

NZS 4210 :2001



New Zealand Standard

Masonry Construction: Materials and Workmanship

Superseding NZS 4210:1989

Amendment No 1
Appended

NZS 4210 :2001

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This Standard was prepared under the supervision of the Masonry Committee (P 4210) for the Standards Council established under the Standards Act 1988.

The Masonry Committee consisted of representatives of the following:

Building Research Association of New Zealand
Cement and Concrete Association of New Zealand
Local Government New Zealand
New Zealand Concrete Masonry Association
New Zealand Institute of Architects
New Zealand Masonry Trades Employers Federation
The Institution of Professional Engineers New Zealand

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RELATED DOCUMENTS

Reference is made in this document to the following:

NEW ZEALAND STANDARDS

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|----------------|--|
| NZS 3101:- - - | Concrete structures standard |
| Part 1:1995 | The design of concrete structures |
| Part 2:1995 | Commentary on the design of concrete structures |
| NZS 3103:1991 | Specification for sands for mortars and plasters |
| NZS 3104:1991 | Specification for concrete production – High grade and special grade |
| NZS 3105:1986 | Specification for concrete mixers (batch type and truck type) |
| NZS 3109:1997 | Concrete construction |
| NZS 3112:- - - | Methods of test for concrete |
| Part 1:1986 | Tests relating to fresh concrete |
| Part 2:1986 | Tests relating to the determination of strength of concrete |
| NZS 3113:1979 | Specification for chemical admixtures for concrete |
| NZS 3117:1980 | Specification for pigments for Portland cement and Portland cement products |
| NZS 3121:1986 | Specification for water and aggregate for concrete |
| NZS 3122:1995 | Specification for Portland and blended cements (General and special purpose) |
| NZS 3123:1974 | Specification for Portland pozzolan cement (type PP cement) |
| NZS 3124:1987 | Specification for concrete construction for minor works |
| NZS 3125:1991 | Specification for Portland-limestone filler cement |
| NZS 3402:1989 | Steel bars for the reinforcement of concrete |
| NZS 3604:1999 | Timber framed buildings |
| NZS 4229:1999 | Concrete masonry buildings not requiring specific engineering design |
| NZS 4230:1990 | Code of practice for the design of masonry structures |

JOINT AUSTRALIAN/NEW ZEALAND STANDARDS

| | |
|--------------------|--|
| AS/NZS 2699:- - - | Built-in components for masonry construction |
| Part 1:2000 | Wall ties |
| Part 2:2000 | Connectors and accessories |
| Part 3:2000 | Lintels and shelf angles (durability requirements) |
| AS/NZS 4455:1997 | Masonry units and segmental pavers |
| AS/NZS 4456:- - - | Masonry units and segmental pavers – Methods of test |
| Parts 1 to 18:1997 | |

AUSTRALIAN STANDARD

| | |
|--------------|--|
| AS 1478:1992 | Chemical admixtures for concrete |
| AS 2163:1995 | Laboratory glassware – Measuring cylinders |
| AS 3700:1998 | Masonry structures |

OVERSEAS STANDARDS

| | |
|--------------|---|
| BS 604:1982 | Specification for graduated glass measuring cylinders |
| BS 890:1995 | Specification for building limes |
| BS 5390:1976 | Code of practice for stone masonry |

OTHER DOCUMENTS

Building Industry Authority
New Zealand Building Code (NZBC)

The users of this Standard should ensure that their copies of the above mentioned New Zealand Standards or of overseas Standards endorsed 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.

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.

FOREWORD

In 1989 this Standard was originally developed following significant changes in masonry design construction. This revision has built on the experience and development of the industry since 1989. It has also been revised to reflect the changes necessary to work with NZS 4229, NZS 4230 and masonry work constructed to the requirements of NZS 3604 in relation to the New Zealand Building Code.

Manufacturing and testing requirements for wall ties, Part 3 of the previous edition, have been deleted because these matters are now dealt with in AS/NZS 2699.

A major addition to the Standard, in the absence of a revised NZS 4230, has been the introduction of environmental zones of durability risk. While the zones follow the pattern set by NZS 3101 and NZS 3604 for New Zealand conditions, the primary reinforcement cover relationships follow the provisions of AS 3700.

To assist users, clauses dealing with veneer construction have been grouped together where possible.

The Standard sets out an acceptable level of workmanship. Where masonry is of a loadbearing structural nature, the Standard recommends the use of a registered mason.

It is believed that the requirements of this Standard will continue to promote high quality procedures of masonry construction throughout New Zealand.

NEW ZEALAND STANDARD

MASONRY CONSTRUCTION: MATERIALS AND WORKMANSHIP

Part 1 GENERAL

1.1 Scope

1.1.1

This Standard sets out requirements for the materials and workmanship of clay, concrete and natural stone masonry to be used in conjunction with NZS 3604, NZS 4229 and NZS 4230 for the construction of masonry buildings and masonry veneers.

C1.1.1

This Standard does not specifically cover other forms of masonry nor the use of adhesives other than cement mortar between the masonry units. Such forms of masonry construction are outside the scope of this Standard but may be dealt with in terms of 2.1.3 or by reference to AS 3700.

1.1.2

NZS 3604, NZS 4229 and NZS 4230 are Standards cited in the Building Industry Authority's Approved Documents. Compliance with NZS 4210 is an essential requirement of all of these Standards.

1.2 Interpretation

1.2.1

In this Standard the word "shall" identifies a mandatory requirement for compliance with the Standard. The word "should" refers to practices which are advised or recommended.

All the Appendices form an integral part of this Standard.

1.2.2

Clauses prefixed by "C" and printed in italic type are intended as comments on the corresponding mandatory clauses. 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.

1.2.3

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

1.2.4

Where this Standard has non-specific requirements such as the words "suitable", "adequate", "acceptable" or other similar qualifiers like "as far as is reasonably practicable" then the method described shall be to the satisfaction of the Territorial Authority.

Also in this Standard, where reference is made to "the manufacturer's recommendations or instructions" or similar, these are outside the scope of this Standard and shall be to the satisfaction of the Territorial Authority.

Where this Standard requires specific engineering design then this is outside the scope of this Standard and shall be to the satisfaction of the Territorial Authority.

1.3 Definitions

In this Standard, unless inconsistent with the context the following definitions apply:

BOND BEAM. A horizontal course of concrete masonry containing steel reinforcement and being fully grouted.

BOND – RUNNING OR STRETCHER. The bond where the units of each course overlap the units of the preceding course by between 25 % and 75 % of the length of the units.

BOND – STACK. The bond where the units of each course do not overlap the units of the preceding course by the amount specified for running or stretcher bond.

CAVITY WALL. A wall built of two or more skins of masonry units arranged to provide a continuous air space between the skins.

NOTE –

- (1) This definition refers to two reinforced skins of masonry which are connected by ties to enable load sharing to take place between the skins. It does not refer to a masonry veneer attached to a masonry wall.
- (2) Unreinforced masonry walls are not permitted, either of single or multiple skins, except for a masonry veneer.

FACE LOAD. The load applied normal to the face of a wall that imposes either compression or tensile forces on the ties.

GROUT. The material used to fill cells, flues or cavities in masonry.

GROUT SPACE. Any space to be grouted or through which grout is intended to pass, and includes grouted cells and grouted cavities.

IN-JOINT REINFORCEMENT. Steel wire/s system embedded into a horizontal fresh mortar joint during laying.

MASON. A person who on the basis of qualification, training or experience is competent to lay masonry in accordance with this Standard.

MASONRY. Any construction in units of fired clay, concrete, or stone laid to a bond in, and joined together with, mortar.

MASONRY SUPERVISOR, A person who, on the basis of experience or qualification, is competent to check that the requirements of this Standard are being met.

MASONRY UNIT:

CORED UNIT. Unit with cores, intended to be laid with its cores vertical and with full bed joints.

HOLLOW UNIT. Unit with cores, intended to be laid with its cores vertical and with face-shell-bedded joints.

HORIZONTALLY CORED UNIT. Unit with cores, intended to be laid with its cores horizontal and with full bed joints.

SOLID UNIT. Unit without core but which may contain recesses (commonly called frogs) not greater than 10 % of gross volume and intended to be laid with full bed joints.

SPECIAL PURPOSE UNIT. Unit intended for a special purpose that does not fall within the definitions of the above units, e.g. sill units, lintels and so on.

MORTAR. The cement/sand mix in which masonry units are bedded.

POINTING. Finishing previously raked joints of masonry with mortar.

REGISTERED MASON. A mason who is accepted for registration by the New Zealand Masonry Trades Registration Board and is the holder of a current registration certificate.

REINFORCED CAVITY MASONRY. A construction of two or more skins of masonry with reinforcing steel in the completely grouted cavity between skins and complying with the requirements for reinforced masonry.

REINFORCED MASONRY. Any masonry in which reinforcing steel is so bedded and bonded that the two materials act together in resisting forces.

PARTIAL OR INTERMITTENT FILLED REINFORCED MASONRY. All hollow cells containing steel reinforcement are filled with grout.

SOLID FILLED REINFORCED MASONRY. All hollow cells irrespective of whether they contain steel reinforcement or not are filled with grout.

REINFORCED VENEER. A veneer incorporating a system of steel reinforcement vertically and/ or horizontally within the veneer thickness.

SEISMIC ZONES. Areas of seismic activity as shown in Figure 1.

SKIN or WYTHE. A continuous vertical tier of masonry one unit in thickness.

STRUCTURAL WALL. An element which is required to provide resistance to actions from forces imposed on a building.

TERRITORIAL AUTHORITY. A Territorial Authority as defined in the Local Government Act 1974 and includes a building certifier acting within the scope of their authority.

VENEER. A single skin of non-loadbearing masonry which is attached to and laterally supported by a structural element.

WALL TIE. A tie, together with its fixings or anchorages, used to transfer face loads from a veneer to a structural wall, or between skins of a cavity wall, while being capable of accommodating differential in-plane horizontal and vertical deflections between the attached elements.

WEATHERPROOFING. A system able to demonstrate compliance with the requirements of clause E2 of the New Zealand Building Code.

WYTHE see SKIN.

1.4 Inspection

1.4.1

All masonry construction shall be inspected by the masonry supervisor to establish that the work in place is constructed in accordance with the plans and specifications.

1.4.2

Masonry designed to NZS 3604 or NZS 4229 does not require engineering inspection.

1.4.3

For masonry specifically designed to NZS 4230 the engineering inspection requirements of that Standard shall be met.

1.5 Workmanship

The construction of masonry works deemed to comply with this Standard shall be carried out by competent, experienced tradesmen who shall be fully conversant with the detailed provisions of the Standard.

C1.5

The New Zealand Masonry Trades Registration Board provides a scheme which examines the competency of masons to comply with 1.5. Those qualified masons, whose practical work and knowledge are found to be satisfactory, are registered by the Board. A registered mason may be deemed to have the skills and knowledge to be able to comply with the requirements of 1.5.

