

Australian Standard™

**Strengthening existing buildings
for earthquake**

This Australian Standard was prepared by Committee BD/76, Strengthening Existing Buildings for Earthquake. It was approved on behalf of the Council of Standards Australia on 15 May 1998 and published on 5 June 1998.

The following interests are represented on Committee BD/76:

The Association of Consulting Engineers
Australian Building Codes Board
Bureau of Steel Manufactures of Australia
Department of Local Government W.A.
Institution of Engineers Australia
Master Builders Australia
Newcastle City Council
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This Standard was issued in draft form for comment as DR 96498.

Australian Standard™

Strengthening existing buildings for earthquake

First published as AS 3826—1998.

Published by Standards Australia
(Standards Association of Australia)
1 The Crescent, Homebush, NSW 2140

PREFACE

This Standard was prepared by the Standards Australia Committee BD/76, Strengthening Existing Buildings for Earthquake. It should be read in conjunction with the following Standards:

AS

1170 Minimum design loads on structures (known as the SAA Loading Code)

1170.1 Part 1: Dead and live loads and load combinations

1170.4 Part 4: Earthquake loads

1720 Timber structures (known as the SAA Timber Structures Code)

1720.1 Part 1: Design methods

3600 Concrete structures

3700 Masonry structures

4100 Steel structures

AS/NZS

4600 Cold-formed steel structures

The objective of this Standard is to provide users with specifications covering the assessment and analysis of the earthquake resistance of existing buildings, and the design and detailing of any required strengthening in accordance with the strength limit state. In the event of an earthquake, the strengthening is intended to minimize the risk of loss of life and injury due to structural collapse or damage. This Standard is not intended to prevent damage to the building.

For loads resulting from these infrequent events, a greater degree of risk is acceptable in existing buildings than that implied in the design of new buildings. This is achieved by requiring the building be able to resist only a portion of the loads specified in the loading Standards. For live loads, the existing load capacity of the structure is not reduced.

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

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STANDARDS AUSTRALIA

Australian Standard

Strengthening existing buildings for earthquake

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard sets out minimum requirements for the assessment and analysis of the earthquake resistance of existing buildings, and the design and detailing of any required strengthening in accordance with the strength limit state.

This Standard does not apply to Class 1 and Class 10 buildings as defined in the Building Code of Australia.

There are no additional provisions for heritage buildings in this Standard.

NOTE: For background information pertaining to this Standard, see Appendix A.

1.2 REFERENCED DOCUMENTS The following documents are referred to in this Standard:

AS

1170 Minimum design loads on structures (known as the SAA Loading Code)

1170.1 Part 1: Dead and live loads and load combinations

1170.4 Part 4: Earthquake loads

1275 Metric screw threads for fasteners

1720 Timber structures (known as the SAA Timber Structures Code)

1720.1 Part 1: Design methods

3600 Concrete structures

3700 Masonry structures

4100 Steel structures

AS/NZS

4455 Masonry units and segmental pavers

4600 Cold-formed steel structures

1.3 DEFINITIONS For the purpose of this Standard, the definitions below apply.

1.3.1 Can—implies a capability or possibility and refers to the ability of the user of the Standard, or to a possibility that is available or that might occur.

1.3.2 Earthquake load—the design load determined in accordance with AS 1170.4.

1.3.3 May—indicates the existence of an option.

1.3.4 Reinforced concrete—as defined in AS 3600.

1.3.5 Reinforced masonry—as defined in AS 3700.

1.3.6 Shall—indicates that a statement is mandatory.

1.3.7 Should—indicates a recommendation.

1.3.8 Structural steel frames—as defined in AS 4100.

1.3.9 Threshold load—the limit state load determined in accordance with Clause 2.4.

1.3.10 Unreinforced concrete—as defined in AS 3600.

1.3.11 Unreinforced masonry—as defined in AS 3700.

1.3.12 Parts—structural and non-structural elements, attachments, appendages and the like.

1.4 NOTATION The symbols used in this Standard are listed below. The dimensional units for length, force and stress in all expressions or equations are to be taken as millimetres (mm), newtons (N) and megapascals (MPa), respectively, unless specified otherwise.

