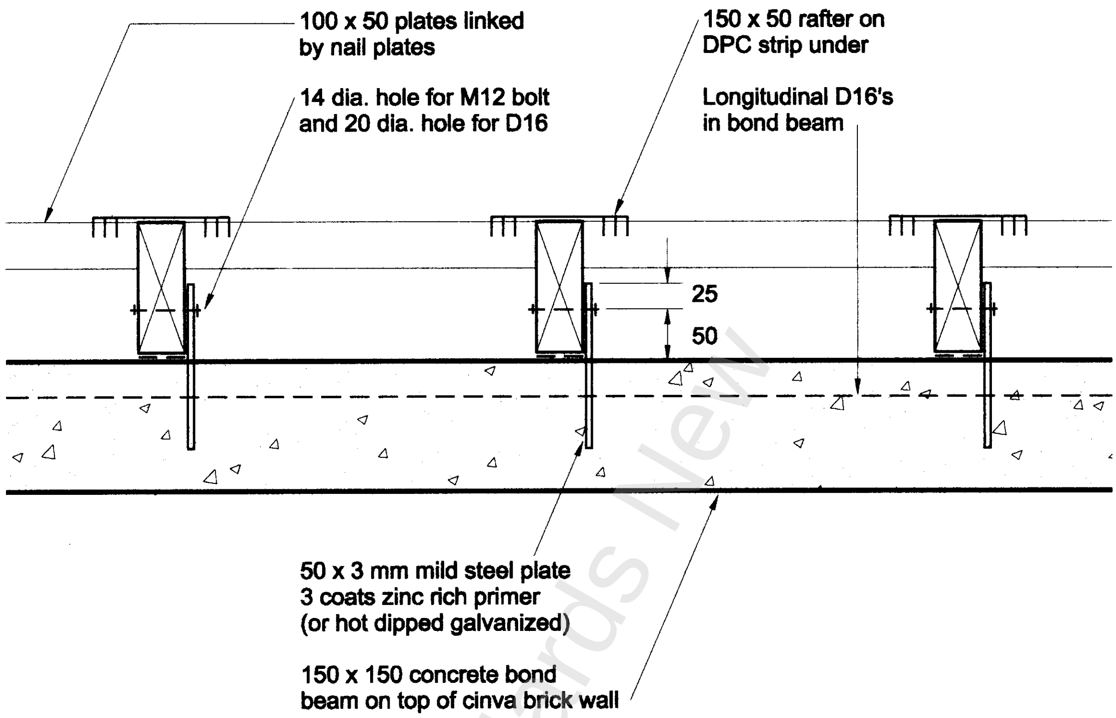


Figure 11.5 – Direct fixed rafters

11.10 Control joints

The provisions of section 10 shall apply but with the details given by figure 11.6 applying to the detail for control joints in cinva brick walls.

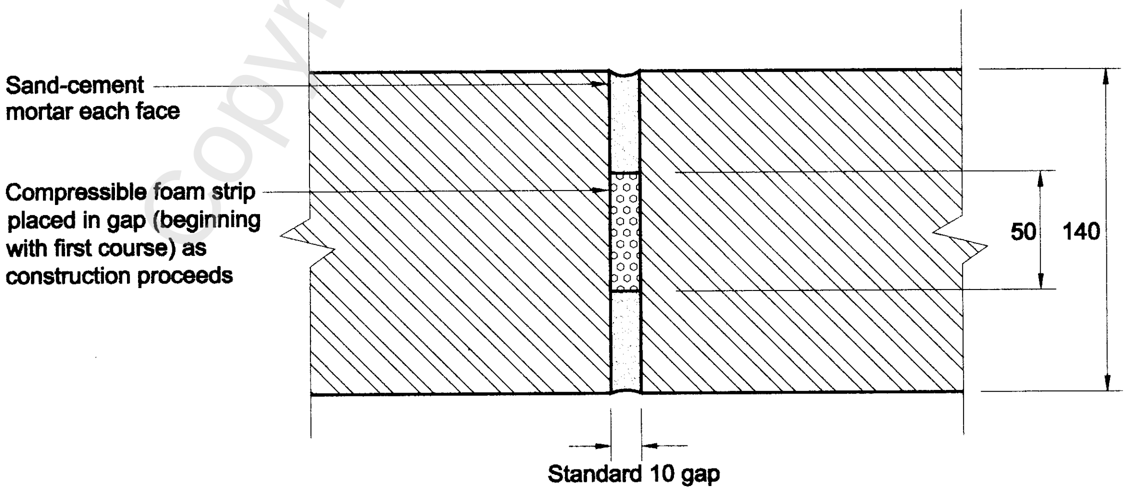


Figure 11.6 – Cinva brick wall control joint – plan view

APPENDIX A
DERIVATION OF TABLES
(Informative)

A1 Design Standards

A1.1
The following New Zealand Standard codes of practice were used in the preparation of the tables and construction details contained in this Standard.