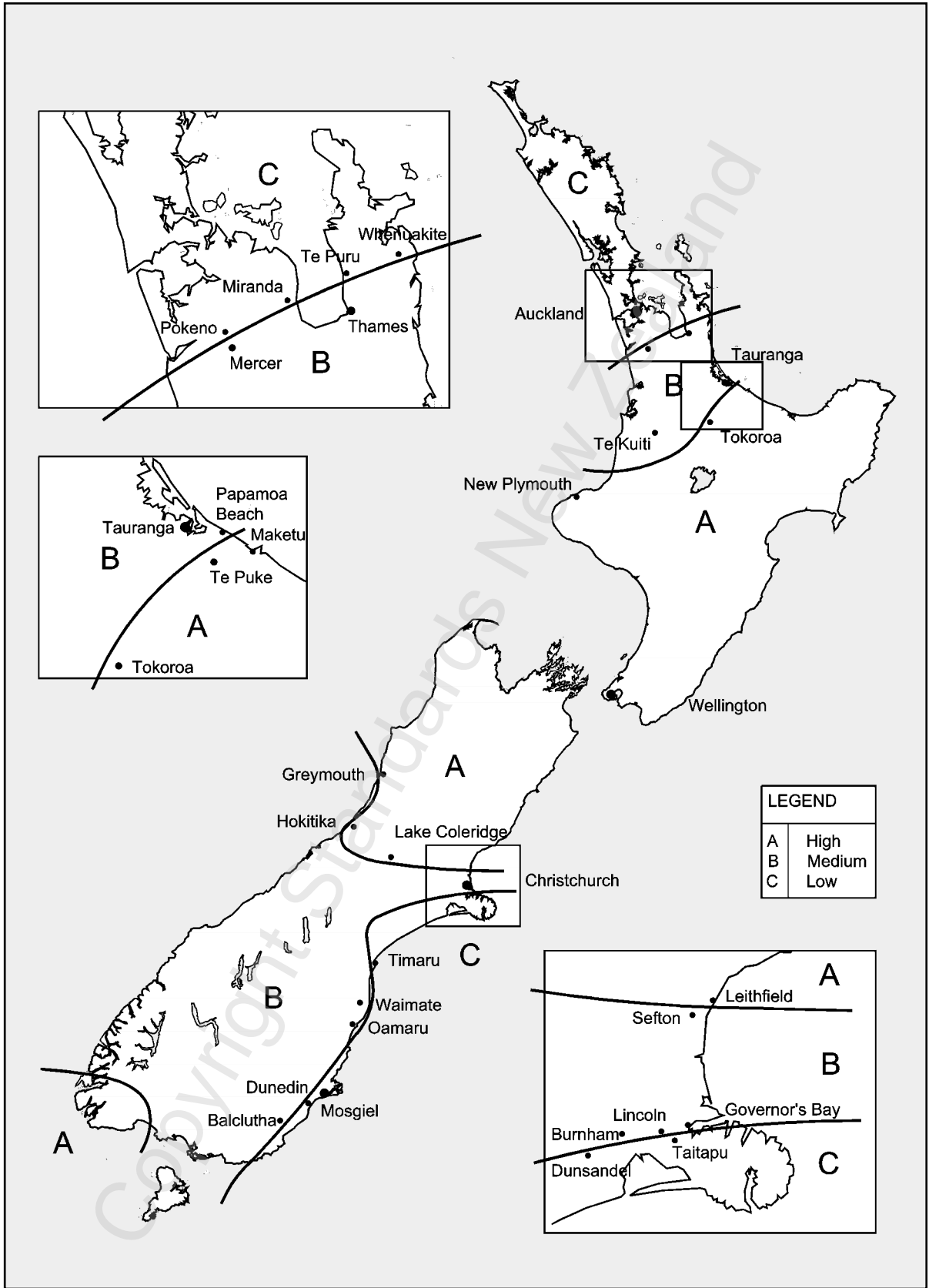


Figure 1 – Seismic zones A, B & C

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Part 2 MASONRY CONSTRUCTION

2.1 Materials

2.1.1 Wall durability

All masonry walls shall comply with the requirements of Appendix 2.E. Where masonry walls are required to meet E2 provisions of the New Zealand Building Code (NZBC), the wall shall, in addition, comply with 2.21.

2.1.2 Corrosion resistant metal

Wall ties in ungrouted cavities, lintel bars, and any other metal components exposed to the weather or in any position where condensation or dampness will occur, shall be protected so as to have an acceptable resistance to corrosion. Materials shall comply with the requirements of table 2.E1 of Appendix 2.E.

2.1.3 Other materials and proprietary products

This Standard does not preclude the use of new materials, components, innovative systems or proprietary products. Such materials, systems or products however are outside the scope of this Standard and full details of any such proposal would need to be submitted to the Territorial Authority for approval.

C2.1.3

Some general performance requirements for particular uses are given in the appropriate clauses of this Standard. Materials, systems or products that have been appraised by suitably qualified people or organizations should be favoured over those that do not have appraisals. Products or systems that have been appraised and then accredited by the Building Industry Authority must be automatically accepted by territorial authorities as complying with those clauses of the Building Code claimed in the appraisal. In all cases where appraisals are involved the products or systems must be used in strict accordance with the conditions and limitations of the appraisal.

2.1.4 Masonry units

2.1.4.1

Masonry units shall comply with AS/NZS 4455 and suppliers of such units shall provide the following information:

- (a) Unconfined compressive strength as determined by AS/NZS 4456:Part 4.
- (b) Work size tolerances as determined by AS/NZS 4456:Part 3.

C2.1.4.1

The strength requirement is to ensure compatibility with the design requirements. Such values are normally expressed as minimum characteristic compressive strengths in MPa. Products would usually be arranged into groups of 5, 10, 15, 20 MPa etc.

2.1.4.2

The salt attack resistance of clay and natural stone masonry units as determined in accordance with AS/NZS 4456:Part 10 shall comply with the requirements of table 2.E1 of Appendix 2.E.

C2.1.4.2

Appropriate salt attack resistance is needed to ensure the durability of the masonry units. It is not necessary to determine the salt attack resistance for concrete masonry products.

2.1.4.3

The suppliers of natural stone shall also comply with BS 5390.

2.1.4.4

Where natural stone is used, the manufacturer shall supply instructions advising all necessary requirements of the installation (see C2.1.4.4).

C2.1.4.4

The properties of a proposed natural stone material should be carefully assessed for the use to which the stone is to be put. Consideration should be given to compressive and tensile strength, splitting properties, mortar bonding characteristics and weathering aspects such as porosity and abrasive and chemical durability.

While an established service record may exist, it is prudent to check that the quality of material being currently quarried meets a level of performance suitable for its intended use.

Stone from sedimentary geological formations almost always needs to be laid with its natural bedding plane horizontal.

The various considerations or limitations of use should form part of any approval issued in terms of this section.

The producer's recommendations relating to bond patterns, tie spacing, tie embedment and placing methods should be followed.

2.1.4.5

Masonry units supplied for use with NZS 3604 and NZS 4229 shall have the minimum required properties:

- (a) Structural applications: Unconfined compressive strength of 12.5 MPa.
- (b) Non-structural veneer applications: Unconfined compressive strength of 2.25 MPa for natural stone or 10 MPa for concrete products.

The unconfined compressive strength of masonry units for designs to NZS 4230 is a matter of specific engineering design. However, for concrete units the strength shall not be less than 10 MPa.

C2.1.4.5

Clay brick strengths are of the order of 15 MPa and above and historically have demonstrated durability to meet the NZBC – B2 requirements. Concrete bricks must have a physical strength in excess of 10 MPa to meet Clause B2 requirements of the NZBC.

2.1.4.6

Masonry units shall not be re-used nor deemed to satisfy the requirements of this and related Standards unless accompanied by evidence of selection of grading, and testing in respect of compressive strengths and 7 day masonry-to-mortar bond strengths (see 2.2.3.2).

C2.1.4.6

Masonry buildings in New Zealand built prior to 1939 mainly used bricks for thick wall construction in which exterior work was frequently rendered for appearance and weatherproofing. Demolition bricks salvaged from these buildings will be a mixture of facings, back-up bricks and underfired plastering quality bricks. Manufactured well before the advent of New Zealand Standards, such bricks will very rarely be shown to comply with present day building standards.

2.1.4.7

If samples of concrete masonry units are taken for testing after delivery from the manufacturer the sample size and storage shall comply with AS/NZS 4456. Tests shall be carried out in accordance with AS/NZS 4456 with compressive strength conforming to section 4 of that Standard.

2.1.5 *Reinforcement*

2.1.5.1

All reinforcement other than ties, stirrups, spirals, joint reinforcement, welded wire fabric and wire strands or high strength alloy steel bars for prestressing tendons shall be deformed unless otherwise required by specific engineering design.

2.1.5.2

Reinforcement shall comply with NZS 3402 unless otherwise required by specific engineering design.

2.1.5.3

In-joint reinforcement for use within the thickness of the mortar joints, where used as part of a specific engineering design, shall be of corrosion-resistant metal complying with 2.1.2.

2.1.6 *Cementitious materials*

2.1.6.1

Portland cement shall comply with NZS 3122, NZS 3123 or NZS 3125.

2.1.6.2

Building lime shall comply with BS 890 and shall be slaked with water to form hydrated lime before use in mortar.

2.1.7 *Aggregate and water*

2.1.7.1

Aggregate and water for grout shall comply with NZS 3121.

2.1.7.2

Sand for mortar shall comply with NZS 3103 and water for mortar shall comply with NZS 3121.

Sand for grout shall comply with NZS 3121.

Sands used for mortar exposed to the weather shall not have a chloride content in excess of 0.04 % by mass.

2.1.8 *Admixtures*

2.1.8.1

Chemical admixtures, being water-reducing admixtures, retarding admixtures, accelerating admixtures, water-reducing and retarding admixtures, water-reducing and accelerating admixtures, and air entraining admixtures shall comply with NZS 3113 or AS 1478.

2.1.8.2

Admixtures shall be dosed in accordance with the manufacturer's instructions. Information shall be supplied by the manufacturer to include advice as to dosage rates and mixing times along with any essential requirements relating to temperature conditions.

2.1.8.3

Calcium chloride based accelerators shall not be used in any mortar exposed to weather unless it can be shown that in combination with the sand, the chloride content of the mortar does not exceed 0.03 % by mass of mortar.

2.1.8.4

Expansive admixtures used in grout shall comply with 2.3.2.1(c) and 2.12.2.1.

2.1.9 *Wall ties***2.1.9.1**

All wall ties and their connections shall comply with masonry durability requirements given in table 2.E1 of Appendix 2.E and testing provisions contained in AS/NZS 2699: Part 1. In addition manufacturers shall ensure all ties tested meet the requirements of 2.9.5.

2.1.9.2

Type, placing and spacing of ties shall be as given in 2.9.6 and 2.9.7.

2.1.10 *Storage and handling of materials***2.1.10.1**

Aggregates shall be stored and handled in such a way as to prevent segregation or contamination by foreign materials. Aggregates of each specified size range shall be brought separately to the place of mixing and shall be stored in such a way as to prevent the materials intermixing.

