MINISTRY OF BUSINESS,
INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Dear Customer

Please find enclosed Amendment 15, effective 1 January 2017, to the Acceptable Solutions and Verification Methods for Clause B1 Structure of the New Zealand Building Code. The previous amendment to B1 was Amendment 14, November 2016.

Section	**Old B1**	**B1 Amendment 15**
Title pages	Remove document history and status pages 1-4	Replace with new document history and status pages 1-4
References	Remove page 13/14	Replace with new page 13/14
B1/VM1	Remove pages 19-22B	Replace with new pages 19-22B
B1/AS1	Remove pages 23/23A, 23D/24	Replace with new ages 23/23A, 23D/24
B1/AS3	Remove pages 37/38, 41/42, 49/50	Replace with new pages 37/38, 41/42, 49/50
B1/VM4	Remove page 53/54	Replace with new page 53/54

MINISTRY OF BUSINESS,
INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Acceptable Solutions and Verification Methods

For New Zealand Building Code Clause **B1 Structure**

B1
BUILDING CODE

Status of Verification Methods and Acceptable Solutions

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A person who complies with a Verification Method or Acceptable Solution will be treated as having complied with the provisions of the Building Code to which the Verification Method or Acceptable Solution relates. However, using a Verification Method or Acceptable Solution is only one method of complying with the Building Code. There may be alternative ways to comply.

Users should make themselves familiar with the preface to the New Zealand Building Code Handbook, which describes the status of Verification Methods and Acceptable Solutions and explains alternative methods of achieving compliance.

Defined words (italicised in the text) and classified uses are explained in Clauses A1 and A2 of the Building Code and in the Definitions at the start of this document.

Enquiries about the content of this document should be directed to:

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Ministry of Business, Innovation and Employment
PO Box 1473, Wellington 6140
Telephone 0800 242 243
Email: info@building.govt.nz

Verification Methods and Acceptable Solutions are available from www.building.govt.nz

New Zealand Government

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Document Status

The most recent version of this document (Amendment 15), as detailed in the Document History, is approved by the Chief Executive of the Ministry of Business, Innovation and Employment. It is effective from 1 January 2017 and supersedes all previous versions of this document.

The previous version of this document (Amendment 14) will cease to have effect on 30 May 2017.

People using this document should check for amendments on a regular basis. The Ministry of Business, Innovation and Employment may amend any part of any Verification Method or Acceptable Solution at any time. Up-to-date versions of Verification Methods and Acceptable Solutions are available from www.building.govt.nz

B1: Document History			
	Date	**Alterations**	
First published	July 1992		
Amendment 1	September 1993	p. ix–xii, References p. 1, 1.3, 1.4.1–1.4.3, 2.1, 2.2, 3.1–3.3, 4.1, 5.1 p. 2, 6.1, 6.2, 8.1, 9.1 p. 4, 11.1, 12.1 p. 5, 1.2, 2.1, 2.2, 3.1, 3.2,s 4.1, 4.2, 6.1, 6.2, 7.1	p. 9, 1.0.1, 1.0.5 b) c) p. 10, 2.3.5 p. 13, Figure 4 p. 14, 2.3.6 p. 16, 2.3.8, 2.3.9 p. 34, Table 1 p. 47, 1.0.1 pp. 49-54, Index
Amendment 2	19 August 1994	pp. i and ii, Document History pp. vii and viii, Contents pp. x and xi, References p. xiv, Definitions p. 1, 1.4.2, 5.1 p. 2, 6.1 p. 5, 1.3, 3.1, 4.1 p. 6, 7.1 p. 10, 2.3.5 p. 12, Figure 3 p. 13, Figure 4 p. 14, 2.3.6, 2.3.7	p. 15, Tables 4 and 5 p.16, 2.4.1 p. 21, Figure 2 p. 22, Figure 3 p. 32, 2.2.4 p. 33, 1.0.2 p. 34, 3.2.1, Table 1 p. 35, 4.1, 4.1.2, 4.1.3, 4.2.1, 4.2.2, 4.3, 4.3.1, 5.0.1, Table 2 p. 36, 6.1.2, 7.1, 7.1.1 p. 37, 7.3.4 pp. 49, 50, 51, 54, Index
Reprintedincorporating Amendments 1 and 2	October 1994		
Amendment 3	1 December 1995	p. ii, Document History p. ix, References p. 1, 3.1	p. 5, 6.2 p. 50, Index
Reprinted incorporating Amendments 1, 2 and 3	July 1996		
Amendment 4	1 December 2000	p. ii, Document History pp. vii and viii, Contents pp. ix – xii, Revised References pp. xiii and xiv, Definitions	pp. 1–4A, Revised B1/VM1 pp. 5 and 6, Revised B1/AS1 pp. 33–63, Revised B1/VM4 p. 65, Revised B1/AS4 pp. 67–72, Revised Index
Erratum	9 February 2001	p. 46, 4.3.2 a) i)	
Amendment 5 incorporating Erratum	1 July 2001	p. 2, Document Status p. 3, Document History p. 7, References	p. 41, 1.7.2 Comment p. 49, 2.2.4 p. 48, 1.9.1 b) i)
Amendment 6	1 March 2005	p. 11, References	
Amendment 7	1 April 2007	pp. 11–12, 14, References pp. 15–16, Definitions	p. 18, 6.1

B1: Document History			
Amendment 8	1 December 2008	p. 2, Document Status p. 3, Document History p. 9, Contents pp. 11–14, References pp. 15–16, Definitions	pp. 17–22B, B1/VM1 p. 51, B1/VM4 1.0.5, 2.0.1 p. 56, B1/VM4 Figure 2 p. 70, B1/VM4 B1.0.2 pp. 83–84, 86 Index
Amendment 9	30 September 2010	pp. 2–3, Document History, Status, pp. 11–14, References p. 20, B1/VM1 2.2.13 p. 21, B1/VM1 3.0, 5.1 pp. 22–22B, B1/VM1 11.0 pp. 23–24, B1/AS1 6.0, 6.1, 6.2, 6.3, 6.4, 7.1, 7.2, 7.3, 7.4	p. 27, B1/AS2 1.0.5 p. 44, B1/AS3 1.7.9 p. 47, B1/AS3 1.8.5, 1.8.6 p. 49, B1/AS3 2.1.1, 2.2.4 p. 63, B1/VM4 4.3.2 p. 67, B1/VM4 5.3.1
Reprinted incorporating Amendments 4–9	30 September 2010		
Erratum 1	30 September 2010	p. 21, B1/VM1 3.1	
Amendment 10 (Canterbury)	Effective from 19 May 2011 until 31 January 2012	p. 9, Contents p. 12–14, References p. 15, Definitions p. 17, B1/VM1	p. 20, B1/VM1 2.2.14A to 2.2.14D pp. 23–23C B1/AS1 1.4, 2.0, 3.0, 4.0 p. 48, B1/AS3 1.9.3 p. 84, Index
Amendment 11	Effective from 1 August 2011 until 14 August 2014	p. 9, Contents p. 11–14, References p. 17–22B, B1/VM1 1.0, 2.0, 2.2.9, 2.2.14C, 5.2, 6.1, 7.1, 8.1, 12.1, 13.0	pp. 23–24, B1/AS1 1.2, 2.0, 3.0, 4.0, 7.0, 8.0, 9.0 pp. 27–34, B1/AS2 pp. 83–87, Index
Amendment 12	Effective from 14 February 2014 until 31 May 2016	p. 9, Contents pp. 11–13, References pp. 15, 16, Definitions pp. 17, 18, 20, 22, 22A, 22B, B1/VM1 2.1, 2.2.6, 2.2.11, 5.2, 9.0, 12.1	pp. 23–23C, 24 B1/AS1 1.1, 1.2, 2.1.1–2.1.10, 3.1.9, 4.1.5, 8.0, 9.0 p. 79 , B1/VM4 C11.0
Amendment 13	Effective from 1 June 2016 until 30 May 2017	p. 13, References	p. 24 , B1/AS1 7.3.3, 7.3.4
Amendment 14	Effective from 4 November 2016 until 30 May 2017 Effective from 1 January 2017 until 30 May 2017	p. 9 Contents p.p. 14 References p. 22 B1/VM1 3.1 d) p. 22C VM1 14.1.1	pp. 22C–22F B1/VM1 14.1, 14.1.2 - 14.1.22 pp. 23, 23B B1/AS1 2.1.3, 3.1.8 pp. 84, 87 Index
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Notes:
- Amendment 15 version is effective from 1 January 2017.
- Up until 30 May 2017, Amendment 13 and Amendment 14 versions may also be used.
- From 31 May 2017, only Amendment 15 version applies, and supersedes all previous versions of the document.