1. NZS 4203:1992 *Code of practice for general structural design and design loadings for buildings*
2. NZS 4230:1990 *Code of practice for the design of masonry structures*
3. NZS 3101:1995 *Concrete structures Standard*
4. NZS 3603:1993 *Timber structures Standard*
5. NZS 4297:1998 *Engineering design of earth buildings*
6. NZS 3604:1990 *Code of practice for light timber frame buildings not requiring specific design*
7. NZS 4229:1986 *Code of practice for concrete masonry buildings not requiring specific design*

A1.2
A format similar to that in NZS 3604 and NZS 4229 was adopted for this Standard.

A2 Design strengths, factors and loads

A2.1
A summary of the design strengths, strength reduction factors and basic loads are shown in tables A1, A2 and A3. Standard grade earth wall construction in accordance with NZS 4297 was assumed.

Table A1 – Design strengths (MPa)

Compressive strength (except for cinva bricks)	f_e = 0.5 MPa
Compressive strength of cinva bricks	f_{es} = 2.0 MPa
Shear strength of earth for limited ductile (μ = 2 or μ = 1.25 for cinva bricks) seismic loading	f_{es} = 0.0
Shear strength of earth for wind loading and for seismic load with elastic response	f_e = 0.09 MPa

Table A2 – Strength reduction factors

Flexure	ϕ = 0.80
Shear	ϕ = 0.70
Axial compression and bearing	ϕ = 0.60

Table A3 – Basic load data

Light roof and roof structure and ceiling dead load	0.4 kPa
Heavy roof and roof structure and ceiling dead load	0.8 kPa
Timber first floor including flooring, joists and ceiling dead load	0.5 kPa
Timber partitions dead load	1 kN/m
Roof live load, NZS 4203	0.25 kPa
First floor live load, NZS 4203	1.50 kPa
Density of earth wall material (except cinva bricks)	18 kN/m^3
Density of cinva brick earth wall material	19 kN/m^3

A2.2
For the derivation of the tables for bracing demand in section 5 it was assumed that typically 30 % of the total building length was openings and that transverse earth walls were at typically 3 m centres. This is more conservative than the typical situation, and more conservative than seismic loads derived from an analysis of approximately 40 specifically designed earth houses using the 95 percentile value.

A3 Structural concept for earth walls

A3.1
Two earthquake zones were adopted in this Standard with the following 2 factors for the determination of seismic loads:

Earthquake zone factor ≤ 0.6, Z = 0.6

Earthquake zone factor > 0.6, Z = 1.2

A3.2
All earth walls for earthquake zone factor > 0.6 shall be reinforced.

A3.3
Earth walls in earthquake zone factor ≤ 0.6 may be reinforced, partially reinforced or unreinforced.

A3.4
Earth walls were designed as spanning between the reinforced concrete foundation at the bottom of the wall and the top plate or bond beam at the top of the wall. Loads from tops of walls, roofs and timber second storeys were assumed to be distributed by concrete or timber bond beams or structural ceiling or roof or first floor diaphragms to transverse earth bracing walls.

A3.5
Designing for earthquake loading is always more critical than designing for wind for the wind exposure limitations imposed in this Standard.

A4 Lateral load provisions

A4.1
The structural ductility factor, μ, was taken as 2.0 for reinforced earth walls except cinva bricks, as 1.25 for cinva bricks and as 1.0 for unreinforced and partially reinforced earth walls.

A4.2
The seismic design loads were based on NZS 4203 "intermediate ground". Sites with soft ground are not within the scope of this Standard.

A4.3
The seismic coefficient for the design of the earth walls were as follows:

Reinforced earth walls of limited ductility for earthquake zone factor > 0.6 .... $C = 0.394$

Reinforced earth walls of limited ductility for earthquake zone factor ≤ 0.6 .... $C = 0.197$

Unreinforced and partially reinforced earth walls with elastic response for earthquake zone factor ≤ 0.6 .... $C = 0.322$

A4.4
The in-plane strength of unreinforced walls is calculated assuming the following:

(a) 12 bracing units = 1 kN;

(b) The walls having no in-plane tensile strength but resist overturning by a triangular stress block generated by the wallís self weight.

A4.5
The design of concrete bond beams was based on the assumption of 15 % openings within the length of the bond beam.

A5 Rammed earth without horizontal reinforcement

Some rammed earth practitioners have reported construction difficulties arising from the inclusion of horizontal steel.

Rammed earth walls without horizontal reinforcing are therefore permitted on the basis of increasing the seismic demand load corresponding to ≤ = 2 (limited ductile) to ≤ = 1.25 (reinforced masonry elastic response). This entails a seismic demand force increase of 41 %. Rather than inserting new "bracing demand" tables, and "bracing capacity" tables all increased by 41 %, and an increased vertical reinforcing area of the same amount, the BUís required/supplied tables have been left the same and table 5.10, has been included. Table 5.10 increases the vertical reinforcing by 41 % thus meeting the increased design demand forces.

A6 Concrete lintels

A6.1
Concrete lintels were designed for the following load cases:

Load case 1 – roof only or roof and walls only with light roof, with maximum roof span S = 12 m and maximum floor joist span of 6 m.

➤

Load case 2 – roof only or roof and walls only with heavy roof.

Load case 3 – floor and timber walls only and light roof, floor and timber walls only.