2.1.10.2

Cement shall be stored and handled in such a way as to protect it against deterioration or contamination, and to be capable of being inspected at all times.

2.1.10.3

Masonry units shall be so stored and handled as to comply with 2.7.2 at the time of laying.

2.1.10.4

Dry pre-mixed mortar shall be so stored and handled as to comply with 2.1.10.2 (see also 2.2.2.2(e)).

2.1.10.5

Reinforcement shall at the time of erection be undamaged and clean and free from all loose mill scale, dust, loose rust, and coatings such as paint, oil or anything which may reduce bond.

2.2 **Mortar****2.2.1** *Measurement of materials***2.2.1.1**

Materials for mortar shall be accurately measured by weight or volume in suitably calibrated devices.

2.2.2 *Composition and mixing***2.2.2.1**

Mortar shall be composed of Portland cement, sand and hydrated lime and water as required by table 2.1. The durability requirements shall be as given in table 2.E1 of Appendix 2.E.

Hydrated lime may be omitted from the mix if it can be demonstrated that the performance requirements of 2.2.3.1 and 2.2.3.2 will still be achieved. Admixtures may be used in either case subject to the requirements of 2.1.8.

Table 2.1 – Mortar mix composition using parts by volume using hydrated lime

| Durability | Cement | Hydrated lime | Mortar sand |
|------------|--------|---------------|-------------|
| M4 | 1 | 0 – 0.25 | 3 |
| M3 | 1 | 0.5 | 4.5 |
| M2 | 1 | 1 | 6 |

C2.2.2.1

The workability of mortars is significantly affected by sand grading and particle shape. For the majority of mortars it is likely that the use of an admixture or hydrated lime will be necessary to produce the desired workability. Admixture dosage should strictly follow the manufacturer's instructions since significant loss of strength and bond can occur through over dosage.

2.2.2.2

The following provisions shall apply for mixing of mortars:

- (a) All materials shall be thoroughly mixed to an even consistency for a minimum time of 5 min in a mechanical batch mixer, provided that hand-mixing to an equivalent result is permitted for quantities of mortar not exceeding 0.03 m³;
- (b) The volume of hydrated lime in a mix shall not exceed the volume of cement;
- (c) The mixing and proportions of any admixture shall be in accordance with the manufacturer's instructions;
- (d) If a batch of mortar which has been prepared for use has stiffened due to lapse of time, workability may be restored by the addition of water and thorough re-mixing, provided that the properties required by 2.2.3 shall not be impaired. Re-tempering water shall be added to a basin formed by the mortar and the mortar carefully worked into it. Re-tempering by dashing water over the mortar shall not be permitted;
- (e) Any mortar not used within 1.5 hours after the addition of cement to the mix shall be discarded, provided that in cold weather (below 5 °C) this period may be extended to 2 hours, and provided that this requirement may be waived in the case of ready-mixed and retarded mortars if it can be established that such mortars meet the requirements of 2.2.3;
- (f) Where mortar is to be coloured, this shall be achieved by the use of coloured cement or by the addition of mineral oxide pigment conforming to NZS 3117. Dosages of mineral oxide shall not exceed 3 % by weight of cement unless it can be shown that greater concentrations do not cause a reduction of mortar strength. In any case dosages in excess of 6 % by weight of cement shall not be used.

C2.2.2.2(f)

Dosages of some mineral oxide pigments in excess of 3 % may lead to unacceptable reductions in bond strength.

2.2.3 Properties

2.2.3.1 Compressive strength

2.2.3.1.1

The 28 day compressive strength of mortar when tested in accordance with Appendix 2.A shall be not less than 12.5 MPa for structural compliance with NZS 3604 and NZS 4229.

2.2.3.1.2

For masonry to NZS 4230 the compressive strength is a matter for the designer to nominate as part of a specific engineering design.

2.2.3.1.3

The minimum 28 day compressive strength of mortars used for veneer construction shall follow the requirements of the masonry suppliers.

2.2.3.2 Bond strength

The 7 day masonry-to-mortar bond strength when tested in accordance with Appendix 2.B shall be not less than 200 kPa for structural compliance with NZS 3604 and NZS 4229.

For masonry to NZS 4230 the 7 day masonry-to-mortar bond strength is a matter for the designer to nominate as part of a specific engineering design.

C2.2.3.2

The relevance of bond strength in the seismic resistance of reinforced structural masonry construction is limited, due to the presence of tensile reinforcement.

The bond strength value is more significant in the construction of unreinforced and lightly reinforced veneers. Apart from providing weather resistance and the structural connection mechanism to transfer the face loads of the veneer into the wall ties, mortar bond strength has an important effect on in-plane and out-of-plane flexural and shear strength of a brick veneer. Transverse strength tests of full scale walls indicate that bond between mortar and brick is the most important single factor affecting wall strength.

With the permitted use of unreinforced two storey veneers and multi-storey reinforced veneers, mortar bond strengths become a significant factor in the overall performances of veneers.

The typical mortar bond values for masonry construction laid to the requirement of this Standard are:

| | |
|------------------------|----------------|
| Clay brick masonry | 500 – 1000 kPa |
| Concrete brick masonry | 400 – 900 kPa |

2.3 Grout

2.3.1 General

2.3.1.1

Grout shall be either fine grout complying with 2.3.3 or coarse grout complying with 2.3.4.

2.3.1.2

Only fine grout shall be used where any dimension of grout spaces is less than 60 mm.

2.3.2 Properties

2.3.2.1

Grout shall be mixed in such proportions that:

- (a) It shall have a minimum compressive strength of 17.5 MPa for all durability zones (table 2.E1) except for Seaspray (B2) where the minimum compressive strength shall be 25 MPa, when tested in accordance with Appendix 2.A and the test results are evaluated as required by NZS 3104;



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- (b) It shall have a spread value within the range 450 mm to 530 mm for concrete masonry and 500 mm to 580 mm for clay masonry or natural stone masonry when tested in accordance with section 11 of NZS 3112: Part 1;
- (c) If using an expansive admixture, the mix proportions shall be such as to give an increase in volume of between 2 % and 4 % before the initial setting of the grout, when tested in accordance with Appendix 2.C. Only expansive admixtures which enable expansion to be completed within 4 hours of dosage shall be used.

C2.3.2.1

Grout infill must have characteristics of flow which are considerably different from those for concrete. While the slump test is an appropriate test for measuring characteristics of concrete, it is technically inappropriate for grout.

For this reason, the spread test only is included as the method of determining the required properties of grout flow for various masonry applications.

2.3.2.2

17.5 MPa volume batched, site mixed grout shall be as follows:

| | Parts by volume | | |
|--------------|-----------------|-----------------|------------------------------------|
| | Cement | Concreting sand | Coarse aggregate 13.2 – 4.75 mm |
| Coarse grout | 3 | 8 | 4 |
| Fine grout | 2 | 7 | – |

NOTE – Water is added in sufficient quantity to bring the grout within the specified range of spread.

25 MPa grout shall be supplied by a concrete producer certified as having production compliance with NZS 3104.

C2.3.2.2

When using materials for which no previous compression tests were taken, it is advisable at the start of the project to produce a test mix for sampling and compression testing in accordance with Appendix 2.A. The compressive strength at 28 days of this 17.5 MPa test mix must be at least 25 MPa. This higher strength value for the project test mix reflects a requirement to include a strength margin to allow for variations in the accuracy of producing the prescribed mix.

2.3.2.3

The expansive admixture shall be dosed at site immediately prior to placing but allowing sufficient time for mixing, to ensure that grout expansion takes place within the masonry cells or cavity and while the material is still fluid.

C2.3.2.3

Expansive admixtures that cause expansion of the hardened concrete are not considered appropriate for fulfilling the requirements of a grout.

2.3.3 Fine grout

Fine grout shall consist of Portland cement, sand complying with NZS 3121 and water, and may contain admixtures, except that the grouting of the small cores of knock-out-end clay bricks shall be by means of mortar used in laying the bricks, tamped into place.

2.3.4 Coarse grout

Coarse grout shall consist of Portland cement, sand complying with NZS 3121, coarse aggregate and water, and may contain admixtures. The coarse aggregate shall have a nominal size range of 13.2 mm to 4.75 mm except that in specific engineering design the designer may select up to 19 mm maximum size aggregate.

2.3.5 Mixing of grout**2.3.5.1 At the site**

The mixing of grout shall be done in a power-driven batch mixer complying with the provisions of NZS 3105, or other approved type which will ensure the thorough mixing of all materials to the degree of uniformity required by that Standard. The volume of the mixed material for each batch shall not exceed the manufacturer's maximum rated capacity of the mixer. The entire batch shall be discharged before re-charging. The mixing time shall be measured from the time when all the materials are in the mixer drum. The minimum time of mixing shall be 1.5 minutes for mixers having a capacity of 0.75 m³ or less, and mixers of larger capacity shall have the time of mixing increased by 15 s for each additional 0.3 m³ capacity or fraction thereof.

2.3.5.2 Off the site (ready mixed)

Grout supplied ready mixed from off the site shall comply with the relevant provisions of NZS 3104.

2.3.5.3 Time for placing

Grout shall only be placed up until such time as the spread value required by 2.3.2.1(b) can not be met.

C2.3.5.3

Usually grout should be placed within 1.5 hours but this will vary with ambient temperature and the use of admixtures.

2.4 Testing**2.4.1 Building requiring specific engineering design**

Where masonry is the subject of specific engineering design, the following tests on mortar and grout shall be conducted, when requested, in accordance with the Standards, or Appendices to this Standard, noted below at frequencies specified by the specific engineering design:

- (a) Compressive strength of mortar, Appendix 2.A;
- (b) Masonry-to-mortar bond strength, Appendix 2.B;
- (c) Compressive strength of grout, Appendix 2.A;
- (d) Spread of grout, NZS 3112: Part 1;
- (e) Expansion of grout (where an expansive admixture is used), Appendix 2.C.

2.4.2 Building not requiring specific engineering design

For buildings not requiring specific engineering design built in accordance with NZS 4229 and NZS 3604, no testing is required but the mason shall ensure that the following records are kept:

- (a) Proportions of mortar used, including admixtures;
- (b) Supplier of grout and test certificates received or proportions of grout if site mixed;
- (c) Supplier of mortar sand;
- (d) Use or not of an expansive admixture.

C2.4.2

It is recommended that the mason, as a competent tradesman should have compressive strength tests of mortar carried out at regular intervals, particularly if the source of supply of sand is changed. In addition to being a check on the suitability of the mortar mix, such tests serve as a check on the cleanliness of the sand.

The reactivity of the expansive admixture in the grout can be directly observed at the top of a grouted wall. Any adjustments in dosing rates for temperature conditions should be made in accordance with the manufacturer's instructions.