- A_b = bedded area of a masonry cross-section
- A_c = minor diameter area of a bolt, as defined in AS 1275
- A_{dw} = combined bedded area and grout area
- A_j = gross area of upper and lower bed joints in the case of solid masonry, or net mortar bedded area for the case of hollow-unit masonry
- A_o = plain shank area of a bolt
- A_s = total cross-sectional area of the main reinforcement in a reinforced masonry member
- a = acceleration coefficient
- E_l = long-term modulus of elasticity of masonry
- E_s = short-term modulus of elasticity of masonry
- F_b = basic shear strength capacity of the masonry
- F_{eq} = threshold load determined in accordance with Clause 2.4
- f_d = superimposed compressive stress
- f_{sy} = characteristic tensile strength of reinforcement
- f_{uf} = minimum tensile strength of a bolt
- f'_c = characteristic compressive cylinder strength of concrete at 28 days
- f'_m = characteristic compressive strength of masonry
- f'_{ms} = characteristic shear strength of masonry
- f'_{mt} = characteristic flexural tensile strength of masonry
- f'_{ut} = characteristic lateral modulus of rupture of masonry units
- G = shear modulus of masonry
- h = minimum of floor to floor, floor to roof height, and horizontal distance between individual thickness
- k_b = concentrated bearing factor
- k_r = reduction factor to account for the length of a bolted or welded lap splice connection
- k_v = shear factor
- M_{ch} = horizontal bending capacity of masonry
- n_n = number of shear planes with threads intercepting the shear plane—bolted connections
- n_x = number of shear planes without threads intercepting the shear plane—bolted connections
- P_h = maximum horizontal force resisted by the test unit

- r_h = proportion of the area of a vertical mortar joint in a member that is intersected by masonry header units
- T = tension capacity of the bolt
- t = thickness of wall, partition or infill panel. For cavity walls, t is two-thirds of the sum of the individual thickness
- V = shear capacity of the bolt
- V_d = shear capacity of a plane with superimposed compression
- V_o = basic shear strength capacity of the shear section
- Z_u = lateral section modulus of masonry units
- μ = coefficient of friction for the masonry
- ν = Poisson's ratio
- σ_v = magnitude of the vertical compressive stress at the test location
- τ = shear strength
- τ_o = reduced shear strength
- ϕ = capacity reduction factor

SECTION 2 GENERAL REQUIREMENTS

2.1 GENERAL Where required, an existing building including its parts and connections shall be assessed to determine whether it is satisfactory for resisting earthquakes.

A building shall be deemed to be satisfactory if it—

- (a) complies with Clause 2.3; or
- (b) resists the load combinations given in AS 1170.1 for vertical dead and live loads, and in AS 1170.4 for earthquake load combinations, where F_{eq} shall be taken as the threshold load determined in accordance with Clause 2.4. A building classified as Type III in AS 1170.4 shall be assessed as satisfactory only if it complies with this Item (b).

If the building is found to be unsatisfactory, it shall be strengthened in accordance with Clause 2.2.

NOTE: For commentary on this Clause, see Paragraph B2.1 of Appendix B.

2.2 METHODOLOGY FOR ASSESSMENT AND STRENGTHENING The building structure shall be inspected and visually assessed to determine its materials, condition, connections and the disposition and integrity of its load-resisting members.

The building structure shall be assessed to determine if it complies with Clause 2.3. If it does not comply with Clause 2.3, then the following procedure shall be adopted:

- (a) Assess the load capacity of the building structure using the capacity of the existing elements. If this is greater than the design load effects arising from the load combinations for vertical load given in AS 1170.1 and the earthquake load combinations given in AS 1170.4, where F_{eq} is taken as the threshold load determined in accordance with Clause 2.4, then the building structure shall be deemed to be satisfactory.
- (b) If the building structure does not comply with Item (a) of this Clause, connect the existing elements together to improve the load paths and resistance, and check the load capacity of the building structure again in accordance with Item (a) of this Clause.
- (c) If the building structure still does not comply with Item (a) of this Clause, add new elements to increase the load capacity of the building structure to the required level.

In all cases, all parts and their connections to the building structure shall be assessed to ensure that the required load capacity is achieved.

The analysis of the existing building and the design of strengthening elements shall be carried out in accordance with Section 4.

NOTE: For commentary on this Clause, see Paragraph B2.2 of Appendix B.

2.3 DEEMED-TO-SATISFY REQUIREMENT

2.3.1 General An existing building, except a building classified as Type III in AS 1170.4, shall be deemed to satisfy the requirement for having a minimum resistance to earthquake loads provided it complies with Clause 2.3.2 and the appropriate parts of Clause 2.3.3.

NOTE: For commentary on this Clause, see Paragraph B2.3.1 of Appendix B.

2.3.2 All types of buildings For all types of buildings, the following shall apply:

- (a) The building shall be visually assessed.