A7 Cinva ram brick walls

A7.1

In the case of cinva brick walls of 140 mm thickness, out-of-plane flexure loads under "Very High Wind"(design wind speed at ultimate limit state, Vu = 50 m/s) make the greatest demand on the material, and exceed those of seismic zone factor z = 1.2 face loads. (Very High Wind can occur anywhere, as wind speeds are highly site-specific). To resist the Very High Wind out-of-plane loads it was necessary to set the design compressive strength at 2.0 MPa in the design of cinva brick, and corresponding values of production target strengths were set in the Materials and Workmanship Standard NZS 4298.

A7.2

Owing to the high design compressive strengths compared with unstabilized earth, it was possible to use the same footing details, and in the case of lateral in-plane load resistance, the same horizontal and vertical reinforcing requirements, as well as the same "bracing capacity" tables. "Bracing demand" tables are increased because, although cinva brick walls are lighter, total bracing demand is increased because μ = 1.25 is used to provide for elastic response of the reinforced cinva brick masonry.

A8 Worked examples

A8.1

An illustrative worked example is provided in Appendix B to demonstrate the recommended method for determining the bracing requirements for buildings with earth walls using the figures, tables and relevant clauses in this Standard.

APPENDIX B
WORKED EXAMPLES
DETERMINATION OF BRACING
(Informative)

EXAMPLE 1 – SINGLE STOREY BUILDING WITH LIGHT ROOF

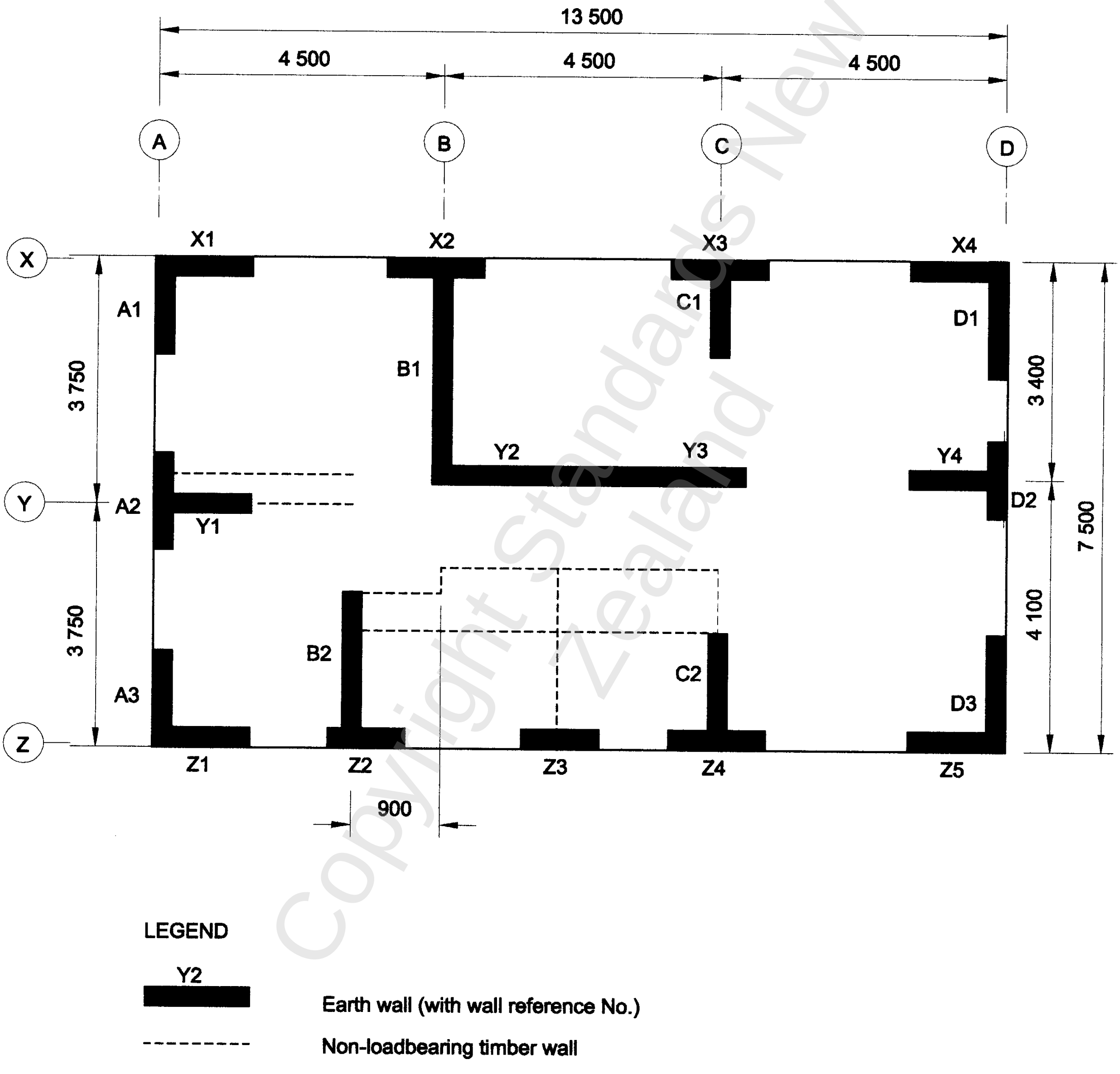


Figure B1 – Example 1 building

B1

A building in the earthquake zone > 0.6 has 280 thick walls, that are 2 700 high with light hip roof and ceiling structural diaphragm. Earth walls are at support line spacings of 4 500 in the north-south direction and 3 750 in the east-west direction. Distances are to the centreline of each support line.