Page numbers relate to the document at the time of Amendment and may not match page numbers in current document.

			Where quoted
	AS/NZS 3725: 2007	Design for installation of buried concrete pipes	VM1 11.1
Amend 8 Dec 2008			
	AS/NZS 3869: 1999	Domestic solid fuel burning appliances – Design and construction	AS3 2.1
Amend 9 Sep 2010	AS/NZS 4058: 2007	Pre cast concrete pipes(pressure and non-pressure)	VM1 11.1
Amends 10 and 11	NZS 4210: 2001	Code of practice for masonry construction: materials and workmanship	AS3 1.8.1, 1.8.3 (f and g)
Amend 9 Sep 2010		*Amend: 1*	
Amend 11 Aug 2011	NZS 4211: 2008	Specification for performance of windows	VM1 12.1
Amend 8 Dec 2008			
Amend 11 Aug 2011	NZS 4219 : 2009	Seismic Performance of Engineering Systems in Buildings	VM1 1.3.1
	NZS 4223:-	Glazing in buildings	
Amend 9 Sep 2010	Part 1: 2008	Glass selection and glazing	AS1 7.1, 7.2.1, 7.3.7
Amend 9 Sep 2010		*Amend 1*	
Amend 15 Jan 2017	Part 2: 2016	Insulating glass units	AS1 7.2
Amends 13 & 15	Part 3: 2016	Human impact safety requirements	AS1 7.3
Amend 15 Jan 2017		*Amend: 1*	
Amend 9 Sep 2010	Part 4: 2008	Wind, dead, snow, and live actions	AS1 7.4
Amend 15 Jan 2017		*Amend 1*	
Amends 10 and 11	NZS 4229: 2013	Concrete masonry buildings not requiring specific engineering design	AS1 1.4, 2.1 AS3 1.1.1, 1.8.4, 1.9.2, 1.9.5, 2.2.1 b)
Amend 12 Feb 2014			
Amend 8 Dec 2008	NZS 4230: 2004	Design of reinforced concrete masonry structures *Amend: 1*	VM1 4.0
	NZS 4251:-	Solid plastering	AS1 5.1
Amend 11 Aug 2011	Part 1: 2007	Cement plasters for walls, ceilings and soffits	
	NZS 4297: 1998	Engineering design of earth buildings	VM1 8.1
Amends 10 and 11	NZS 4299: 1998	Earth buildings not requiring specific design *Amend: 1*	AS1 1.4, 4.1
	NZS 4402:-	Methods of testing soils for civil engineering purposes. Parts 2, 4 and 5:1986 and 1988	VM1 11.1
	Part 2:	Soil classification tests	
	Test 2.2: 1986	Determination of liquid limit	Definitions
	Test 2.6: 1986	Determination of the linear shrinkage	Definitions

			Where quoted
	Part 4: Test 4.2.3: 1988	Soil compaction tests Relative densities	VM4 4.1.1
	NZS 4431: 1989	Code of practice for earth fill for residential development *Amend: 1*	VM1 10.1
	AS/NZS 4600: 2005	Cold-formed steel structures	VM1 5.2
Amends 10 and 11	AS/NZS 4671: 2001	Steel Reinforcing Materials *Amend: 1*	AS1 2.1.5, 3.1.8 AS3 1.8.5, VM1 14.0 (Amend 14 Nov 2016)
	AS/NZS 4680: 2006	Hot-Dip Galvanised (zinc) Coating	AS3 1.8.6
Amend 9 Sep 2010			
Amend 8 Dec 2008	SNZ HB 8630: 2004	Tracks and outdoor visitor structures	VM1 2.2.9
	The National Association of Steel Framed Housing Inc (NASH)		
Amend 11 Aug 2011	NASH Standard: Residential and Low Rise Steel Framing Part 1 2010	Design Criteria	VM1 5.3
	British Standards Institution		
	BS 8004: 1986	Code of practice for foundations	VM4 4.0.3
	Standards Australia		
Amend 14 Nov 2016	AS 1391: 2007	Metallic materials – Tensile testing at ambient temperature	VM1 14.1.1
Amend 9 Sep 2010	AS 1397: 2001	Steel sheet and strip – Hot-dipped zinc-coated or aluminium/zinc-coated	AS3 1.7.9
Amend 11 Aug 2011	AS 2159: 1995	Rules for the design and installation of piling (known as the SAA Piling Code) *Amend: 1*	VM4 4.0.3
	American Society of Testing and Materials		
	ASTM D1143: 1981	Test method for piles under static axial compressive load	VM4 4.0.3
	New Zealand Geomechanics Society		
	Guidelines for the field descriptions of soils and rocks in engineering use. Nov 1988		VM1 11.1
	New Zealand Legislation		
Amend 8 Dec 2008	Chartered Professional Engineers of New Zealand Act 2002		VM1 1.0
Amend 14 Nov 2016	**International Organization for Standardization**		
	ISO 15630-2 2010:	Steel for the reinforcement and and prestressing of concrete – Test Methods – Part 2 Welded Fabric	VM1 14.1.1
	ISO 17025: 2005	General requirements for the competence of testing and calibration laboratories	VM1 14.1.1

– where the top of the barrier is not a rail and where it is less than 200 mm above the top rail, the horizontal load to the top of the barrier may be reduced by 50%, otherwise apply the full horizontal load
– apply the vertical load to the top of the barrier.

• For barriers without a rail, apply:
– the horizontal load at 900 mm above the floor (or stair pitch line)
– 50% of the horizontal load to the top of the barrier
– the vertical load to the top of the barrier.

(ii) For all types of occupancy other than Row 2 of Table 3.3:

• apply the loads to the top edge of the barrier and to the top rail
• where the top of the barrier is not a rail and where it is less than 200 mm above the top rail, the horizontal load to the top of the barrier may be reduced by 50%, otherwise apply the full horizontal load.

(b) Distributed loads (kPa):

For all types of occupancy:

• consider the load as acting over the whole area bounded by the top of the barrier and the floor line for the full length of the barrier
• distribute this load to the appropriate solid portions of the barrier.

(c) Concentrated loads (kN):

For all types of occupancy:

• consider each concentrated load to be distributed over a circular or square area of 2000 mm^2
• apply concentrated loads so as to produce the most severe effect on the structural element being considered
• concentrated loads applied more than 1200 mm above the floor (or stair pitch line) may be reduced by 50%
• where the barrier infill or *balustrade* consists of parallel vertical members, less than 100 mm wide and with spaces between them of less than 100 mm, 50% of the concentrated load may be applied to each vertical member."

Amend 8
Dec 2008

COMMENT

In Table 3.3, "external balconies" for domestic and residential activities applies to decks, balconies, verandahs and the like of individual houses as well as multi household unit buildings. Such barriers may be required by Clause F4 of the *Building Code*.

2.2.8 AS/NZS 1170 Part 1, Clause 3.8

Car park Add to the last paragraph of Clause 3.8:

"The basis for determining the horizontal impact actions on barriers quoted in the Clause, including the assumed deceleration distances, is given in Clause C 3.8 of the Commentary to AS/NZS 1170 Part 1. Different design actions may be derived using Equation C3.8, provided that:

(i) The deceleration length applied is based on analysis or tests.

(ii) The vehicle mass and associated velocity are not reduced from those quoted in Commentary Clause C3.8."