2.5 Initial preparation

2.5.1 Concrete base

2.5.1.1

Any discrepancies in the vertical alignment, other than those that can be corrected by a mortar bed not exceeding 20 mm thick at any point as provided by 2.7.1.3, and any discrepancies in the horizontal alignment of the supporting concrete base shall be corrected as specified in table 2.2 before masonry units are laid.

2.5.1.2

The base shall be clean and free from laitance, loose aggregate, and anything that would prevent the mortar from bonding to the base, except where (a) a damp-proof course is permitted at the base of a veneer wall or (b) allowance for non-bonding has been made by specific engineering design.

C2.5.1.2

Designers may require a properly prepared construction joint as specified for Type B in NZS 3109, except that it is recommended that the surface be broken to a depth of approximately 1.5 mm above and below the average level.

2.5.1.3

The units shall not overhang the supporting foundation by more than 20 mm.

2.5.2 Starter bars

Starter bars shall be carefully set out to suit masonry modules and required locations within cells and cavities to the tolerances specified in 2.6.5.1. They shall be firmly tied in their correct position before concreting of the base is commenced.

C2.5.2

The correct location of starter bars is always important. For some applications, for instance retaining walls, misplacement of 10 mm in one direction may necessitate demolition and reconstruction of the foundations. Where starter bar misplacement exceeds the location tolerance, construction should only be permitted subject to specific engineering design, by a registered engineer. Particular attention should be paid to the location of starter bars at corners, intersections and openings in walls.

2.6 Reinforcing details

2.6.1 General

2.6.1.1

In buildings subject to specific design, reinforcement shall be as specified.

2.6.1.2

In buildings not requiring specific design, reinforcement shall be as required by NZS 4229 and NZS 3604.

2.6.1.3

All reinforcement shall be detailed, bent and placed in accordance with NZS 3109 or NZS 3124, except where modified in this Standard or by specific design. Details of standard bends are given in Appendix 2.D.

2.6.2 Vertical reinforcement

2.6.2.1

Vertical bars shall be tied and fixed securely to starter bars unless required otherwise by specific design.

2.6.2.2

Vertical bars shall be securely held in position at the top of the wall, and at intervals not exceeding 1.2 m for 10 mm bars, 2.4 m for 12 mm bars, or 3.6 m for 16 mm or larger bars.

2.6.2.3

Long bars projecting above the top of the wall shall be further held to maintain the bars in their correct position, and shall be braced firmly against wind or other movement.

2.6.2.4

Unless required otherwise by specific engineering design or detailed in accordance with NZS 4229, each vertical bar shall be positioned in the centre of its cell, or in the middle of the cavity in grouted-cavity construction.

2.6.3 Horizontal reinforcement

2.6.3.1

Horizontal bars required to be in grouted cells shall be at least 25 mm above or below a mortar joint and fully embedded in grout.

2.6.3.2

Each horizontal bar shall be positively held in position by tying the bar to the vertical reinforcement or by the use of specially designed units, or steel spacers or links.

2.6.3.3

In-joint reinforcement where required by specific engineering design shall be steel hot dipped galvanized after fabrication or 316 stainless steel and shall be fully embedded within the mortar joint with a minimum side cover of 15 mm.

C2.6.3.3

The minimum recommended joint thickness for using such a reinforcing system is 10 mm.

2.6.4 Laps

2.6.4.1

Laps shall be not less than 40 diameters for grade 300 steel and 54 diameters for grade 430 steel.

C2.6.4.1

Laps at corners should be avoided because they may reduce the width of grout space (see 2.6.6). Laps for grade 500 steel are to be advised through specific engineering design.

2.6.4.2

Where there is more than one bar in a vertical grouted cell the laps shall be staggered to ensure that not more than one bar is lapping at any point.

2.6.5 Tolerances

2.6.5.1

Reinforcement shall be placed in the specified positions within the following tolerances subject to 2.6.6:

- (a) Measured across the thickness of the wall: ± 6 mm, except for retaining walls detailed in accordance with NZS 4229;
- (b) Measured along the length of the wall: ± 50 mm or one-quarter of the length of the grouted cell, whichever is the less;
- (c) In columns and piers: ± 6 mm.

2.6.5.2

The tolerance range given shall not reduce the cover requirements specified in 2.6.6.

2.6.6 Cover

The minimum cover to reinforcement shall comply with the requirements of table 2.E1.

2.7 Laying the units

2.7.1 General

2.7.1.1

All masonry units shall be laid in mortar in courses, true to line, plumb, and level to the tolerances specified in table 2.2.

C2.7.1.1

The corners should be laid first, levelled and aligned. The first course should be laid with great care as it will assist the mason in laying succeeding courses.

2.7.1.2

The units shall be set in soft plastic mortar to ensure proper embedment and bond.

2.7.1.3

The thickness of mortar joints shall be $10 \text{ mm} \pm 3 \text{ mm}$ except that a joint thickness up to 20 mm may be accepted on the bottom course in order to take up the permitted tolerances of the supporting concrete.

C2.7.1.3

Where the *in situ* concrete surfaces on which masonry is to be laid vary such that the thickness of the mortar bed beneath the bottom course cannot be maintained within the tolerances given, remedial measures will be necessary. These may include cutting back the concrete surface (with possible reinstatement), or cutting the masonry units of the bottom course where necessary. Other options, including placing a high strength levelling screed (but not floor levelling compound), should be subject to specific engineering design.

2.7.1.4

For masonry constructions to NZS 3604 and NZS 4229 the tolerances shall be as given in table 2.2. Constructions to NZS 4230 shall comply with table 2.2 unless varied as part of the specific engineering design.

Table 2.2 – Maximum tolerances

| Item | Tolerances |
|--|-------------------------------|
| Deviation from the position shown on plan for a building more than one storey in height | 15 mm |
| Deviation from vertical within a storey | 10 mm per 3 m of height |
| Deviation from vertical in total height of building | 20 mm |
| Relative vertical displacement between masonry courses (a) Nominated fair face (one side only) (b) Structural face | 3 mm 5 mm |
| Relative displacement between loadbearing walls in adjacent storeys intended to be in vertical alignment | 5 mm |
| Deviation from line in plan (a) In any length up to 10 m (b) In any length over 10 m | 5 mm 10 mm total |
| Deviation of bed joint from horizontal (a) In any length up to 10 m (b) In any length over 10 m | 5 mm 10 mm total |
| Average thickness of bed joint, cross joint, or perpend | ± 3 mm on thickness specified |

NOTE – Tolerances shall not breach minimum cavity widths.

2.7.1.5

Should a unit need to be moved after it has been bedded in place, it shall be lifted, cleaned, and relaid in fresh mortar.

2.7.1.6

Precautions shall be taken to prevent mortar from falling down cells and cavities. (See 2.8).

2.7.1.7

Any mortar protruding more than 5 mm into cells or cavities shall be removed. No mortar protrusions shall be closer than 5 mm to reinforcing steel.

2.7.2 Condition of units

2.7.2.1

The masonry units shall comply with the requirements of 2.1.4 and, when placed in the structure shall be clean, sound and free of defects which could impair the strength, weather resistance or performance of the construction.

When cutting of a unit is necessary it shall be cut neatly and true to the shape required.

2.7.2.2

Masonry units shall be protected from the weather prior to laying to ensure they are not laid in a saturated state.

C2.7.2.2

Masonry units should be in an air dry state i.e., not wet to the touch. Some surface dampening may be required in hot dry weather to avoid significant amounts of water being drawn out of the mortar. The manufacturers' instructions on their products should be followed.

2.7.3 Hollow units

Hollow units shall have full mortar beds under face shells and shall have vertical joints filled to the same depth. In reinforced hollow masonry the cross-webs that adjoin cells containing reinforcing shall be fully bedded on mortar, provided that this requirement need not apply when all cells in a particular wall are to be grouted.

2.7.4 Solid and cored units

2.7.4.1

Solid and cored units shall have all joints completely filled with mortar.

2.7.4.2

Furrowing of bed joints shall not exceed 25 % of the joint thickness.

2.7.5 Grout spaces

The minimum dimensions of a grouted cell or cavity in reinforced masonry construction shall be:

- (a) 32 mm for low lift grouting with a maximum of 400 mm lift (refer to 2.14.1(b));
- (b) 50 mm for low lift grouting with a maximum of 1200 mm lift (refer to 2.14.1(a));
- (c) 65 mm for any of the high lift grouting methods (refer to sections 2.12, 2.13 and 2.15).

2.7.6 Bonding

2.7.6.1

Units shall be laid up in straight uniform courses with running bond, unless alternative patterns are specified.

Stack bonding is not permitted in NZS 3604 and NZS 4229.

C2.7.6.1

Where stack bond is specified under NZS 4230, extra care with grouting is necessary to avoid shell failures of concrete masonry.

2.7.6.2

Units in intersections of all structural loadbearing walls shall be built in on alternate courses unless detailed otherwise by specific engineering design.

C2.7.6.2

Veneer is not regarded as loadbearing masonry and need not be lapped in successive courses at corners and at re-entries.

2.7.7 Mortar joints**2.7.7.1**

Mortar joints on external walls shall be:

- (a) Concave tooled to a depth not exceeding 6 mm and burnished after the initial stiffening has occurred; or
- (b) Raked out pointed and tooled to a depth not exceeding 6 mm after the initial stiffening has occurred.

2.7.7.2

Flashing or other means of weatherproofing shall be provided:

- (a) Around openings in the wall;
- (b) Where different exterior cladding materials abut.

This Standard does not provide flashing or weatherproofing details and all proposals must be submitted to and approved by the territorial authority as part of the building consent process.

2.7.8 Clean-out openings**2.7.8.1**

Where low-lift grouting methods (see 2.14.1) are to be used, cleaning-out shall be carried out as the work proceeds.

No clean outs are specifically required for this method. However, if circumstances restrict the cleaning out as work proceeds the clean out openings shall be provided as required in 2.7.8.2.

2.7.8.2

Where one of the high-lift grouting methods is to be used, temporary clean-out openings, to ensure the satisfactory cleaning out, shall be provided as follows:

- (a) Partially filled vertical cells. A minimum of 100 mm x 75 mm opening at the foundation or beam level of each cell to be filled;
- (b) Solid filled masonry fitted with a masonry unit allowing horizontal grout flow at the first course. A minimum 100 mm x 75 mm opening at a reinforcing bar position but not further than 800 mm;
- (c) Solid filled cavity masonry. Openings at least 100 mm x 75 mm at a vertical reinforcing bar tied to a starter bar, and no further apart than 800 mm.

C2.7.8.2

In all-cells-filled reinforced hollow unit masonry it is strongly recommended that the first course be of open-end bond-beam units laid upside down to facilitate cleaning out.

Where clean-out openings have to be in fair face work, boxing to clean-outs should be either set in so that grout is visible after grouting, followed by mortaring-in part or whole face shells on completion or by replacing the shells after cleaning but before grouting and supporting the shells against grout pressure.

2.8 Cleaning out

2.8.1

Grout spaces shall be cleaned out before grout is poured (see 2.5.1.2). Any drained cavities between veneers and supporting structural walls shall also be cleaned out.