Determination of bracing
Calculation for example 1

B1.1 Bracing demand for bracing support lines in north-south direction

Support line spacing 4 500 mm

Building length in north-south direction 7 500 mm

With reference to table 5.1 for single storey earth with light roof bracing demand for exterior walls $= \frac{424 + 636}{2} =$ 530 Bracing Units (BU)

(Linear interpolation between 6 m and 9 m building lengths)

With reference to table 5.6

Nominally require 2/1.5 long walls or 1/2.4 long wall

Bracing demand for interior walls $= \frac{619 + 928}{2} = 774$ BU

Nominally require 1/1.8 and 1/2.1 long walls

B1.2 Bracing demand for bracing support lines in east-west direction

External walls

Support line spacing = 3 750 mm

Building length in east-west direction = 13 500 mm

Linear interpolation between 3.0 m and 4.5 m support line spacings and 12 m and 15 m building lengths)

Bracing demand for exterior walls $= \left(\frac{711 + 848}{2} + \frac{888 + 1060}{2}\right)\frac{1}{2}$

= 877 BU

Nominally require 2/2.1 long walls or 3/1.5 long walls.

Interior walls

Linear interpolation between 3.0 m and 4.5 m support line spacings and 12 m and 15 m building lengths)

Bracing demand for interior walls $= \left(\frac{962+1237}{2} + \frac{1203+1546}{2}\right)\frac{1}{2}$

$= 1237$ BU

Nominally require 2/2.4 and 1/2.1 long walls

B1.3 Minimum bracing capacity per square metre

With reference to table 5.5

Minimum No. of bracing units per m^2 in north-south direction $= 24$ BU/m^2

Plan area of building (distances measured to external corners) $= 107.2$ m^2

Minimum bracing capacity in north-south direction $= 107.2 \times 24$

$= 2573$ BU

Minimum bracing capacity in bracing units per m^2 in east-west direction $= \frac{24+28}{2} = 26$ BU

(Linear interpolation between 3.0 and 4.5 in support line spacings)

Minimum bracing capacity in east-west direction $= 107.2 \times 26$

$= 2787$ BU

Note with reference to clause 5.4.2 bracing requirements for individual bracing support lines can be reduced up to 30 % provided the minimum bracing capacity in accordance with table 5.5 is achieved.

Refer to table B1 for summary of bracing demand.

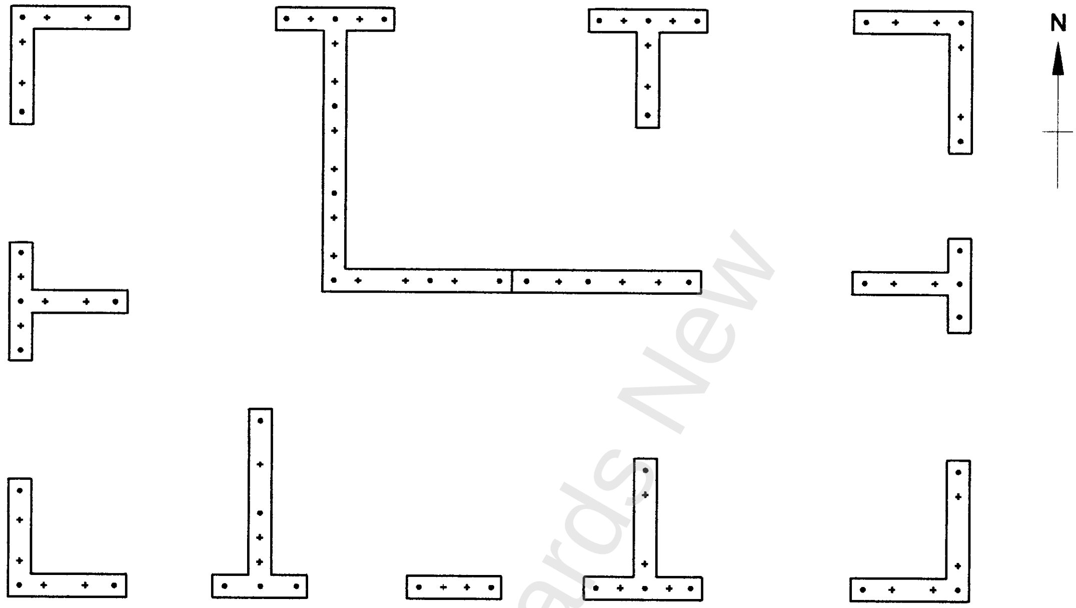
Refer to table B2 for detailed wall bracing calculations to confirm bracing capacity.