2.2.9 AS/NZS 1170 Part 1, Appendix B

Replace the last paragraph with the following:

"For the design of outdoor visitor structures as defined in SNZ HB 8630: 2004, the imposed actions must be as given by that publication with references to NZS 4203 replaced by equivalent references to AS/NZS 1170."

Amend 11
Aug 2011

2.2.10 AS/NZS 1170 Part 2, Clauses 3.2 and 4.4.3 Add the following at the end of Clauses 3.2 and 4.4.3:

"Where local wind design information is more onerous than determined by this Standard and is published and required to be used by any *territorial authority* for its area, this local wind design information shall take precedence over the equivalent information in this Standard for the determination of wind actions on *buildings*.

Amend 8
Dec 2008

Where such local wind design information is less onerous than that of this Standard, the use of such information is not part of this *Verification Method.*"

Amend 12 Feb 2014

2.2.12 AS/NZS 1170 Part 3, Clause 2.1
Add the following at the end of Clause 2.1:

"Where local snow and ice design information is more onerous than determined by this Standard and is published by any *territorial authority* for its area, this local snow and ice design information shall take precedence over the equivalent information in this Standard for the determination of snow and ice actions on *buildings*.

Where such local snow and ice design information is less onerous than that of this Standard, the use of such information is not part of this *Verification Method.*"

2.2.13 AS/NZS 1170 Part 3, Clause 5.4.3
Add the following to end of Clause 5.4.3:

Amend 9 Sep 2010

"For Regions N4 and N5 the minimum value of s_g for the ultimate limit state only must be taken as 0.9 kPa."

2.2.14 NZS 1170 Part 5, Clause 1.4
Add the following to the end of the Clause 1.4:

"Where a special study yields a site-specific uniform risk design spectrum for 500 year return period equivalent to a hazard factor, *Z,* of less than 0.08, a design spectrum equivalent to at least $Z = 0.10$ may be adopted and the minimum magnitude 6.5 earthquake need not be considered.

COMMENT:
In areas where the uniform risk hazard factor is less than 0.08, the use of a minimum hazard factor $Z = 0.13$ implies design for earthquakes with extremely low probabilities of occurrence. For some projects in these areas this may involve considerable cost consequences and a reduction in requirements is acceptable when site-specific hazard studies are undertaken."

Amend 8 Dec 2008

Consequential changes due to 2010/11 Canterbury earthquakes

COMMENT:

1. As a result of the 2010/11 sequence of earthquakes in Canterbury, there is a heightened risk of seismic activity over the next few decades above that currently factored into structural design requirements. B1/VM1 is amended to reflect an increased seismic hazard factor for the *Canterbury earthquake region*.
2. The seismic hazard factor Z defined in NZS 1170 Part 5 (Table 3.3) has been raised for the *Canterbury earthquake region*. This is reflected in the following amendments to B1/VM1.

2.2.14A NZS 1170 Part 5, Clause 3.1.4
Add (to the end of Clause 3.1.4):

"The minimum hazard factor Z (defined in Table 3.3) for the *Canterbury earthquake region* shall be 0.3. Where factors within this region are greater than 0.3 as provided by NZS 1170 Part 5, then the higher value shall apply.

Amend 15 Jan 2017

2.2.14B NZS 1170 Part 5, Table 3.3

Delete row:	102	Christchurch	0.22	-
Replace with:	102	Christchurch	0.3	-
Delete row:	101	Akaroa	0.16	-
Replace with:	101	Akaroa	0.3	-

Amend 15 Jan 2017

Amend 11 Aug 2011

2.2.14D NZS 1170 Part 5, Figure 3.4
Figure 3.4 Hazard factor Z for the South Island is amended as per Paragraph 2.2.14A above.

Amend 10 May 2011

2.2.15 NZS 1170 Part 5, Clause 4.2 Seismic weight and seismic mass After: "0.3 is the earthquake imposed action (live load) combination factor for all other applications" add the following:

"except roofs.

ψ_E = 0.0 is the earthquake imposed action (live load) combination factor for roofs."

2.2.16 NZS 1170 Part 5, Sections 5 and 6 Time history analysis Time history analysis is not part of this *Verification Method.*

COMMENT:

Time history analysis is a highly specialised method of assessing structural response to earthquakes. It requires many detailed and interdependent assumptions to be made in relation to the nature of earthquake shaking and its propagation from the source, the properties of the *building* site and the detailed characteristics of the *building* and its structural elements.

AS/NZS 1170 outlines the steps for time history analysis in some detail, but the applicability of each step needs to be evaluated on a *building*-by-*building* basis. More importantly, the output of the analysis needs to be examined carefully in each particular context.

Time history analysis can be an acceptable aid to verifying compliance with structural requirements provided that:

- It is carried out by specialists with in-depth experience in applying the technique.
- The output of the analysis and the viability of the resulting structural design are reviewed by an independent team experienced in both analysis and design.

2.2.17 NZS 1170 Part 5, Clause 5.2.2.3, equation 5.2(4) Delete equation 5.2(4) and replace with:

$$C_d(T) = \frac{C(T)\, S_p}{k_\mu} \qquad \text{... 5.2(4)}$$

2.2.18 NZS 1170 Part 5, Clause 6.1.4.1 Requirement for modelling Delete the last sentence of the first paragraph and replace with:

"The model shall include representation of the diaphragm's flexibility."

Delete the third (last) paragraph.

Amend 8
Dec 2008

3.0 Concrete

3.1 NZS 3101: Part 1 subject to the following modifications:

a) Replace clause 4.8 **External walls that could collapse outward in fire** with:

4.8 External walls that could collapse inwards or outwards in fire

4.8.1 Application

This clause applies to external walls which could collapse inwards or outwards from a building as a result of internal fire exposure. All such walls shall:

(a) Be attached to the building structure by steel connections;

(b) Be restrained by these connections, when subject to fire, from inwards or outward movement of the wall relative to the building structure; and

(c) Comply with the appropriate provisions of this Standard for walls.

4.8.2 Forces on connections

The connections between each wall and the supporting structure shall be designed to resist all anticipated forces. In the absence of a detailed analysis, the connections shall be designed to resist the largest of:

(a) The force resulting from applying Clause 2.2.4 of Verification Method B1/VM1;

(b) for walls fixed to a flexible structure of unprotected steel, the force required to develop the nominal flexural strength of the wall at its base;

(c) for walls fixed to a rigid structure such as reinforced concrete columns or protected steel columns or another wall at right angles, the force required to develop the nominal flexural strength of the wall at mid-height.

b) Amend Clause **9.3.9.4.13 Minimum area of shear reinforcement**

In Clause 9.3.9.4.13 c) delete the words after "750 mm" and substitute "and the depth of the precast unit is equal to or less than 300 mm and the overall depth is equal to or less than 400mm."

Amend 9
Sep 2010

Amend 15
Jan 2017

c) Amend Clause **18.7.4 Floor or roof members supported by bearing on a seating**

Add to the end of Clause 18.7.4 (g)(ii) add an additional sentence:

Erratum 1 Sep 2010

"The details given by C18.6.7(e) may be applied to hollow-core units where the depth of the precast unit is equal to or less than 300 mm."

Amend 9 Sep 2010

d) Amend NZS 3101 Clause **5.3.2.6 Ductile welded wire fabric**

Delete the clause and replace with:

"Welded steel mesh shall be Ductility Class E in accordance with Paragraph 14 of this Verification Method unless the conditions of Clause 5.3.2.7 for the use of lower ductility welded wire fabric are satisfied."

Amend 14 Nov 2016

Amend 9 Sep 2010

3.2 NZS 3106

4.0 Concrete Masonry

Amend 8 Dec 2008

4.1 NZS 4230

5.0 Steel

Amend 9 Sep 2010

5.1 NZS 3404: Part 1

Amend 8 Dec 2008

5.2 AS/NZS 4600 subject to the following modifications:

Amend 11 Aug 2011

a) Actions must be determined in accordance with AS/NZS 1170. All references to NZS 4203 are replaced by equivalent references to AS/NZS 1170.