- (b) The original construction shall be of a high standard of workmanship.
- (c) Materials, ties and connections shall be in serviceable condition.
- (d) The structure of the building shall be of regular shape and shall be free from significant weaknesses.
- (e) The building shall comply with the deemed-to-satisfy details set out in Appendix C. These details set out principles in detailing connections that shall be followed. They do not include other engineering or architectural details, which shall comply with the relevant material Standards and accepted building practice.

NOTE: For commentary on this Clause, see Paragraph B2.3.2 of Appendix B.

2.3.3 Predominant structural system

2.3.3.1 General The capacity of the predominant structural system to resist horizontal earthquake loads shall be assessed and the requirements of Clauses 2.3.3.2 to 2.3.3.4 shall be applied as appropriate.

NOTE: For commentary on this Clause, see Paragraph B2.3.3.1 of Appendix B.

2.3.3.2 Unreinforced masonry or unreinforced concrete bearing walls For buildings with a predominant structural system of unreinforced masonry or unreinforced concrete bearing walls, or both, the following shall apply:

- (a) Buildings up to and including three storeys high shall have—
 - (i) a gross floor area at each level up to 300 m²;
 - (ii) horizontal load resisting walls at 8 m centres maximum in each direction;
 - (iii) walls course-bonded at corners or equivalently connected;
 - (iv) walls with an h/t ratio of less than or equal to 18:1;
 - (v) a timber-framed roof connected to walls or concrete roof bearing on walls;
 - (vi) timber-framed first and second floors connected to walls or concrete floors bearing on walls; and
 - (vii) a timber-framed ground floor or concrete ground floor up to 1 m clear above ground level at any point, which need not be connected to walls.
- (b) Buildings up to and including two storeys high shall be subject to the requirements of Item (a), except that timber-framed first floors need not be connected to walls.

NOTE: For commentary on this Clause, see Paragraph B2.3.3.2 of Appendix B.

2.3.3.3 Reinforced masonry or reinforced concrete bearing walls For buildings with a predominant structural system of reinforced masonry or reinforced concrete bearing walls, or both, the following shall apply:

- (a) Buildings up to and including four storeys high shall—
 - (i) be subject to the requirements set out in Clause 2.3.3.2(a), except for Clause 2.3.3.2(a)(vi); and
 - (ii) have timber-framed first, second and third floors, each connected to walls.
- (b) Buildings up to and including five storeys high shall—
 - (i) be subject to the requirements set out in Item (a), except that timber floors are not permitted; and
 - (ii) have any suspended concrete floor slabs bearing on or connected to walls.

NOTE: For commentary on this Clause, see Paragraph B2.3.3.3 of Appendix B.

2.3.3.4 Reinforced concrete or structural steel frames For reinforced concrete or structural steel frames, or both, the requirements of Clause 2.3.3.3 shall apply and, in addition, the frame shall be considered to replace the walls and shall extend to the full height of the building.

NOTE: For commentary on this Clause, see Paragraph B2.3.3.4 of Appendix B.

2.3.3.5 Lightweight constructions There are no limitations on lightweight frame building structures.

NOTE: For commentary on this Clause, see Paragraph B2.3.3.5 of Appendix B.

2.3.4 Parts of buildings The following shall apply to elements other than the main structure:

- (a) Unreinforced masonry or unreinforced concrete parapets and chimneys, which have a ratio of unrestrained height above the uppermost connections to effective thickness greater than or equal to 3:1, shall be connected to the roof structure to prevent them from falling.
- (b) Minarets, cupolas, orbs and other similar ornamentations shall be connected to the building to prevent them from falling.
- (c) Cornices and similar projections in external walls shall project no further from the wall face than the thickness of the wall.
- (d) Veneers and external leafs of cavity walls shall be tied to the supporting wall.
- (e) Unreinforced masonry partitions, infill panels, gables and other non-load-bearing elements shall be connected to the structure either at the top or at both side edges, and they shall have an h/t ratio less than or equal to 27:1. If they are not connected, they shall have an h/t ratio less than or equal to 6:1.
- (f) Awnings shall be positively anchored to the structure and a suitable load path shall be established for the transmission of the awning forces that will be imposed on the structure. It shall not be assumed that an awning is capable of supporting masonry and other heavy materials falling from above.
- (g) Major items of plant and equipment shall be connected to the main structure.

NOTE: For commentary on this Clause, see Paragraph B2.3.4 of Appendix B.

2.4 THRESHOLD LOADS

2.4.1 General In determining the appropriate threshold loads, the structure types as defined in AS 1170.4 shall be used.

NOTE: For commentary on this Clause, see Paragraph B2.4.1 of Appendix B.