Table B1 – Summary of bracing demand for example one

Item	Description	Design criteria		
		General	North-south	East-west
1	Earthquake zone	> 0.6		
2	Building type	SSLR		
3	Wall thickness (mm)	280		
4	Wall height (mm)	2700		
5	Bracing demand table	5.1		
6	Building length (centreline measurement) (mm)		7500	13500
7	Building external length (mm)		7780	13780
8	Building plan area (m^2)	107.2		
9	Total wall area of earth gable end walls above nominal storey or wall height (4) multiplied by 50	0		
10	Minimum No. of BU's per m^2 (from table 5.5)		24	26
11	Minimum No. of BU's 8x10 + 9		2573	2787
12	Support line spacing (mm)		4500	3750
13	BU demand for exterior support lines		530	877
14	70 % of BU demand for exterior support lines		371	614
15	BU demand for interior support lines		774	1237
16	70 % of BU demand for interior support lines		542	866

Table B2 – Detailed wall bracing capacity calculations for example one

Wall or bracing line label	BU demand	70 % of BU's	Wall ref No.	Wall length	Capacity BU's	Totals	Notes
North – South			A1	1.5	309		
A			A2	1.5	309		
			A3	1.5	309		
	530	371	Total	4.5	927	927	OK
B			B1	3.6	798		
			B2	2.4	535		
	774	542	Total	6.1	1333	1333	OK
C			C1	1.5	309		
			C2	1.8	384		
	774	542	Total	3.3	693	693	OK
D			D1	1.8	384		
			D2	1.2	0		
			D3	1.8	384		
	530	371	Total	4.8	768	768	OK
Total provided						3721	
Total required						2573	OK
East – West			X1	1.5	309		
X			X2	1.5	309		
			X3	1.5	309		
			X4	1.5	309		
	877	614	Total	6.0	1236	1236	OK
Y			Y1	1.5	309		
			Y2	2.4	535		
			Y3	2.4	535		
			Y4	1.5	309		
	1237	866	Total	7.8	1688	1688	OK
Z			Z1	1.5	309		
			Z2	1.2	0		
			Z3	1.2	0		
			Z4	1.5	309		
			Z5	1.5	309		
	877	614	Total	609	927	927	OK
Total capacity						3851	
Total demand						2787	OK
Check for 5.3.8 – OK							



LEGEND

- D12 vertical reinforcing rod
- Dowel connection through top plate and top of wall
- Control joint

NOTE -

(1) Refer to figure 5.5 for construction details of reinforced earth walls.
(2) Refer to table 5.9 for spacing of vertical reinforcement.
(3) Refer table B2 for dimensions of walls.