Amend 8 Dec 2008

b) The term "normative" identifies a mandatory requirement for compliance with this Standard.

c) The term "informative" identifies information provided for guidance or background which may be of interest to the Standard's users. Informative provisions do not form part of the mandatory requirements of the Standard.

d) Where this Standard has provisions that are in non-specific or unquantified terms then these do not form part of the *Verification Method* and the proposed details must be submitted to the *territorial authority* for approval as part of the *building consent* application. This includes, but is not limited to, special studies and manufacturer's advice.

e) All stages of *construction* of a structure or part of a structure to which this Standard is applied shall be adequately reviewed by a person who, on the basis of experience or qualifications, is competent to undertake the review.

f) The extent of the review to be undertaken shall be nominated by the design ngineer, taking into account those materials and work-manship factors which are likely to influence the ability of the finished construction to perform in the predicted manner.

g) At the end of the first paragraph of Appendix A add the words "Unless noted otherwise a document referred to below shall be the version of that document current at the date of issue of this Standard or if amendments are cited to this Standard in the "References" pages of this document at the latest date of those amendments."

Amend 12 Feb 2014

h) Appendix B shall be read as normative with "shoulds" changed to "shalls".

5.3 NASH Standard – Residential and Low-rise Steel Framing Part 1: Design Criteria.

Amend 11 Aug 2011

6.0 Timber

6.1 NZS 3603 subject to the following modifications:

a) Actions must be determined in accordance with AS/NZS 1170. All references to NZS 4203 are replaced by equivalent references to AS/NZS 1170.

Amend 11 Aug 2011

Amend 11 Aug 2011

b) Delete Clause 2.2.1.2 and replace with:

"Machine stress-grading shall be in accordance with AS/NZS 1748 as modified by NZS 3622. Machine stress-graded timber shall have its properties verified, and be identified, in accordance with the requirements of NZS 3622."

Amend 7 Apr 2007

Amend 8 Dec 2008

7.0 Aluminium

7.1 AS/NZS 1664.1 subject to the following modifications:

Amend 11 Aug 2011 / Amend 8 Dec 2008

a) Actions must be determined in accordance with AS/NZS 1170. All references to NZS 4203 are replaced by equivalent references to AS/NZS 1170.

b) The terms "capacity factor" and "strength limit state" are to be read as "*strength reduction factor*" and "ultimate limit state" respectively.

c) Where this Standard has provisions that are in non-specific or unquantified terms then these do not form part of the *Verification Method* and the proposed details must be submitted to the *territorial authority* for approval as part of the *building consent* application. This includes, but is not limited to, special studies and manufacturer's advice.

d) All stages of *construction* of a structure or part of a structure to which this Standard is applied shall be adequately reviewed by a person who, on the basis of experience or qualifications, is competent to undertake the review.

Amend 8 Dec 2008

e) The extent of the review to be undertaken shall be nominated by the design engineer, taking into account those materials and workmanship factors which are likely to influence the ability of the finished *construction* to perform in the predicted manner.

Amend 8 Dec 2008

f) Clause 1.2 to read "**MATERIALS** This Standard applies to aluminium alloys listed in Table 3.3(A) that comply with AS 1734, AS 1865, AS 1866, AS 1867 and AS 2748.1."

g) At the end of the first paragraph of Clause 1.4 add the words "Unless noted otherwise a document referred to below shall be the version of that document current at the date of issue of this Standard or if amendments are cited to this Standard in the "References" pages of the Acceptable Solutions and Verification Methods at the latest date of those amendments."

Amend 8 Dec 2008

Amend 12 Feb 2014

8.0 Earth Buildings

8.1 NZS 4297 subject to the following modifications:

Actions must be determined in accordance with AS/NZS 1170. All references to NZS 4203 are replaced by equivalent references to AS/NZS 1170.

Amend 11 Aug 2011

9.0 Foundations

See B1/VM4.

Amend 12 Feb 2014

10.0 Siteworks

10.1 NZS 4431

11.0 Drains

11.1 AS/NZS 3725 subject to the following modifications:

Clause 3 Add to the list of reference documents:

"NZS 3101 The design of concrete structures.

NZS 4402 Methods of testing soils for civil engineering purposes: Tests 2.4, 2.8, 4.1.1, 4.2.1, 4.2.2, 4.2.3 and 5.1.1.

New Zealand Geomechanics Society, Guidelines for the field description of soils and rocks in engineering use."

Clause 4 In the paragraph headed "(c) Select fill", after the words "given in Table 1" add "or the New Zealand Geomechanics Society Guidelines".

Clause 5 In definition of Pt, replace "AS 4058" with "AS/NZS 4058"

Clause 6.4 Replace the word "may" with "shall". Delete the words "Superimposed concentrated dead loads should be avoided."

Clause 6.5.3.1 Delete the words "The appropriate road vehicle loading shall be specified by the relevant highway authority or owner".

Clause 6.5.3.2.2.2 Replace the word "may" with "shall".

Amend 9 Sep 2010

Clause 6.5.4.3 Delete the words "unless otherwise specified by the Relevant Authority".

Clause 6.5.5 Delete the first words "For" and after the words "for aircraft types" add the words "is outside the scope of this Standard but..."

Clause 7 Replace the word "should" with "shall".

Clause 10.3 After the words "the test load" add "or proof load".

Appendix A Delete "Normative" and replace with "Informative"

Appendix B Delete "Normative" and replace with "Informative"

12.0 Windows

12.1 NZS 4211 subject to the following modification:

References to air leakage, water leakage and operational effectiveness of opening sashes in NZS 4211, are non-structural considerations and do not apply to this document.

Amend 11
Aug 2011

Amend 12
Feb 2014

13.0 Seismic Performance of Engineering Systems in Buildings

13.1 NZS 4219 subject to the following modifications in the *Canterbury earthquake region:*

The zone factor Z shall be determined from the Standard but shall not be less than 0.3.

Amend 11
Aug 2011

Amend 15
Jan 2017

Amend 9
Sep 2010

Amend 8
Jun 2008

Acceptable Solution B1/AS1 General

1.0 Explanatory Note

Amend 12 Feb 2014

1.1 B1/AS1 contains Acceptable Solutions for Masonry (Paragraph 2.0), Timber (Paragraph 3.0), Earth Buildings (Paragraph 4.0) and Stucco (Paragraph 5.0), Drains (Paragraph 6.0) and Glazing (Paragraph 7.0).

Amend 11 Aug 2011

1.2 B1/AS gives an Acceptable Solution for small *chimneys* (referred to in Paragraph 8.0).

1.3 Modifications to the Standards, necessary for compliance with the New Zealand Building Code, are given against the relevant clause number of each Standard.

1.4 Consequential changes due to 2010/11 Canterbury earthquakes

Amend 11 Aug 2011

COMMENT:

Raising the seismic hazard factor Z in NZS 1170 Part 5 (Table 3.3) for the *Canterbury earthquake region* through amendments to B1/VM1 requires consequential amendments to NZS 4229, NZS 3604 and NZS 4299 referenced in B1/AS1.

2.0 Masonry

2.1 NZS 4229 subject to the following modifications:

2.1.1 NZS 4229 Clause 7.8.3

Delete clause 7.8.3.

Replace with:

"All slab-on-ground reinforcing shall extend to within 75 mm of the outside edge of the slab (including the foundation wall) and shall consist of a minimum 2.27kg/m^2 welded Grade 500E reinforcing mesh sheets (1.14 kg/m^2 in each direction), which shall be lapped at sheet joints such that the overlap measurement between the outermost cross wires of each fabric sheet is equal to the greater of one of the following:

- the spacing of cross wires plus 50 mm;

- 150 mm; or

- the manufacturer's requirements.

Slabs shall have a maximum dimension of 18 m between free joints."

Amend 12 Feb 2014

2.1.2 NZS 4229

Foundations in the *Canterbury earthquake region* only where *good ground* has not been established.