2.8.2

Cleaning out shall include the removal of any mortar from ties and reinforcing bars, the removal of any mortar protruding into cells or cavities at joints, and the removal of all mortar droppings and other loose material.

C2.8.2

Loose material may be removed by hosing through the clean-out openings with a water jet at the end of each day's work, or alternatively a fine layer of sand can be provided at the bottom of the grout space and this sand together with other loose material removed by compressed air or other means through the clean-out openings.

2.8.3

Clean-out openings shall be closed after inspection and prior to grouting. This closing may be by boxing with timber at concealed surfaces or by mortaring-in face shells at visible surfaces. Clean-out boxing shall be braced, and supports shall be provided to closure units at ends of walls and at openings as required to resist grout pressure.

2.9 Veneer and cavity wall construction

2.9.1 General

2.9.1.1

In a wall consisting of a veneer and a structural element complying with NZS 3604 and NZS 4229 which are separated by an ungrouted cavity or are in unbonded contact, the two components shall be connected together using wall ties meeting the type, placing and spacing requirements given in Appendix 2.E, 2.9.6 and 2.9.7.

2.9.1.2

Veneer construction, other than that deemed to comply with the limitations of NZS 3604 and NZS 4229, together with associated separation joints to allow the veneer to accommodate differential movements of the structural elements under seismic load, shall be subject to specific engineering design in accordance with NZS 4203 and NZS 4230: Part 1.

C2.9.1.2

NZS 4230: Part 2 offers advice on separation joint details to accommodate differential movement between veneers, and veneers and their structural backing.

Where the supporting structural element is significantly more flexible under racking load than the veneer, significant damage to the veneer can occur particularly at internal and external corners. The

displacement can be either reduced by using a stiffer supporting wall or by providing appropriate separation details. The acceptable levels of seismic damage to a cladding such as veneer is not clearly defined. In Coalinga, USA, which experienced an earthquake of force 6.5 on the Richter scale, veneer with poor fixings collapsed but veneer with correctly installed ties survived undamaged despite the absence of special separation details. Veneer damage at Edgcumbe in 1987 revealed primarily a problem in inadequate tie provision and fixing. The adoption of full corner and window separation details is seen as a logical engineering step towards limiting damage in veneers. Veneer construction in these cases is likely to make use of the special flexible ties whose performance is set out in AS/NZS 2699: Part 1.

2.9.1.3

Where a veneer and its supporting element are separated by an ungrouted cavity, the masonry units of the veneer shall have a minimum width of 70 mm.

2.9.1.4

Where a veneer and its supporting element are in contact, the wall shall be subject to specific engineering design to prevent water from penetrating the structural wall.

2.9.2 Width of cavity

No ungrouted cavity, including any cavity between a veneer and its structural element, shall be less than 40 mm nor more than 75 mm wide unless subject to specific engineering design.

C2.9.2

It is recommended that the minimum specified width is 50 mm to accommodate tolerances in timber construction of the supporting wall.

2.9.3 Weep holes and ventilation of cavities

2.9.3.1

Weep holes in masonry veneers and in ungrouted hollow masonry walls shall be provided at the bottom of cavities and cells to drain moisture to the outside air.

Weep holes in veneer to NZS 3604 and NZS 4229 shall be a minimum of 75 mm in height by the width of the vertical mortar joint at centres not exceeding 800 mm. If 75 mm height cannot be achieved the horizontal spacing shall be decreased to give a ventilation area of 1000 mm² per lineal metre.

C2.9.3.1

Weep holes may be provided over flashings if the spacing dictates.

2.9.3.2

The top of all cavities shall be ventilated to the outside air.

C2.9.3.2

Veneer and cavity wall construction provides a rain shield with a drained and ventilated air gap between the veneer and the outside wall of the building. This provides an effective means of allowing water that enters the veneer and adjoining openings to drain to the outside of the building envelope. While this system has been in existence in New Zealand for over a hundred years it works well and is only now being recognized as a system for solving leakage problems in other cladding systems. NZS 3604 requires a 10 mm continuous gap to the top of veneer walls to ventilate the veneer cavity where there is an eaves protection. For other situations, follow the provisions for weep holes of 2.9.3.1.

Wall ties to AS/NZS 2699 are provided with a mechanism to prevent water from being transferred across the cavity to the wall and to be effective must remain free of mortar.

2.9.4 Pipes and services

Pipes and services shall not be placed in the cavity other than those passing directly through the cavity to the exterior.

2.9.5 Tie anchorage, cover and fixing

2.9.5.1

Wall ties shall be installed so that they are contained within the mortar bed over the full contact length, with a layer of mortar both above and below the tie. Mortar less than 24 hours old shall not be subject to vibration.

2.9.5.2

Wall ties shall be of such a length that:

- (a) They have an embedment length of at least half the width of the veneer;
- (b) They have an end cover in the bed joint of not less than 15 mm.

2.9.5.3

For timber frame buildings wall ties shall be fixed to framing members with screws or other non-impact fasteners.

When the studs are covered with a solid sheet material such as plywood, this shall also be face fixed providing the fixings pass through the plywood to provide full anchorage in the supporting stud.

2.9.5.4

The mortar bed shall completely fill the width of the masonry unit to secure the wall tie. This ensures that the length of the wall tie within the masonry unit is completely embedded in mortar.

C2.9.5.4

The structural performance of a wall tie to resist axial and inplane loading as tested in accordance in AS/NZS 2699 is usually undertaken using solid or cored units where the mortar covers the full width of the masonry unit. The holes in cored units can vary from 10 mm to 20 mm in diameter in clay masonry that can be partially filled with mortar in the laying process and provide a continuous bed to place the wall ties.

2.9.6 Placing of ties

Wall ties as specified herein shall be placed within 5° of a right angle to the plane of the masonry.

2.9.7 Tie classification and spacing

2.9.7.1

For unreinforced veneers to the provisions of NZS 3604 for single storey veneers and their gable ends and those covered in NZS 4229, wall ties shall be selected for type and spacing from table 2.3.

C2.9.7.1

Tie designations of type, size and application are required to be clearly labelled by the manufacturer using the terms set out in AS/NZS 2699.

Table 2.3 – Specification of Type B veneer ties for spacing of 600 mm (max.) horizontal x 400 mm (max.) vertical

| Seismic zone | VENEER | | |
|--------------|----------------------------------|-----------------------------------|-----------------------------------|
| | Less than 180 kg/m ² | 180 – 220 kg/m ² | More than 220 kg/m ² |
| | (Typically 70 – 90 mm thickness) | (Typically 91 – 110 mm thickness) | (Typically over 110 mm thickness) |
| A | EM | EH ⁽¹⁾ | SED ⁽²⁾ |
| B | EM | EM | SED ⁽²⁾ |
| C | EL | EM | SED ⁽²⁾ |

NOTE –

- (1) EM may be used if the supported area does not exceed 0.20 m² e.g., 600 x 300 on a timber frame; 500 x 400 on a concrete masonry wall.
- (2) Spacing of ties to be determined by specific engineering design (SED).
- (3) Type B and prefix E indicate ties are manufactured to meet seismic testing conditions set out in AS/NZS 2699.
- (4) L (light), M (medium) and H (high) indicate strength capacities of ties to meet the testing conditions set out in AS/NZS 2699.
- (5) Using higher strength ties does not permit the maximum spacing of ties to be increased.

2.9.7.2

For reinforced veneers and grouted reinforced cavity walls which are outside the scope of NZS 3604 and NZS 4229, wall tie type and spacing shall be the subject of specific engineering design. Refer to NZS 4230.

C2.9.7.2

In the case of the grouted reinforced cavity wall the ties may only be required to resist hydrostatic grout pressure.

2.9.7.3

Two storey veneer construction to NZS 3604 is not permitted. In such cases veneer wall ties and spacing shall be subject to specific engineering design to the provisions of NZS 4203, NZS 4230 and selected for Classification for Seismic Veneer Tie from table 2 of AS/NZS 2699.1.

C2.9.7.3

Some limited 2 storey construction is permitted by NZS 4229.

2.9.8 Openings

2.9.8.1

Openings with masonry veneer above shall be spanned by steel lintel angles or flats protected against corrosion to the provisions of Appendix 2.E.

2.9.8.2

For alternative materials or spans outside those permitted by NZS 3604 and NZS 4229, specific engineering design shall be required.

2.9.8.3

Steel lintel angles or flats shall have a minimum seating of 100 mm for spans up to and including 2 m and 200 mm for over 2 m unless covered by specific engineering design.

2.10 Methods of controlling wall movements

2.10.1 General

2.10.1.1

Horizontal wall movements, along the length of the wall, shall be accommodated by using control joints or by the incorporation of specific engineering designed reinforcing steel to distribute the movement evenly along the wall.

2.10.1.2

The following shall apply to control joints:

(a) *Specific engineering designed structures to NZS 4230*

The design shall have positioned the control joints on the plans with due regard to the constraints and reinforcement selected;

(b) *Non-specific engineering designed structures to NZS 4229*

Control joint details shall be as shown in figure 2 and located on the plans in accordance with section 13 of NZS 4229;

(c) *Non-specific engineering designed solid filled foundation structures to NZS 3604*

Control joint details shall be as shown in figure 2 and located on the plans in accordance with section 13 of NZS 4229 except that:

(i) For walls up to 2 m high the spacing of joints shall be 8 m maximum

(ii) For walls up to 1.2 m high the spacing of joints shall be 12 m maximum

(iii) For walls up to 800 mm high the spacing of joints shall be 24 m maximum.

(d) *Veneer construction to NZS 3604 and NZS 4229*

Control joint positions and details shall follow the manufacturer's requirements for the specific masonry product used, which shall include spacing between joints, requirements at windows, openings, intersections and corners.

C2.10.1.2

All masonry materials undergo some movement changes and as each material has its own characteristic properties, it is appropriate that manufacturers stipulate requirements for their products. Generally there is no need to require shrinkage control joints for clay bricks but natural stone and concrete products are more likely to need such control joints depending upon the nature of supply. Advice as per 2.10.1.2(d) should be obtained from the manufacturer.

2.10.2 Vertical control joints

The width of a vertical control joint shall be as follows:

(a) For shrinkage movements the width shall be 10 mm unless amended by specific engineering design (see figure 2);

(b) For expansion movements the width shall be determined by specific engineering design. For buildings of the size limited by NZS 3604 and NZS 4229, expansion movement joints are not required.

2.10.3 Separation joints

Panel blockwork contained within a structural frame and the associated separation joints shall be subject to specific engineering design.

2.10.4 Weatherproofing

2.10.4.1

Control and separation joints shall be weatherproof when located on external walls. Details of how the joint is proposed to be weatherproof shall be submitted to and approved by the Territorial Authority as part of the building consent application.

2.10.4.2

Sealants used in NZS 3604 and NZS 4229 shall be capable of allowing a 25 % extension on a joint of 10 mm.

2.10.5 Horizontal reinforcement

2.10.5.1

Reinforcement in lintels and in top course bond beams connecting to floors and roofs shall be continuous through control joints.