Figure B2 – Example 1 building – Vertical reinforcement layout

EXAMPLE 2 – SINGLE STOREY BUILDING WITH LIGHT ROOF, UNREINFORCED EARTH WALLS IN EARTHQUAKE ZONE ≤ 0.6

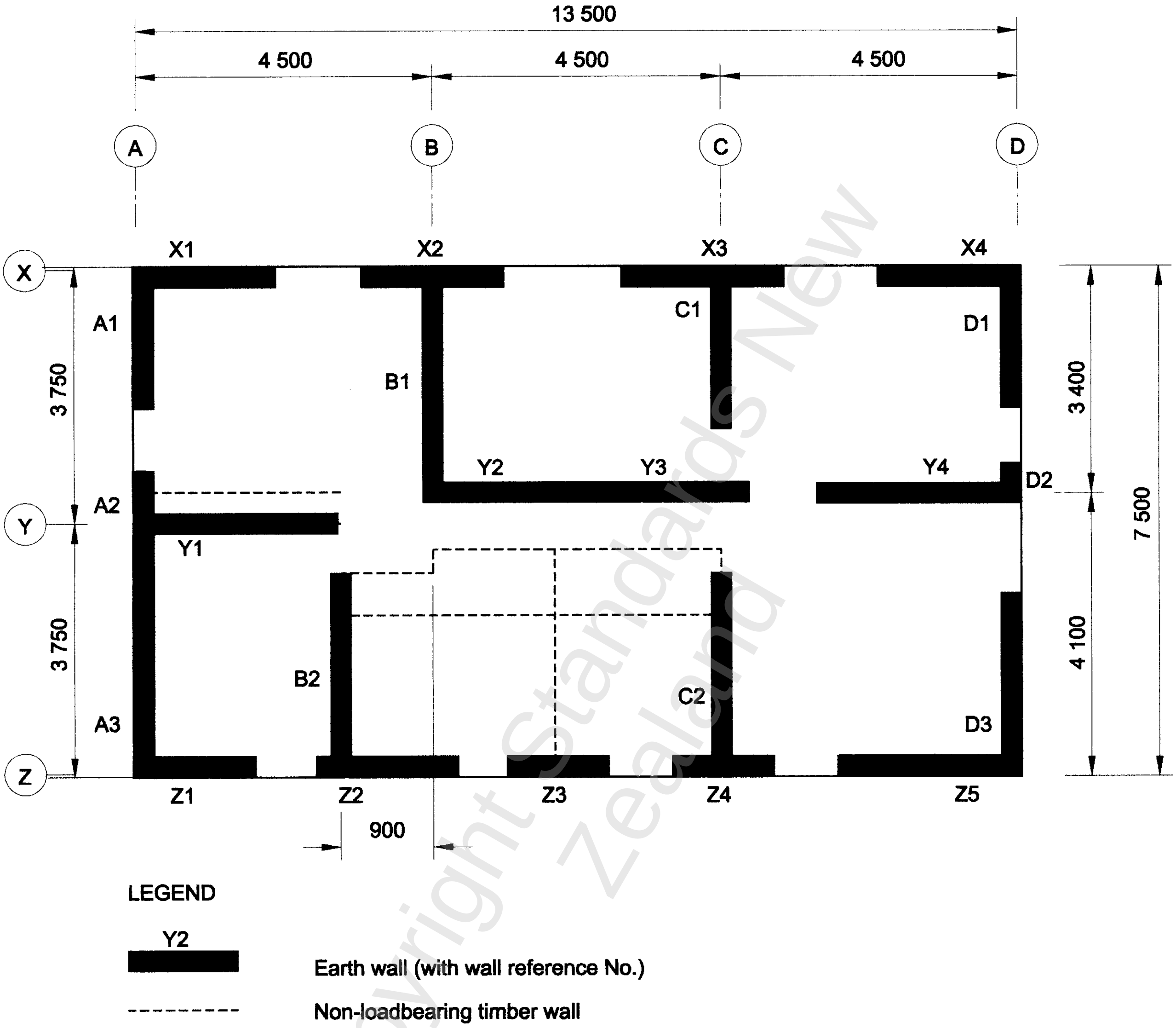


Figure B3 – Example 2 unreinforced earth building

B2

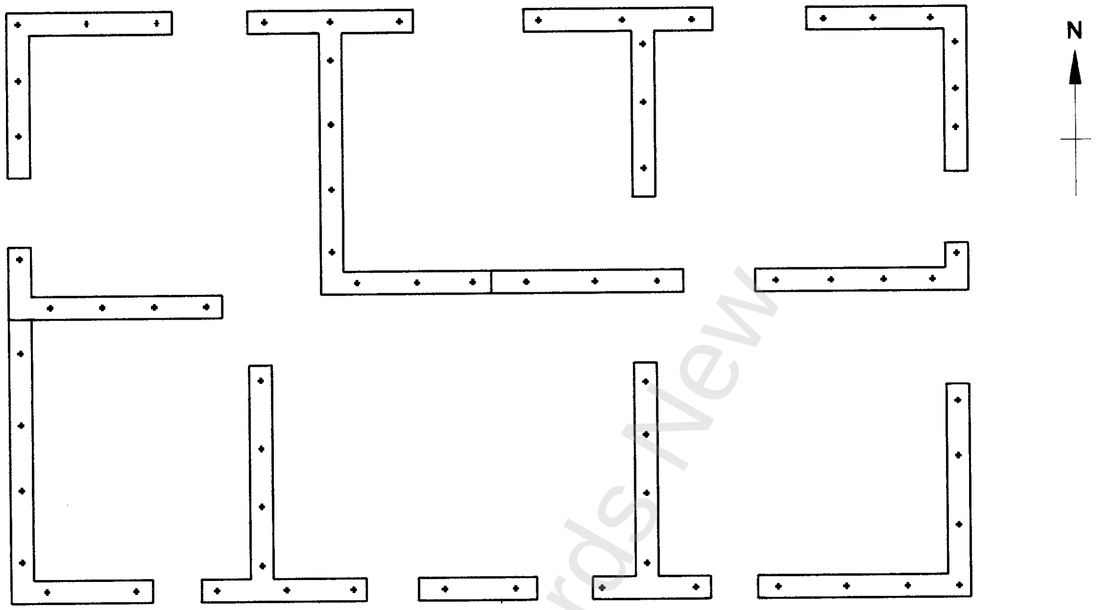
Building in the earthquake zone ≤ 0.6. Other details are as for example 1 except for some wall lengths which have changed as shown on table B4.

Table B3 – Summary of bracing demand for examples two and three

Item	Description	Design criteria		
		General	North-south	East-west
1	Earthquake zone	≤ 0.6		
2	Building type	SSLR		
3	Wall thickness (mm)	280		
4	Wall height (mm)	2700		
5	Bracing demand table	5.1		
6	Building length (centreline measurement) (mm)		7500	13500
7	Building external length (mm)		7780	13780
8	Building plan area (m^2)	107.2		
9	Total wall area of earth gable end walls above nominal storey or wall height (4) multiplied by 50	0		
10	Minimum No. of BU's per m^2 (from table 5.5)		12	13
11	Minimum No. of BU's 8 x 10 + 9		1287	1394
12	Support line spacing (mm)		4500	3750
13	BU demand for exterior support lines		265	439
14	70 % of BU demand for exterior support lines		186	307
15	BU demand for interior support lines		387	619
16	70 % of BU demand for interior support lines		271	434