COMMENT:

Foundations for houses built on ground that has the potential for liquefaction or lateral spread are outside the scope of B1/AS1.

Foundation designs for houses built in areas that have the potential for liquefaction, as defined by the Christchurch City Council, the Selwyn District Council and the Waimakariri District Council, may be in accordance with the MBIE Guidance Document "Repairing and rebuilding houses affected by the Canterbury earthquakes" (refer to www.mbie.govt.nz).

The foundation options in the MBIE Guidance Document apply to properties in the *Canterbury earthquake region* that have been categorised as Technical Category 1 to 3 (TC1, TC2 and TC3).

For TC1 properties, provided the conditions for *good ground* in Section 3 of NZS 3604 are met, house foundations following B1/AS1 can be used.

For TC2 and TC3 properties the MBIE Guidance Document provides a range of foundation solutions depending on expected ground movement and available bearing capacity. These parameters also determine the degree of involvement of structural and geotechnical engineers and the extent of specific engineering design.

Further guidance is being developed for other New Zealand regions and it is expected that this will inform the wider building and construction sector in due course. In the meantime for properties outside the *Canterbury earthquake region* that have the potential for liquefaction, MBIE recommends that further engineering advice is sought. For these properties a foundation solution following those provided for TC2 in the MBIE Guidance Document may be appropriate.

Amends 11 and 12

2.1.3 NZS 4229 Grade 500E welded steel mesh

Where Grade 500E welded steel mesh is specified, it shall meet the requirements of Paragraph 14.0 in B1/VM1.

Amend 14 Nov 2016

Amend 12 Feb 2014

3.0 Timber

3.1 NZS 3604 subject to the following modifications:

3.1.1 NZS 3604 Paragraph 1.3 Definitions
Add (in the definition for Good Ground): "(liquefaction, lateral spread – for the *Canterbury earthquake region* only)" after "subsidence" in subparagraph (c).

Amend 11 Aug 2011

Amend 10 May 2011

3.1.2 NZS 3604 Section 5 Bracing Design

Make the following amendments:

Amend Figure 5.4, Earthquake zones, so that all the area within the Christchurch City Council boundary is within Zone 2.

Amend Figure 5.4 Earthquake zones, so that the lowest zone within the Selwyn or Waimakariri District Council boundaries is within Zone 2. Areas within Selwyn District that are designated as Zone 1 in NZS 3604 shall become Zone 2.

Amend 11 Aug 2011

Amend 15 Jan 2017

3.1.2A NZS 3604 Clause 7.4.1.3

Delete Subclause 7.4.1.3 (c).

3.1.2B NZS 3604 Figure 7.10(b)

On the plan view replace the text "2/M12 x 250 mm coach screws at 140 crs" with "2/M12 x 240 mm coach screws at 140 crs vertically."

On the plan view replace "2/M12 at 400 crs" twice with "2 M12 bolts at 140crs vertically to capture end joist laminations and blocking, and boundary joist laminations and blocking, at post centrelines."

Add to Note 3: "All coach screws to have 50 x 50 washers."

3.1.2C NZS 3604 Figure 7.10(c)

On the plan view insert the text "At each strap location (at joist ends and nogging), 2/M12 x 240 mm long coach screws are required."

On the plan view, replace the text " 2/M12 x 250 mm coach screws at 140 crs vertically" with " 2/M12 x 200mm coach screws at 140 crs vertically."

On the section view, replace the text "M12 x 200 mm coach screws at 400 crs vertically" with M12 x 240 mm coach screws at 140 crs vertically.

Delete "2/M12 bolts at 400crs" which tie laminations together along edge joists and along boundary joists.

Amend 15 Jan 2017

3.1.3 NZS 3604 Clause 7.5.2.3
Delete: Clause 7.5.2.3

Replace with: "Clause 7.5.2.3 The combined foundation and edge details shall be constructed as shown in Figures 7.13(B), 7.14(B) or (C) (and Figures 7.15(B) and 7.16(B) or (C) for foundations supporting a masonry veneer)."

3.1.4 NZS 3604 Figure 7.13
Delete: Figure 7.13(A) – Foundation edge details – In situ concrete – Dimensions & reinforcing for single storey.

Amend 11 Aug 2011

Amend title of Figure 7.13(B) to "Dimensions & reinforcing for 1 or 2 storeys".

Amend 11 Aug 2011

3.1.5 NZS 3604 Figure 7.14
Delete: Figure 7.14(A) – Foundation edge details – Concrete masonry – Single storey

Amend title of Figure 7.14(B) to "1 or 2 storeys", and add a note: "for a single storey foundation, 15 Series masonry may be used and the minimum footing width may be 190 mm".

Amend 11 Aug 2011

COMMENT:
Unreinforced and untied slab to footing single storey option removed.

3.1.6 NZS 3604 Figure 7.15

Delete: Figure 7.15(A) – Masonry veneer foundation edge details – Dimensions and reinforcement for single storeys.

Amend 11 Aug 2011

Amend 10 May 2011

6.0 Drains

6.1 AS/NZS 2566.1

6.2 AS/NZS 2566.2

6.3 AS/NZS 2032

6.4 AS/NZS 2033

Amends 9, 11, 15

7.0 Glazing

7.1 NZS 4223.1

7.2 NZS 4223.2

7.3 NZS 4223.3

7.3.1 Clause 22.4.3 modified

Delete clause 22.4.3

Replace with:

"22.4.3 Structural glass barriers

Structural glass barriers use glass as a structural element and are normally classified by the following types. Glass design for these types shall comply with the following tables (see note 1):

Table 14 - Structural balustrade – cantilevered glass;

Table 15 - Structural balustrade – two-edge point fixed;

Table 16 - Structural balustrade – two-edge support;

Table 17 - Structural balustrade – three-edge support.

Design types and glass types not shown in Tables 14 to 17 require specific design.

All structural glass barriers safeguarding a fall of 1000 mm or more shall have interlinking rails, which in the event a glass pane breaks, spans the broken pane at the required barrier height and,

i) resists Line and Concentrated design loads (SLS) specified in Tables 14 to 17, and

ii) does not deflect more than 100 mm, in any direction, under the design loads.

Interlinking rails are not required for a heat-strengthened or toughened laminated safety glass barrier that:

(a) has a top capping, corner brackets or a proprietary system and will, when both panes of the laminate are fractured, resist a 0.2 kN concentrated load and not deflect more than 250 mm (see note 2), or

(b) has two or three edges supported by structural sealant joints or continuous clamps, and will, when both panes of the laminate are fractured, resist a 0.2 kN concentrated load and not deflect more than 250 mm (see note 2), or

(c) has a stiff interlayer and will, when both panes of the laminate are fractured, resist a 0.2 kN concentrated load and not deflect more than 250 mm (see note 2). Physical testing must be undertaken to demonstrate compliance with the load and deflection requirements for laminated glass barriers with a stiff interlayer (see note 3).

Physical testing of glass barriers must include all components of the barrier system, including all structural connections. Loads and deflections must be applied and measured horizontally, at midspan, at the required barrier height. The concentrated load shall be applied over an area of 100 mm x 100 mm and for at least one minute.

NOTE –

(1) The design of structural connections, fasteners and mounting hardware, that are part of the glass barrier, is outside the scope of this Standard and must be specifically designed.

(2) Laminated glass is susceptible to minor edge delamination, depending on the interlayer type and laminating process. Normally this will not affect the mechanical properties but can be noticeable on exposed edges.

(3) Test results for dual pane fracture of laminated glass barriers with stiff interlayers are not applicable to barriers that have narrower glass panes than that tested"

Amend 15 Jan 2017

Amend 13 Jun 2016

7.4 NZS 4223.4

Amend 11 Aug 2011

8.0 Small Chimneys

Amend 12 Feb 2014

See Acceptable Solution B1/AS3.

Acceptable Solution B1/AS3 Small Chimneys

Scope

This acceptable solution applies to small *chimneys* and to supporting *hearth* slabs for solid fuel burning domestic appliances. It is to be read in conjunction with Acceptable Solution C/AS1 Part 7, which has additional requirements to prevent outbreak of *fire*.