2.10.5.2

Horizontal reinforcement other than that defined in 2.10.5.1 shall be discontinuous at control joints as shown in figure 2.

C2.10.5.2

The debonding of the reinforcement is to provide for shrinkage movement to be taken up by an induced crack.

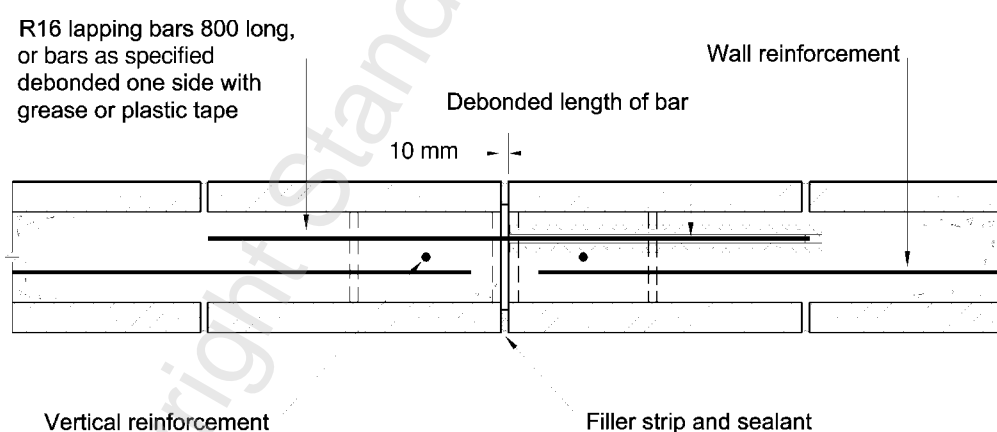


Figure 2 – Control joint

2.10.5.3

Cells within the masonry units either side of control joints shall be vertically reinforced and grouted.

2.11 Grouting of cells and cavities: general

2.11.1

Grouting shall not commence until the mortar joints have attained sufficient strength to resist blow-outs and grout spaces have been cleaned out.

C2.11.1

The height of individual lifts in any pour should be limited so as to prevent blow-outs.

2.11.2

Grout shall completely fill all cells and cavities containing reinforcement and such other cells required by NZS 3604, NZS 4229 and specific engineering design to NZS 4230 using the appropriate method (see 2.11.6).

2.11.3

Cells that are not to be filled shall be covered to prevent the entry of grout, provided that this shall be done in such a manner that the mortar bond between courses is not impaired.

2.11.4

Grout in each lift shall be thoroughly compacted in order to fill all voids and ensure bond between grout and masonry or construction joints.

2.11.5

The tops of grouted walls shall be protected in order to prevent too rapid drying during hot or drying weather or winds.

2.11.6

The following grouting methods shall be used for masonry construction to:

(a) NZS 3604

- (i) High lift grouting with expansive admixture as defined in 2.12
- (ii) High lift grouting with reduced compaction and without expansive admixture as defined in 2.15
- (iii) Low lift grouting as defined in 2.14.

(b) NZS 4229

- (i) High lift grouting with expansive admixture as defined in 2.12
- (ii) High lift grouting without expansive admixture as defined in 2.13
- (iii) Low lift grouting as defined in 2.14.

(c) NZS 4230

Any of the methods in 2.12, 2.13, 2.14 and 2.15 nominated as part of specific engineering design.

C2.11.6

High lift grouting using an expansive admixture relying upon the action of aluminium powder to form a gas generated expansion of the grout has been found to provide significantly superior results in both supervised and unsupervised masonry work. The expansive action avoids the re-consolidation actions required of all other high lift grout methods.

Requirements of the expansive grout are detailed in 2.1.8 and 2.3.2.1. Expansive grouts are not considered necessary for low lift methods.

The extent of the gas generation is affected by temperature and expansions become smaller as the temperature is reduced. In temperatures below 5 °C some supplementary re-consolidation of the grout may be required.

2.12 The high lift grouting with expansive admixture method

2.12.1 General

Grouting using an expansive admixture shall be carried out as a semi-continuous operation without horizontal construction joints for pours up to a maximum of 3.6 m with consolidation provided as the pour height proceeds with recompaction.

2.12.2 Procedure

2.12.2.1

An expansive admixture shall be dosed in accordance with the manufacturer's instructions and mixed immediately prior to placing in the masonry. Information shall be supplied by the manufacturer to include advice as to dosage rates and mixing times along with any essential requirements regarding consolidation of the grout especially when the grout is being placed in extreme conditions of hot or cold.

2.12.2.2

The placing and consolidation shall be as follows:

- (a) Place grout into cells to be grouted in a semi-continuous operation allowing for consolidation as the work proceeds up to a maximum height of 3.6 m;
- (b) After filling and waiting for expansion to take place, the wall tops shall be locally recompacted by trowelling. Alternatively a weighted or fixed restraining board shall be placed on top of the wall immediately after grouting and left in place for at least 4 hours.

2.12.2.3

Consolidation shall be carried out by mechanical immersion vibration or rodding with a solid bar or rod of minimum dimension 16 mm until no settlement of top surface occurs.

2.13 The high lift grouting without expansive admixture method

2.13.1 General

The high lift grouting without expansive admixture method means grouting a pour not exceeding 3.6 m high as a semi-continuous operation without intermediate horizontal construction joints. Grouting is done in a series of lifts, each not exceeding 1.2 m high. Compaction is by consolidation followed by reconsolidation.

2.13.2 Procedure

2.13.2.1

The placing and consolidation shall be as follows:

- (a) Grout the first lift to a height not exceeding 1.2 m;
- (b) Consolidate the first lift by mechanical immersion vibration;
- (c) Wait for the first lift to settle, which generally shall not be less than 15 min nor more than 60 min;
- (d) Grout the second lift;
- (e) Consolidate the second lift and simultaneously re-consolidate the first lift by mechanical vibration;
- (f) Repeat this sequence of operations of grouting, consolidation and waiting as necessary until the end of the waiting period for the final lift of the pour;
- (g) Reconsolidate the final lift and top off as necessary.

2.13.2.2

Consolidation and reconsolidation in this method shall be by the use of a mechanical immersion vibrator.

2.14 The low lift grouting method

2.14.1 General

The low lift grouting method means grouting in increments between horizontal construction joints conforming to 2.16. The spacing of construction joints shall not exceed:

- (a) 1200 mm where no dimension of the grout space is less than 50 mm;
- (b) 400 mm where any dimension of the grout space is less than 50 mm.

2.14.2 Procedure

2.14.2.1

The procedure shall be as follows:

- (a) Lay units to the height of the first lift;
- (b) Grout the first lift;
- (c) Consolidate the first lift so as to fill all voids;
- (d) Prepare the construction joint in accordance with 2.16;
- (e) Repeat this sequence of operations until the final lift is completed, grouted and consolidated.

2.14.2.2

Consolidation shall be carried out by mechanical immersion vibration or rodding with a solid bar or rod of minimum dimension 16 mm until no settlement of top surface occurs.

2.15 The high lift grouting method with reduced compaction

2.15.1 General

The high lift grouting method with reduced compaction means grouting in a continuous single pour to a maximum height of 2.4 m, with thorough vibration during the placement of the grout.

2.15.2 Procedure

The procedure shall be as follows:

- (a) Grout with continuous mechanical immersion vibration to a maximum height of 2.4 m;
- (b) Wait for a period of 15 to 60 min and then re-vibrate and top up the wall with grout as required.

C2.15.2

Waiting time is to allow surrounding masonry to absorb moisture.

2.16 Horizontal construction joints

2.16.1

Horizontal construction joints shall preferably be formed at the top of the uppermost masonry units. In no case shall they be formed more than 20 mm below the top.

2.16.2

Horizontal construction joints in grout shall be prepared by thoroughly cleaning the surface of the hardened grout and removing all laitance and loose and foreign matter.

2.17 Bracing during construction

Temporary bracing shall be provided to masonry where necessary to resist lateral loads during construction.

C2.17

Unfilled blockwork 190 mm thick, 1 m high becomes unstable when subjected to a wind gust of velocity above about 90 km/h, while a similar wall 2.4 m high becomes unstable at a gust velocity above about 60 km/h. Thinner walls become unstable at lower gust velocities.

2.18 Cold weather construction

When masonry construction is carried out at an air temperature below 5 °C the following precautions shall be taken:

- (a) Masonry shall be protected for not less than 24 hours after laying by covers, blankets, heated enclosures, or the like to ensure that the mortar can gain strength without freezing or harmful effects from cold winds, and
- (b) No frozen materials nor materials containing ice shall be used.

2.19 Hot weather construction

When masonry construction is carried out at an air temperature above 25 °C the following precautions shall be taken:

- (a) Masonry units may be lightly dampened before laying (see 2.7.2.2);
- (b) Mortar shall be kept moist and shall not be spread on the wall so far ahead of the units being placed as to cause loss of plasticity;
- (c) All wall surfaces shall be maintained in a damp condition for the first 24 hours;
- (d) The top surface of the grout shall be protected from premature drying for 24 hours. Such protection shall be by any of the methods below:
 - (i) The application of a suitable anti-evaporative spray (aliphatic alcohol) to the fresh grout, or
 - (ii) Covering the top of the wall with a suitable impermeable membrane. The membrane must be effectively sealed by tapping it down to the wall surfaces and around any penetrations through the membrane, or
 - (iii) Placing hessian or other suitable permeable covering on the top surface of the grout and maintaining it in a damp condition.

2.20 Chases, recesses, sleeves, conduits or other pipes

Chases and recesses in masonry shall be constructed only as permitted by specific engineering design.

2.21 External moisture protection

2.21.1 General

The waterproofing or weatherproofing of masonry walls to NZS 4230 shall be a matter of specific engineering design.

Masonry walls designed to NZS 3604 and NZS 4229 and required to keep external moisture out shall be weatherproofed to the requirements of 2.21.2. These requirements do not apply to veneer walls built to these Standards.

C2.21.1

Concrete blocks manufactured to AS/NZS 4455 using normal weight aggregates can be considered satisfactory to meet the performance requirements of Clause B2 provisions in the NZBC. However, they are not considered able to meet Clause E2 provisions of the NZBC. Veneers to NZS 3604 and NZS 4229 do not require waterproofing as the cavity and associated construction requirements of these Standards ensure compliance with Clause E2 of the NZBC.

2.21.2 Weatherproofing methods

2.21.2.1

Masonry walls subject to hydrostatic ground water shall have a waterproof system specifically designed for the conditions. Such design is outside the scope of this Standard.

2.21.2.2

External masonry walls for building applications except veneer walls, where compliance with Clause E2 provisions of the NZBC is required, shall be weatherproofed by the application of a surface coating that shall extend at least 50 mm below the top level of an adjoining concrete floor slab.

2.21.2.3

The surface coating shall be an alkali resistant water-based dispersion coating system, formulated below the critical pigment volume concentration (CPVC) having a dry film thickness of between 180 and 250 µm (micrometres).