Table B4 – Detailed wall bracing capacity calculations for example two

Wall or bracing line label	BU demand	70 % of BU's	Wall ref No.	Wall length	Capacity BU's	Totals	Notes
North – South			A1	3.1	90		
A			A2	0.9	0		
			A3	3.6	259		
	265	186	Total	6.6	349	349	OK
B			B1	3.6	238		
			B2	3.0	180		
	387	271	Total	6.6	418	418	OK
C			C1	2.4	115		
			C2	3.0	180		
	387	271	Total	5.4	295	295	OK
D			D1	2.1	90		
			D2	0.6	0		
			D3	2.7	145		
	265	186	Total	5.4	255	235	OK
Total provided						1297	
Total required						1287	OK
East – West			X1	2.1	90		
X			X2	2.1	90		
			X3	2.4	115		
			X4	2.1	90		
	439	307	Total	8.7	385	385	OK
Y			Y1	3.0	180		
			Y2	3.4	115		
			Y3	2.7	145		
			Y4	3.0	180		
	619	434	Total	8.4	620	620	OK
Z			Z1	1.8	65		
			Z2	2.1	90		
			Z3	1.5	45		
			Z4	1.5	45		
			Z5	2.7	145		
	439	301	Total			390	OK
Total provided						1395	
Total required						1394	OK
Check for 5.3.8 – OK							



LEGEND

Dowel connection through top plate and top of wall

Control joint

NOTE - Refer to table B4 for dimensions of walls.

Figure B4 – Example 2 building – Wall and dowel layout

EXAMPLE 3 – SINGLE STOREY BUILDING WITH LIGHT ROOF, PARTIALLY REINFORCED EARTH WALLS IN EARTHQUAKE ZONE ≤ 0.6

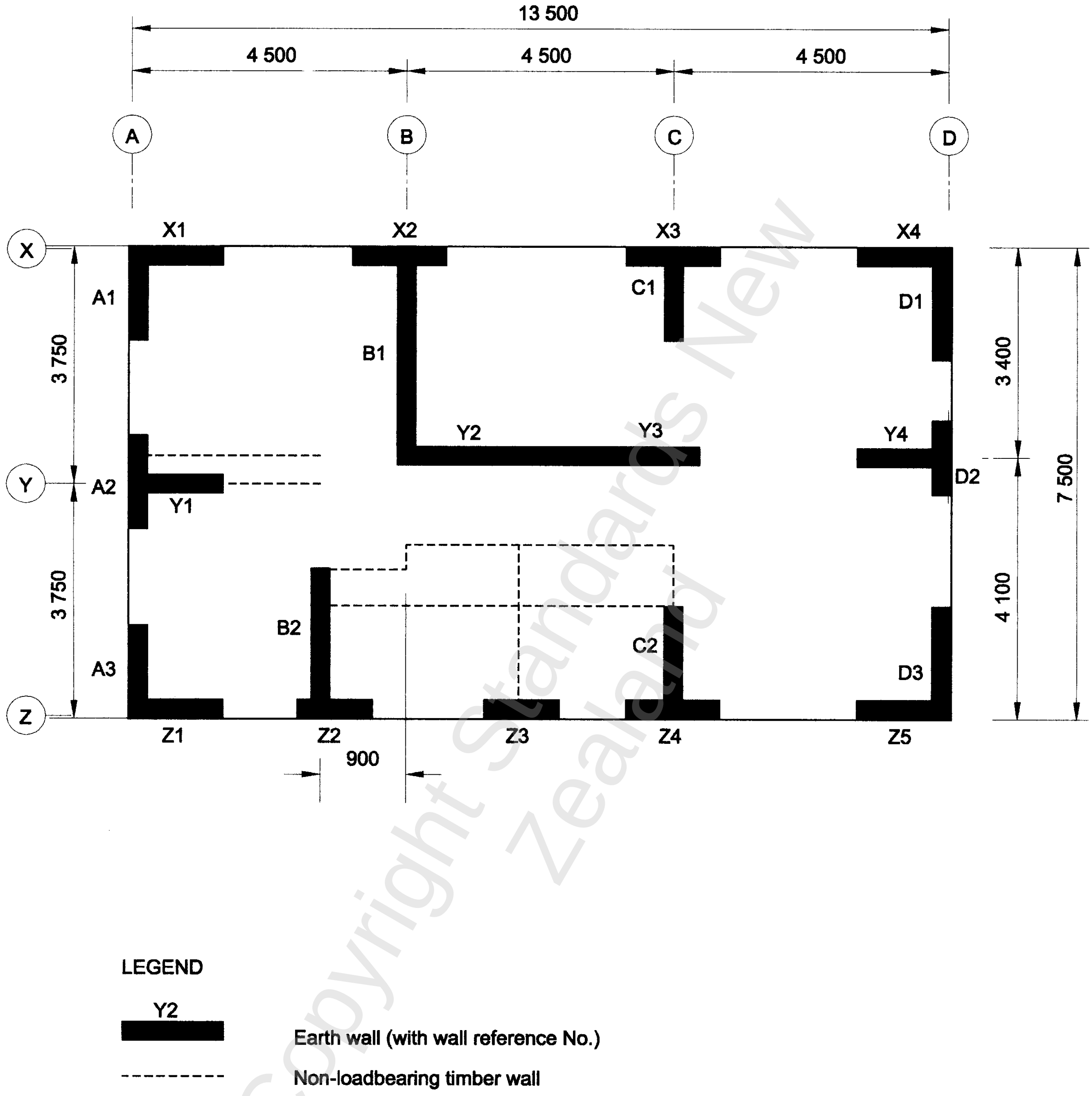


Figure B5 – Example 3 partially reinforced earth building

B3
Building in the earthquake zone ≤ 0.6. Other details are as for example 1. In table B5 bracing demand for the building is the same as for example 2 and is shown in table B3.