Amend 15
Jan 2017

1.0 Chimney Construction

1.1 General

1.1.1 Type

The acceptable solutions described in this document are for *chimneys* built of brickwork, concrete or precast pumice concrete, that are connected to timber frame or masonry *buildings* complying with NZS 3604 or NZS 4229.

1.1.2 Height

The height of any *chimney* measured from the top of the *chimney* foundation slab to the top of the *chimney* stack shall not exceed 9 m. *Chimneys* shall not cantilever more than 2.4 m above the fixing at roof level (refer Paragraph 1.7).

1.1.3 Size

The width (measured along the *building* line) and depth (measured perpendicular to the *building line*) shall not exceed:

a) For the foundation and *chimney base*

– precast pumice concrete	1600 mm wide x 1050 mm deep
– brickwork or concrete	1200 mm wide x 1050 mm deep

b) For a brick *chimney* stack

– single skin (see Figure 2)	500 mm wide x 500 mm deep
– double skin (see Figure 3)	1200 mm wide x 680 mm deep

c) For a concrete or precast pumice concrete *chimney* stack — 1200 mm wide x 700 mm deep

1.1.4 Chimney liners

Where *chimney* liners are used they are to be separated from the *chimney* to ensure free thermal movement. This shall be achieved by coating the liner with a suitable debonding agent or by wrapping it in a *combustible* material no less than 0.25 mm thick.

1.2 Chimney wall thickness

1.2.1 *Chimney* wall thicknesses shall be no less than:

a) Brick

– single skin (see Figure 2)	155 mm
– double skin (see Figure 3)	245 mm

b) Concrete 170 mm

c) Precast pumice concrete 85 mm

These thicknesses apply to the *chimney* stack, *gather* and *chimney base*.

1.3 Foundations

1.3.1 *Chimneys* shall be built on a foundation comprising walls and slab for suspended floors (see Figure 1(a)), or on a thickened slab for floor slabs on ground (see Figure 1(b)).

1.3.2 The *chimney* foundation slab shall be constructed in reinforced concrete, founded on *good ground*, and have:

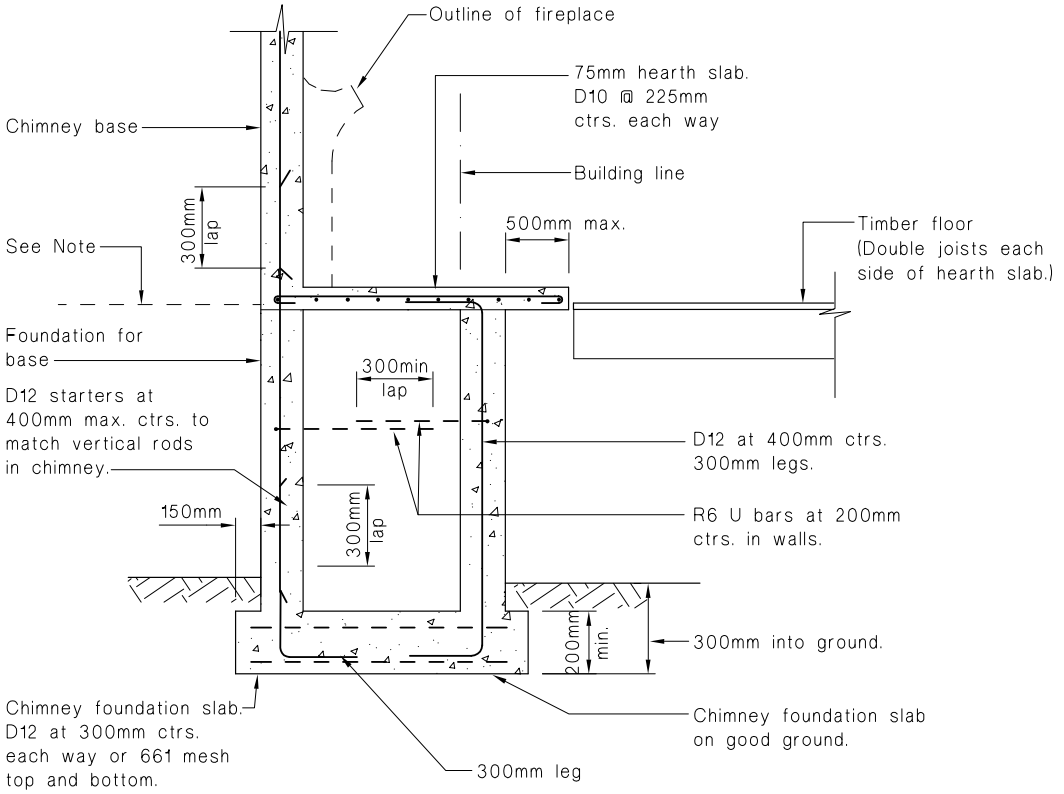
a) A thickness of no less than 200 mm, and be placed at a depth of no less than 300 mm below surrounding ground level.

b) Reinforcement as shown in Figure 1.

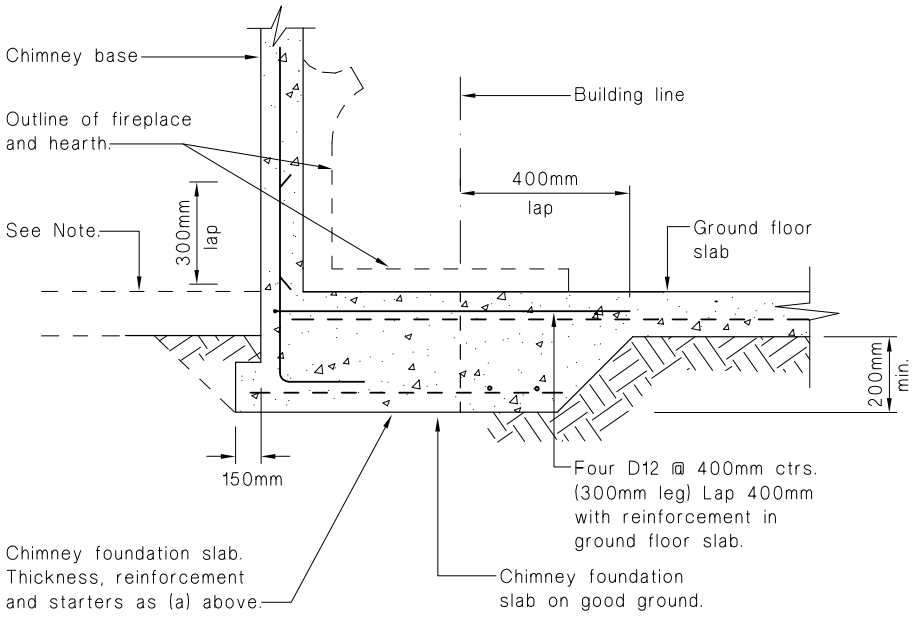
c) D12 starters at 400 mm maximum centres, to match vertical steel locations in the *chimney*.

1.3.3 The *chimney* foundation walls shall be 150 mm thick reinforced concrete, 190 mm thick concrete masonry, or brick *construction* complying with Figures 2 or 3. Vertical and horizontal reinforcing steel shall be as given in Paragraph 1.6.

Figure 1: **Chimney Foundation**
Paragraphs 1.3.1, 1.3.2 b) and 1.4.1, and Figures 2, 3, 4 and 5



(a) Suspended floor



(b) Slab on ground

NOTE:
Figures 1(a) and 1(b) have been drawn for the chimney being exterior to the building. The dotted line indicates the timber floor in Figure 1(a) and the ground floor slab in Figure 1(b) for the situation where the chimney is internal.

1.4 Hearths

1.4.1 *Hearth* slabs shall be of concrete no less than 75 mm thick, reinforced with D10 bars located centrally at 225 mm centres each way. See Figure 1.