2.21.2.4

This shall be achieved with two or three coats, depending on the product used and the texture of the surface.

2.21.2.5

The surface coating shall not be applied until the moisture content of the wall is below 70 % relative humidity and is suitable for the application of the paint system.

C2.21.2

Uncoated masonry walls cannot be assumed to be completely waterproof.

Moisture should be controlled firstly by trying to eliminate its entry and secondly by allowing it to dissipate without causing damage to building elements.

An acrylic system, applied by a suitably qualified painter to the approval of the territorial authority, is called up as the coating to prevent the entry of liquid water yet allow the ready transmission of water vapour.

The range of thickness relates to the surface texture of the masonry where an open texture may require the higher coating application including a substrate preparation coat to fill any surface voids.

The method of testing relative humidity is to seal an RH meter on the surface to be painted for a period of 24 hours. If the reading at the end of that period is 70 % or less, then the surface is acceptable for painting.

2.21.3 Maintenance

The completed coating system shall be regularly maintained to ensure continued resistance to water entry. Maintenance shall include the removal of dirt, mould and other organic deposits, the repair of cracks or other defects, and repainting as necessary to preserve the waterproof finish.

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APPENDIX 2.A COMPRESSIVE STRENGTH TESTS FOR MORTAR AND GROUT

2.A1 Scope

This Appendix sets out the method of test for the determination of the 28 day compressive strength of mortar and grout.

2.A2 Sampling of mortar and grout

C2.A2

Two methods of sampling mortar (2.A2.1 and 2.A2.2) and of moulding grout (2.A3.2 and 2.A3.3) are given for flexibility. The use of freshly mixed samples to be compacted directly into non-absorbent moulds gives easily operated tests which may be more effective for control purposes. The alternative sampling for mortar taken from the mortar bed and moulding of grout into absorbent moulds are more difficult tests but will give compressive strengths more related to the strength in the masonry.

2.A2.1

Except as provided in 2.A2.2 the sample shall be of freshly mixed material.

2.A2.2

Mortar may be taken from a mortar bed which has been spread on the masonry for a period of 1 min and then remixed by hand for 30 s.

2.A2.3

The sample shall be taken from at least 3 widely distributed locations in the batch and sufficient shall be taken for a total of at least 3 test specimens.

2.A2.4

Grout sampling shall be taken prior to the addition of an expansive admixture.

2.A3 Moulding and compaction of test specimens

2.A3.1

Each test, whether for mortar or grout, shall consist of a minimum of 3 specimens.

2.A3.2

Except as provided in 2.A3.3 and 2.A3.4 test specimens of mortar and grout shall be moulded and compacted in cylindrical moulds conforming to section 3 of NZS 3112: Part 2.

2.A3.3

Test specimens of grout may be moulded and compacted in square section moulds formed of masonry units of the same type and condition as those being used in the structure and lined with absorbent paper.

2.A3.4

The minimum lateral dimension of test specimens shall be not less than 4 times the nominal maximum aggregate size or 50 mm whichever is the greater. The length of test specimens, whether capped or uncapped, shall be not less than 1.90 and not greater than 2.10 times the minimum lateral dimension.

2.A4 Curing, capping and testing of specimens

2.A4.1

Curing of specimens shall be in accordance with 3.5.1 or 3.5.2 of section 3 of NZS 3112: Part 2.

2.A4.2

Where necessary, capping of specimens shall be in accordance with section 4 of NZS 3112: Part 2.

2.A5

Testing of specimens shall be carried out at an age of 28 days after mixing of the mortar or grout in accordance with section 6 of NZS 3112: Part 2.

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**APPENDIX 2.B
MASONRY-TO-MORTAR BOND STRENGTH TEST**

2.B1 Scope

AS 3700 Appendix D6 sets out a test method for masonry to mortar bond strength.

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APPENDIX 2.C TEST FOR EXPANSION OF GROUT

2.C1 Scope

This Appendix sets out the method of test for the determination of the expansion by volume of a grout containing an expansive admixture by monitoring the rise in surface level of a sample of the grout in a measuring cylinder.

2.C2 Apparatus

The following apparatus is required for the test:

- (a) A 2000 ml graduated glass measuring cylinder conforming to BS 604 or AS 2163;
- (b) A vibration free level surface;
- (c) A timing device readable and accurate to 1 minute;
- (d) A scoop small enough to fit inside the measuring cylinder.

2.C3 Procedure

Use the following test procedure:

- (a) Obtain a representative sample of grout by one of the methods set out in section 3 of NZS 3112: Part 1 within 10 min of the addition of the expansive admixture to the grout.

This test shall be performed immediately after the grout has been sampled. Hence a sample which has already been subjected to the spread test is not acceptable.

- (b) Using the scoop, fill the measuring cylinder to 1600 ± 20 ml with grout. Level the surface and stand the measuring cylinder on the vibration free surface.
- (c) Start the timing device and record the grout level to the nearest 10 ml.
- (d) Record the level of grout solids at regular intervals (no more than 15 minutes) until no further change can be observed.

C2.C3(d)

Often a grout containing an expansive admixture will form more bleed water than the same grout without an expansive admixture. The extra bleed water is forced out by the formation of hydrogen gas. It should be noted that the level of the grout solids should be recorded, not the surface level of the bleed water.

2.C4 Other test methods

2.C4.1 Grout expansion

Alternative methods which contain the lateral movement of the grout within a cylinder of constant cross-section and use direct vertical measurement of movement may be used subject to:

- (a) The degree of linear expansion shall be readable to within 0.5 % of the vertical height of the grout sample;
- (b) The diameter of the cylindrical container shall neither be less than 30 mm nor less than 5 times the maximum aggregate size contained in the grout;



- (c) The test procedures shall follow that of 2.C3 except that a rigid cylinder of constant section can be substituted for a measuring cylinder in 2.C3(b);
- (d) Calculations using linear height measurements instead of volume as in 2.C5 before and after expansion shall be used to determine the percentage increase in volume;
- (e) The reported results shall be in accordance with 2.C6.

C2.C4.1

For site testing, the method of 2.C2(a) is often inappropriate and a disposable cylindrical container method can be used. Typically a rigid plastic waste drainage pipe 50 mm in diameter, bottom capped with a height of grout sample 300 mm should show a height movement of not less than 6 mm nor more than 12 mm with an accuracy of measurement being to 1.5 mm i.e. the range of acceptable performance : 2 % – 4 % expansion.

2.C5 Calculations

Calculate the expansion of grout solids, Δ after time, t as a percentage of the initial volume from the formula:

$$\Delta = \frac{(V_t - V_i)}{V_i} \times 100$$

where

V_t = grout volume after time, t (ml).
 V_i = initial grout volume (ml).

2.C6 Report

Report the expansion of grout solids to the nearest 1 % and the time until expansion ceases to the nearest 15 min.

C2.C6

A graph of grout solid volume change against time is often useful and may be included in the report.

APPENDIX 2.D HOOKS AND BENDS FOR REINFORCING BARS

2.D1

Details of the standard hook and bend for main reinforcing bars and for stirrups and ties are given in figure 2.D1.

2.D2

The minimum diameters of bends for main reinforcing bars measured on the inside of the bar shall be as given by table 2.D1.

2.D3

The diameters of bends for stirrups and ties measured on the inside of the bar shall be equal to the diameter of the enclosed bar except that it shall be not less than the appropriate value given in table 2.D1 where d_b is the stirrup or tie bar diameter.

Table 2.D1 – Minimum radii of reinforcement bends

| Steel grade (MPa) | Bar type | Bar diameter (d_b) | Minimum diameter of bend, D (mm) | |
|----------------------|-------------------|---------------------------|---------------------------------------|----------------------------|
| | | | Plain bars (d_b) | Deformed bars (d_b) |
| 300 or 430 | Stirrups and ties | 6 – 20 | 2 | 4 |
| | | 24 | 3 | 6 |
| or 500 | All other bars | 6 – 20 | 5 | 5 |
| | | 24 – 40 | 6 | 6 |

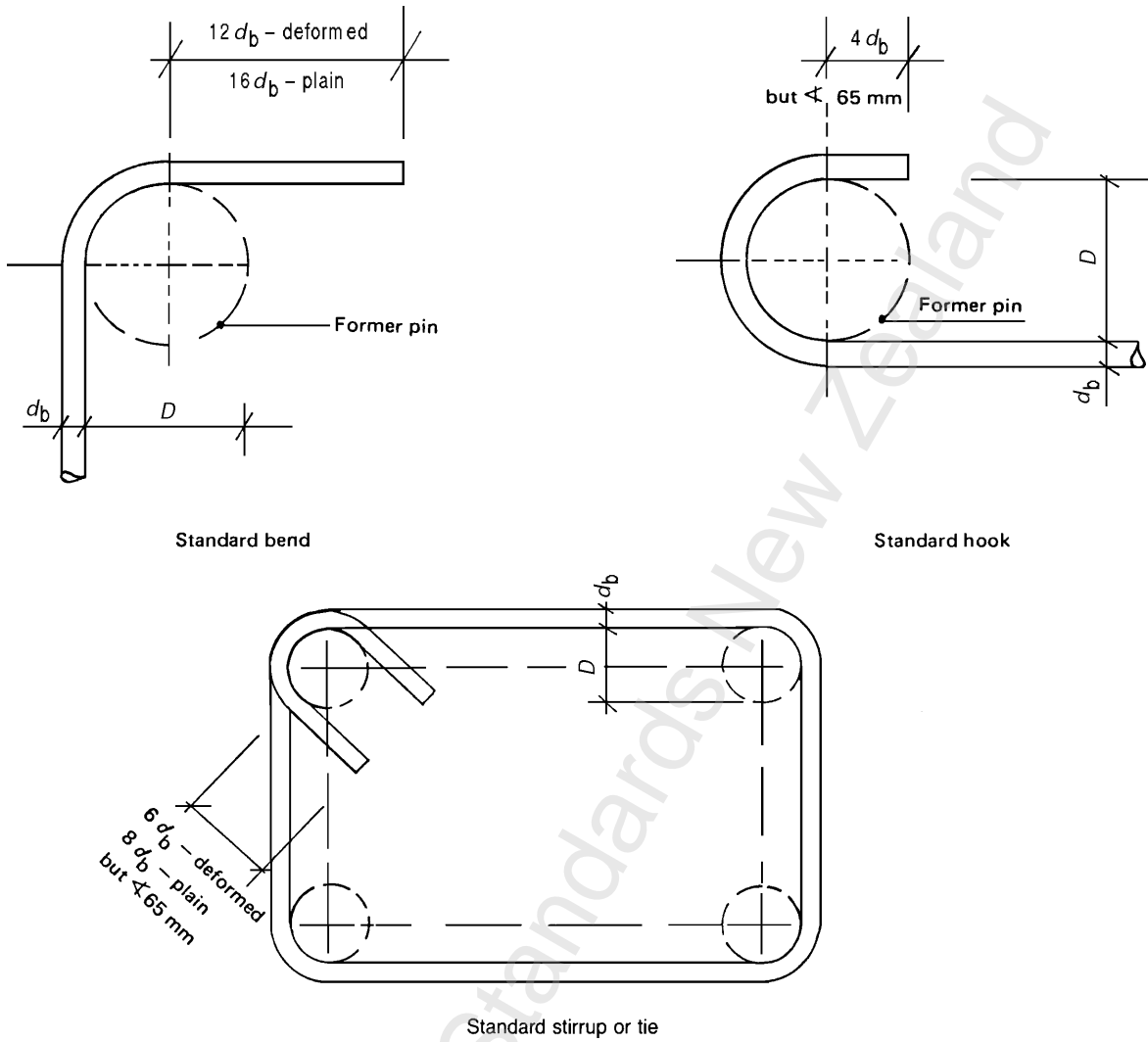


Figure 2.D1 – Standard bend, hook and stirrup or tie

APPENDIX 2.E DURABILITY

2.E1 Scope

When used in conjunction with NZS 3604, NZS 4229 and NZS 4230, this Appendix provides a means of compliance with B2 of the New Zealand Building Code (NZBC).