Table B5 – Detailed wall bracing capacity calculations for example three

Wall or bracing line label	BU demand	70 % of BU's	Wall ref No.	Wall length	Capacity BU's	Totals	Notes
North – South			A1	1.5	185		
A			A2	1.5	185		
			A3	1.5	185		
	265	186	Total	4.5	555	555	OK
B			B1	3.6	479		
			B2	2.4	321		
	387	271	Total	6.0	800	800	OK
C			C1	1.5	185		
			C2	1.8	230		
	387	271	Total	3.3	415	415	OK
D			D1	1.8	230		
			D2	1.2	0		
			D3	1.8	230		
	265	186	Total	4.8	460	460	OK
Total provided						2230	
Total required						1287	OK
East – West			X1	1.5	185		
X			X2	1.5	185		
			X3	1.5	185		
			X4	1.5	185		
	439	307	Total	6.0	740	740	OK
Y			Y1	1.5	185		
			Y2	2.4	535		
			Y3	2.4	535		
			Y4	1.5	185		
	619	434	Total	7.8	1440	1440	OK
Z			Z1	1.5	185		
			Z2	1.2	0		
			Z3	1.2	0		
			Z4	1.5	185		
			Z5	1.5	185		
	439	307	Total	6.9	555	555	OK
Total capacity						2735	
Total demand						1394	OK
Check for 5.3.8 – OK							

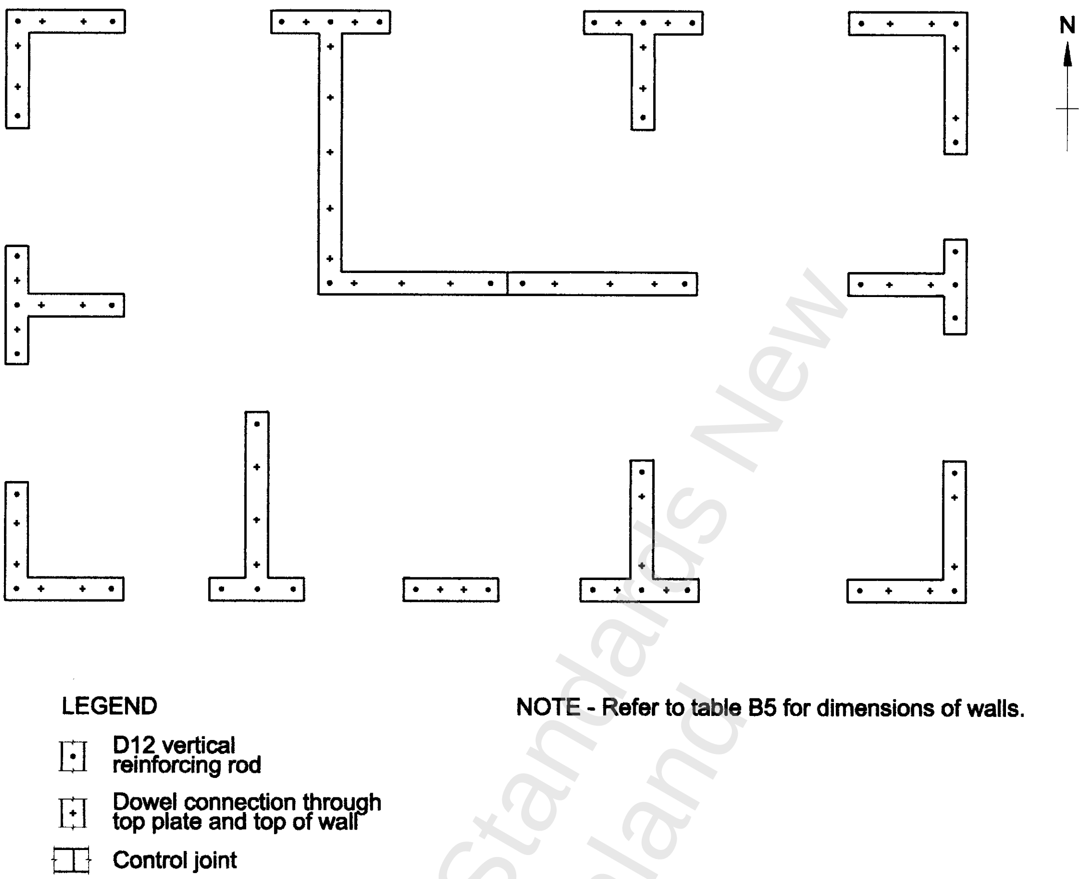


Figure B6 – Example 3 building – Vertical reinforcement layout

NOTES

NOTES

Approved by the Standards Council on 25 September 1998 to be a New Zealand Standard pursuant to the provisions of section 10 of the Standards Act 1988.

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