1.5 Chimney breasts

1.5.1 The widths of openings in *chimney breasts*, and their supporting lintels, shall comply with Table 1.

Table 1: Chimney Breast Openings and Lintels
Paragraph 1.5.1 and Figure 4

Opening width	Lintel reinforcing
Brick	
1.0 m maximum	65 x 10 mm m.s. flat or 80 x 60 x 5 mm m.s. angle
Concrete	
Up to 900 mm	Two D10 rods
900 – 1500 mm	D12 upper rod D16 lower rod
Precast pumice	
1.0 m maximum	Two D10 rods

Note:
Horizontal reinforcing rods to concrete and precast pumice are to be placed one above the other at a spacing of 75 mm, and have R6 ties at 150 mm maximum centres.

1.6 Reinforcing

1.6.1 Reinforcing of foundation walls, *chimney bases* (including the *gathers*) and *chimney* stacks (see Figures 2 to 5 inclusive) shall comprise:

a) D12 bars at 400 mm maximum centres vertically. Laps in bars shall be no less than 300 mm.

b) R6 bars at 200 mm centres horizontally. These will be in the form of closed stirrups in the stack and U bars elsewhere.

c) Double horizontal reinforcing at any change in direction of the vertical steel (e.g. at the *gather*/stack intersection).

1.6.2 Bars which do not extend for the full height of the *chimney* shall be stopped in the *gather*:

a) In reinforced concrete and brick, by continuing these bars through to the far face of the *gather* and terminating with a 200 mm leg.

b) In precast pumice concrete, by anchoring the last 200 mm of the bar in a high strength cementitious grout. (See Figure 5.) Refer Paragraph 1.8.3 g) for grout details.

1.7 Chimney restraint

1.7.1 *Chimneys* which are not constructed integrally with the *building* shall be secured by floor and roof brackets. An acceptable alternative for brick and precast pumice concrete *chimneys* is that they be restrained by a roof tie used in conjunction with closely spaced wall ties. (Refer Paragraphs 1.7.5 to 1.7.16.)

1.7.2 Where a packer (see Figures 2, 3, 6 and 7(b)) is shown between the *chimney* and *building* it shall be:

a) Concrete, brick, steel (angle, channel or Z section), or any insulating material which has a long term operating temperature of no less than 150°C,

b) Secured in place to prevent it dislodging, and

c) Capable of withstanding a compressive force of 10 kN without shortening by more than 1.5 mm.

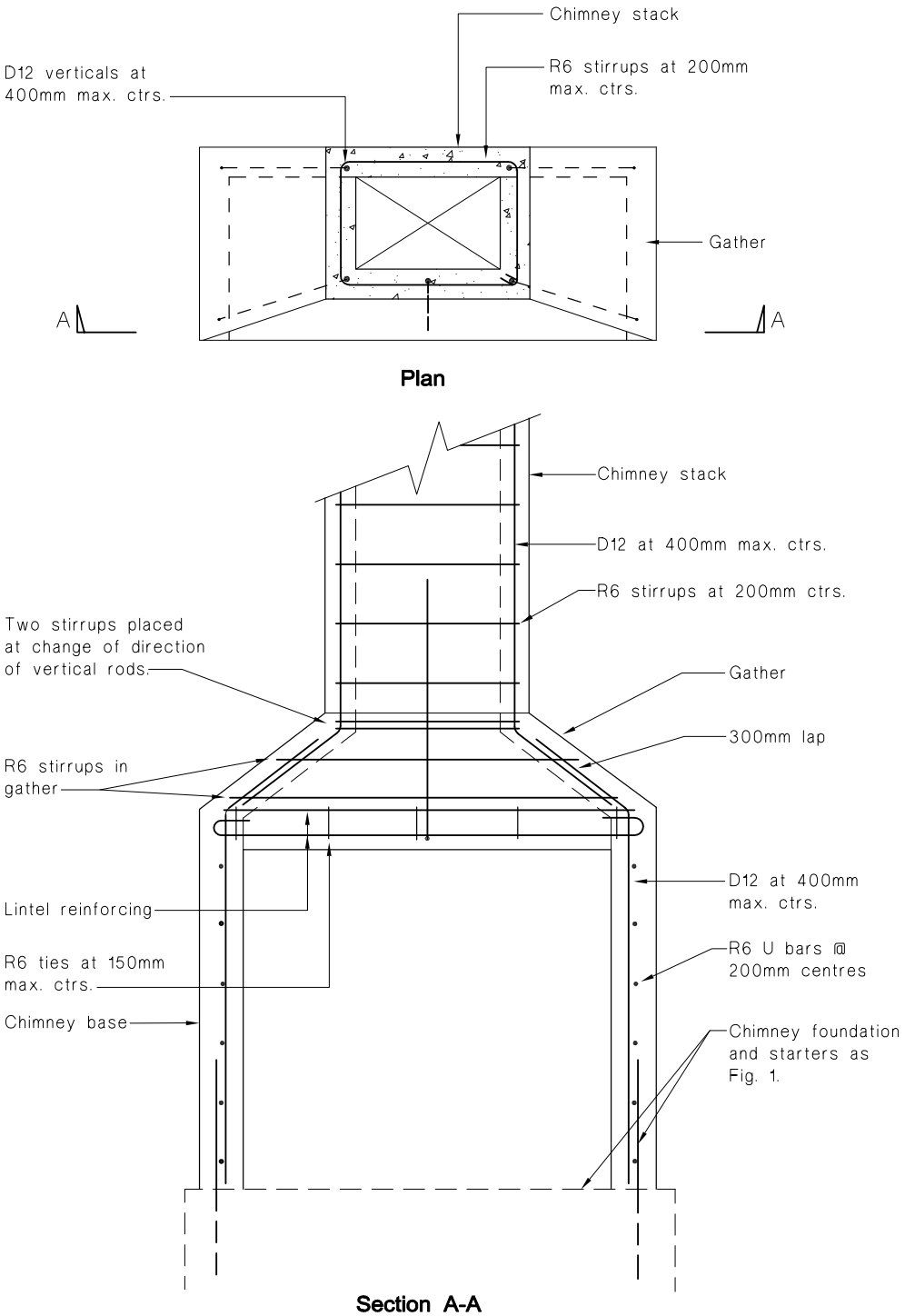
COMMENT:
C/AS1 Part 7 requires a 50 mm separation between the *chimney* and any *combustible* material. Where the *chimney* fixing described does not prevent the *chimney* moving within this gap, a packer is shown.

Amends 5 and 15

1.7.3 Floor and roof brackets

The brackets shall comprise a 50 mm x 4 mm hot dip galvanised steel strap placed around the *chimney*. Each leg of the strap shall be horizontal and shall be bolted to the joists with three M12 bolts at 75 mm centres as shown in Figure 6.

Figure 4: **Reinforcing Details – Concrete and Brick Chimneys**
Paragraph 1.6.1



Note:
Athough drawn for the concrete *chimney*, the reinforcing details apply to brick *chimneys*, except for the lintel which is described in Table 1.

c) At an intermediate floor level: it is held either by a floor bracket or by closely spaced wall ties spanning the floor.

1.9.5 For earthquake ground movement in the direction perpendicular to the wall on which the *chimney* is located, structural diaphragms shall be provided at roof/ceiling level and at each floor level to which the *chimney* is connected. The diaphragms shall comply with all relevant clauses of NZS 3604 and NZS 4229.

1.9.6 For earthquake in the direction parallel to the wall on which the *chimney* is located, the bracing units required as determined from Paragraph 1.9.3 shall be provided solely by that wall.

2.0 Solid Fuel Burning Domestic Appliances

2.1 Chimneys

2.1.1 *Chimneys* for solid fuel burning appliances shall comply with Paragraph 1.0 or with the relevant sections of AS/NZS 3869 and AS/NZS 2918 for sheetmetal *chimneys*.