2.E2 Classification of exposure zones of NZS 3604

2.E2.1

Building sites shall be classified as being in sea spray zones or zones 1, 2, 3 or 4, depending on the severity of exposure to wind-driven sea salt or to geothermal gases.

2.E2.2

Sea spray zones and zones 1, 2, 3 and 4 are shown in figure 2.E1.

2.E2.3

The sea spray zone referred to in table 2.E1 is defined as within 500 m of the sea including harbours, or 100 m from tidal estuaries and sheltered inlets, as well as areas shown in white on figure 2.E1. The sea spray zone also includes all offshore islands including Waiheke, Great Barrier, Stewart Island and the Chatham Islands.

2.E2.4

“Geothermal hot spots” are mainly found in Zone 4 but may occur elsewhere. These are areas within 50 m of a bore, mudpool, steam vent, or other fume source.

2.E2.5

Localised areas subject to corrosive industrial atmospheres are outside the scope of this Standard.

2.E2.6

Table 2.E1 shall be used to determine the masonry durability requirements as follows:

- (a) For masonry designed to NZS 3604 and NZS 4229 the exposure category of NZS 3604 shall be used;
- (b) For masonry to specific engineering design the exposure category shall be chosen from the NZS 3604 or NZS 3101 zones as considered appropriate by the designer.

C2.E2

This Appendix presents a simple solution to what is a very complex problem. It is acknowledged that in some instances this may be a conservative solution. If the corrosion exposure zone, determined for a particular site from this Appendix, appears to be too severe, then the applicant may reclassify the site. Such reclassification however would be outside the scope of NZS 4210 and would be an alternative solution. The alternative solution would need to be submitted to, and approved by the Territorial Authority as part of the building consent process.

To assist the Territorial Authority in its assessment of an alternative solution, it is suggested that the applicant would need to elaborate on all their considerations and in particular would need to address the following issues:

In sea spray zones:

- (a) *Direction of prevailing wind from the sea;*



- (b) *Prevalence of breaking surf;*
- (c) *Existence of salt spray residue on windows or cladding of adjacent buildings;*
- (d) *Existence of constant smell of salt in the air;*
- (e) *Wind classification of site.*

In Zone 1 areas

Shelter provided by ridges or spurs, large belts of trees or other such features.

In Zone 4 areas

Location of building in relation to geothermal hot spots and prevailing wind.

In all zones

Performance of adjacent buildings.

Table 2.E1 – Masonry durability requirements

| Exposure categories | | Durability requirements | | | |
|---------------------|-------------------------|-------------------------|-----------------|---|---|
| NZS 3604 zones | NZS 3101 zones (Note 1) | Masonry units (Note 2) | Mortar (Note 3) | Classification built in components (Note 4) | Minimum cover to reinforcement (Note 5) |
| Seaspray | B2 | Exposed | M4 | R4 | 30 (60) |
| 1 & 4 | B1 | General purpose | M4 | R3 | 20 (50) |
| 2 & 3 | A2 | Protected | M3 | R3 | 15 (45) |
| Closed interior | A1 | Protected | M2 | R1 | 5 (35) |
| Geothermal hotspot | U | Exposed | M4 | R5 | Specific engineering design consideration |

NOTE –

- (1) The NZS 3101 zones shall be as defined in section 5 of that Standard.
- (2) These classifications are defined in AS/NZS 4456.10 for resistance to salt attack. The requirement is not needed for concrete masonry products.
- (3) The requirements of the mortar to meet the classifications nominated in the table are given in 2.2.2.1 of this Standard.
- (4) The classifications are defined in AS/NZ 2699:Part 1 Wall Ties, Part 2 Connectors and Accessories, Part 3 Lintel and shelf angles. A protection specification is given for the component which a manufacturer must meet and label the component to identify the level of corrosion protection.
- (5) The cover is measured from the inside of the cell face of the unit. The figures in brackets are the approximate total cover to the outside face of the wall assuming a face shell thickness of 30 mm. Reinforcements shall be restrained so that the minimum covers are maintained during construction. Retaining walls shall be classed as B2 as specified in NZS 3101.
- (6) When weatherproofed to the requirements of 2.21.2.2 – 2.21.2.5, Exposure Categories 1, 2, 3 & 4 (NZS 3604) or B1 & A2 (NZS 3101) can be reduced to “Closed Interior” or “A1”. When waterproofed to the requirements of 2.21.2.1 all exposure categories can be reduced to “Closed Interior” or “A1”.

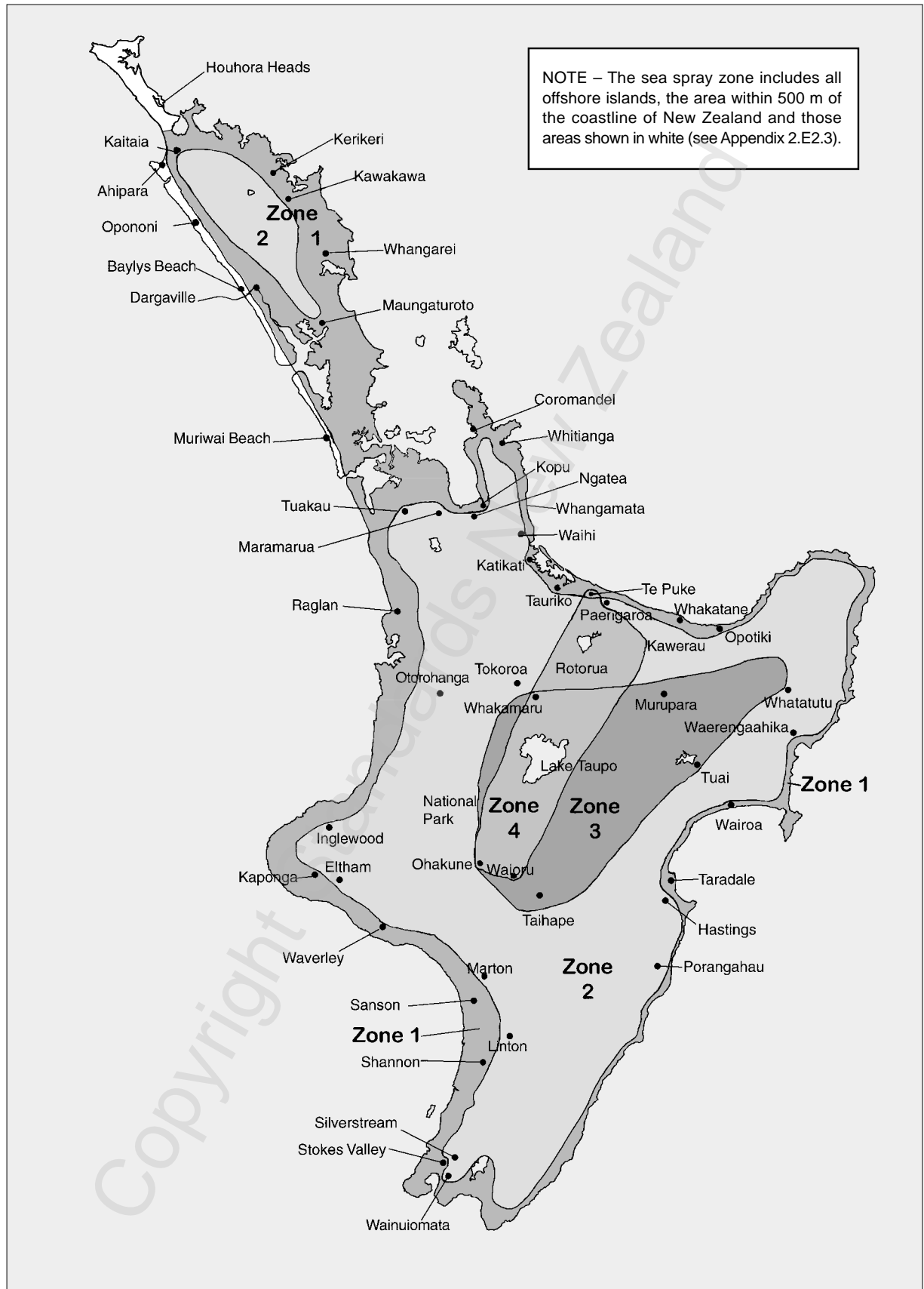


Figure 2.E1 – Corrosion zone map

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Figure 2.E1 – Corrosion zone map (continued)

MASONRY CONSTRUCTION: MATERIALS AND WORKMANSHIP

AMENDMENT No. 1

May 2002

REVISED TEXT

EXPLANATORY NOTE

Amendment No. 1 to NZS 4210:2001 Masonry Construction: Materials and Workmanship has been undertaken to revise clause 2.9.6 and add clauses 2.9.6.1, 2.9.6.2 and 2.9.6.3 dealing with wall ties at unsupported edges and at all openings through veneered walls and where the veneer wall continues above or is interrupted by a damp proof course or waterproof membrane.

APPROVAL

Amendment No.1 was approved on 9 May 2002 by the Standards Council to be an amendment to NZS 4210:2001.

2.9.6 *Placing of ties*

Delete the clause and **substitute** the following:

2.9.6 *Placing of ties*

2.9.6.1

Wall ties as specified herein shall be placed within 5° of a right angle to the plane of the masonry and shall slope down away from the framing, toward the masonry.

2.9.6.2

At unsupported edges and at all openings through veneered walls or non-grouted cavity walls, wall ties spaced as required by 2.9.7.1 shall be provided as follows:

- (a) At the top and bottom of the opening:
Not more than 300 mm or 2 courses, whichever is the smaller;
- (b) At the sides of the opening or at an unsupported edge:
Not more than 300 mm.

2.9.6.3

Where the veneer wall continues above or is interrupted by a damp proof course or waterproof membrane, wall ties spaced as required by 2.9.7.1 shall be provided in each of the first two courses above the membrane.

(Amendment No. 1, May 2002)

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