Amend 9
Sep 2010

2.2 Hearth slab

2.2.1 Solid fuel burning domestic appliances weighing no more than 130 kg shall be supported on a 65 mm thick *hearth* slab that is:

a) Reinforced with 665 mesh, or D10 rods at 300 mm centres each way, placed centrally in the slab thickness,

b) Supported on a timber or concrete floor, or integral with a concrete floor. (The floor supporting the *hearth* slab shall comply with NZS 3604 or NZS 4229 as appropriate), and

c) Comprised of ordinary grade concrete complying with the relevant clauses of NZS 3109.

2.2.2 *Hearth* slabs on a timber floor shall be held in position by supporting members on all four sides of the *hearth*. These members shall each be held by four screws with a minimum shank diameter of 4.88 mm that penetrate the floor framing by 50 mm.

2.2.3 *Hearth* slabs on concrete floors shall be secured in position by four D10 starter rods. The rods shall be located in each corner of the *hearth* slab and they shall terminate each end with standard hooks complying with NZS 3109.

Spread of fire

2.2.4 Paragraphs 2.2.1 to 2.2.3 provide an acceptable structural solution, but depending on the particular installation, different *hearth* dimensions may be necessary to meet the spread of *fire* requirements of NZBC Clause C2.2. *Hearth* slabs for solid fuel burning appliances shall comply with AS/NZS 2918.

Amend 2
Aug 1994

Amend 15
Jan 2017
Amend 9
Sep 2010
Amend 5
Jul 2001

resistance, cohesion, and if appropriate, undrained shear strength.

Notation:

A^{l} effective foundation area (m^2). For a rectangular foundation $A^{l} = B^{l}L^{l}$. For a circular foundation see Figure 2.

B foundation breadth (m).

B^{l} the smaller of $2(X + e_b)$ and $2(B – X – e_b)$ (see Figure 1) (m).

D_e minimum horizontal distance from the edge of the underside of the foundation to the face of an adjacent downward slope (m).

D_f depth to the underside of the foundation (m).

H design horizontal load, the resultant of the factored horizontal forces applied to the foundation (kN).

H_{uf} unfactored horizontal foundation load (kN).

L foundation length (m).

L^{l} the smaller of $2(Y + e_l)$ and $2(L – Y – e_l)$ (see Figure 1) (m).

M_b design moment applied about an axis parallel to the breadth direction of the foundation (kNm).

M_c design moment applied to a circular footing (kNm).

M_l design moment applied about an axis parallel to the length direction of the foundation (kNm).

N_c, N_q, $N\gamma$ bearing strength factors.

P_p ultimate lateral resistance derived from passive earth pressure (kN).

R reaction on underside of foundation = $q_d A^{l}$ (kN).

S ultimate shear strength between the base of the foundation and the ground (kN).

V design factored vertical foundation load (kN).

V_{uf} unfactored vertical foundation load (kN).

V^{l} effective design factored vertical load = $V – u_f A^{l}$ (kN).

X the distance from the edge of the foundation, along the x axis, to the point of application of the design vertical foundation load V (m).

Y the distance from the edge of the foundation, along the y axis, to the point of application of the design vertical foundation load V (m).

Z the distance from the edge of a circular foundation, along the z axis, to the point of application of the design vertical foundation load V (m).

c cohesion (kPa).

c^{l} effective stress cohesion (kPa).

e_b M_l/V (positive when R is further along the x axis than V, see Figure 1) (m).

e_c M_c/V (positive when R is further along the z axis than V, see Figure 2) (m).

e_l M_b/V (positive when R is further along the y axis than V, see Figure 1) (m).

q vertical total stress in ground adjacent to the foundation at depth D_f (kPa).

q^{l} vertical effective stress (σ^{l}_v) in ground adjacent to the foundation at depth D_f (kPa).

q_d design bearing pressure = V/A^{l} (kPa).

q_u ultimate bearing strength (kPa).

q_{dbs} design bearing strength = $\Phi_{bc} q_u$ (kPa).

r radius of a circular foundation (m).

s_u undrained shear strength (kPa).

u pore water pressure at a given position in the soil profile (kPa).

u_f pore water pressure at depth D_f (kPa).

x axis through design vertical foundation load V in direction of foundation breadth. The axis starts at the foundation edge and is positive in the direction towards V.

y axis through design vertical foundation load V in direction of foundation length. The axis starts at the foundation edge and is positive in the direction towards V.

z axis through the centre of a circular foundation and the design vertical foundation load V. The axis starts at the foundation edge and is positive in the direction towards V.

γ soil unit weight (kN/m^3).

γ^I soil unit weight required for effective stress analysis for soil beneath the water table = $\gamma - \gamma_w$ (kN/m^3).

Γ γ when the water table is deeper than 2B beneath the underside of the foundation and γ^I when the water table is above this.

γ_w water unit weight (kN/m^3).

Φ_{bc} *strength reduction factor* for bearing strength (see Paragraph 3.5.1).

Φ_{pp} *strength reduction factor* for resistance derived from passive earth pressure (see Paragraph 3.5.1).

Φ_{sl} *strength reduction factor* for sliding resistance (see Paragraph 3.5.1).

ϕ angle of shearing resistance (degrees).

ϕ^I effective stress angle of shearing resistance (degrees).

σ^I_v vertical effective stress at a given depth in the soil profile = $\Sigma\gamma_i T_i - u$ where γ_i is the unit weight and T_i is the thickness of the ith soil layer above the depth at which σ^I_v is required (kPa).

ω slope, below horizontal, of the ground adjacent to the edge of the foundation (degrees).

3.3.2 Ultimate bearing strength

The general expression for the ultimate bearing strength for a shallow foundation subject to vertical, shear, and moment loading is:

$$q_u = c\lambda_{cs}\lambda_{cd}\lambda_{ci}\lambda_{cg}N_c + q\lambda_{qs}\lambda_{qd}\lambda_{qi}\lambda_{qg}N_q + {}^1/_2\Gamma B^I\lambda_{\gamma s}\lambda_{\gamma d}\lambda_{\gamma i}\lambda_{\gamma g}N_\gamma$$

For undrained analysis ($\phi = 0$) use the following form of the general equation:

$$q_u = s_u\lambda_{cs}\lambda_{cd}\lambda_{ci}\lambda_{cg}N_c + \lambda_{qg}q$$

For drained analysis use the following form of the general equation:

$$q_u = c^I\lambda_{cs}\lambda_{cd}\lambda_{ci}\lambda_{cg}N_c + q^I\lambda_{qs}\lambda_{qd}\lambda_{qi}\lambda_{qg}N_q + {}^1/_2\gamma^I B^I\lambda_{\gamma s}\lambda_{\gamma d}\lambda_{\gamma i}\lambda_{\gamma g}N_\gamma$$

The bearing strength factors are obtained from Figure 3 or the following equations:

$$N_q = e^{\pi\tan\phi}\tan^2\left(45 + \frac{\phi}{2}\right)$$

where e is the mathematical constant = 2.7183

$N_c = (N_q - 1)\cot\phi$ for $\phi > 0$, but has a value of 5.14 for $\phi = 0$

$$N_\gamma = 2(N_q - 1)\tan\phi$$

The λ factors in the above equation are:

a) Shape factors: λ_{cs}, λ_{qs} and $\lambda_{\gamma s}$

where:

$$\lambda_{cs} = 1 + \left(\frac{B^I}{L^I}\right)\left(\frac{N_q}{N_c}\right)$$

$$\lambda_{qs} = 1 + \left(\frac{B^I}{L^I}\right)\tan\phi$$

$$\lambda_{\gamma s} = 1 - 0.4\left(\frac{B^I}{L^I}\right)$$

b) Depth factors: λ_{cd}, λ_{qd} and $\lambda_{\gamma d}$

where:

- for $\phi = 0$ and $\frac{D_f}{B^I} \leq 1$:

$$\lambda_{cd} = 1 + 0.4\left(\frac{D_f}{B^I}\right)$$

Amend 15
Jan 2017

- for $\phi = 0$ and $\frac{D_f}{B^I} > 1$:

$\lambda_{cd} = 1 + 0.4\tan^{-1}\left(\frac{D_f}{B^I}\right)$, where $\tan^{-1}$ is in radians