2.4.2 Threshold load values The threshold load values shall be determined as follows:

- (a) *Types II and I structures* For earthquake design, the threshold load values shall be taken as one-third of the design earthquake load determined in accordance with AS 1170.4.
- (b) *Type III structures* For earthquake design, the threshold load values shall be taken as two-thirds of the design earthquake load determined in accordance with AS 1170.4.

NOTE: For commentary on this Clause, see Paragraph B2.4.2 of Appendix B.

2.4.3 Parts and connections of buildings Parts and connections of building structures with load capacities less than the threshold load capacity for the part shall be strengthened in accordance with Clause 2.4.2, even if the building structure as a whole has a load capacity exceeding the threshold load capacity for the building.

NOTE: For commentary on this Clause, see Paragraph B2.4.3 of Appendix B.

SECTION 3 MATERIALS

3.1 GENERAL The condition of the existing materials of a building shall be assessed for deterioration that may jeopardise the capacity of the vertical or horizontal load resisting system. If the condition is deemed adequate, the deemed-to-comply material properties and strengths specified in Clauses 3.3 and 3.4, or higher values determined from appropriate tests, may be used. If the condition of the structure or component is deemed unsatisfactory, material properties shall be determined from appropriate tests.

NOTE: For commentary on this Clause, see Paragraph D3.1 of Appendix D.

3.2 MEMBER CAPACITIES The capacity of members shall be determined in accordance with the modified strength values given in Clauses 3.3 and 3.4 and the appropriate material Standards (see AS 1720, AS 3600, AS 3700, AS 4100 and AS/NZS 4600).

3.3 EXISTING UNREINFORCED AND REINFORCED MASONRY

NOTE: Unreinforced masonry includes square dressed natural stone laid in mortar.

3.3.1 Monolithic structural action Monolithic action across a vertical joint between two masonry members or between two components of a member may be assumed to be adequate if the bonding or tying complies with AS 3700.

NOTE: For commentary on this Clause, see Paragraph D3.3.1 of Appendix D.

3.3.2 Characteristic compressive strength of masonry In the absence of in situ test data, the characteristic compressive strength of the masonry (f'_m) shall be taken as not more than 3.0 MPa or determined from one of the following procedures:

- (a) Test a representative sample of masonry units taken from the masonry to obtain their characteristic unconfined compressive strength. For an assumed mortar type, a lower bound estimate of the characteristic compressive strength of the masonry can then be obtained from AS 3700.
- (b) Test representative masonry prisms in accordance with AS 3700 on samples cut from the masonry wall by methods that ensure no damage to those samples. Each prism shall contain a minimum of two courses and shall have an aspect height to thickness ratio of between two and five.
- (c) Carry out a series of in situ compression tests of the masonry assemblage using flat jacks.

NOTE: For commentary on this Clause, see Paragraph D3.3.2 of Appendix D.

3.3.3 Characteristic flexural tensile strength of masonry In the absence of in situ test data, the characteristic flexural tensile strength of the masonry (f'_{mt}) shall be either—

- (a) taken as zero; or
- (b) estimated from in situ bond wrench tests on individual joints in accordance with AS 3700.

NOTE: For commentary on this Clause, see Paragraph D3.3.3 of Appendix D.

3.3.4 Characteristic lateral modulus of rupture of masonry units The characteristic lateral modulus of rupture of masonry units (f'_{ut}) shall be determined in accordance with AS/NZS 4455. In the absence of test data, the value of f'_{ut} may be taken as 0.8 MPa.

3.3.5 Horizontal bending capacity of masonry The horizontal bending capacity of masonry (M_{ch}) shall be determined as follows:

- (a) If $f'_{mt} > 0$, M_{ch} shall be calculated in accordance with AS 3700.

- (b) If $f'_{mt} = 0$,

$$M_{ch} = \phi(0.5f'_{ut}Z_u) \quad \dots 3.3.5$$

where

ϕ = capacity reduction factor
= 0.5

f'_{ut} = characteristic lateral modulus of rupture of masonry units

Z_u = lateral section modulus of the masonry units based on—
(i) the gross cross-section for solid or cored units; and
(ii) the minimum face shell dimensions for hollow units.

3.3.6 Characteristic shear strength of masonry In the absence of in situ test data, the characteristic shear strength of masonry (f'_{ms}) used in design shall be as follows:

- (a) At membrane-type damp-proof courses and flashings—

$$f'_{ms} = 0$$

- (b) In horizontal bed joints other than those described in Item (a)—

- (i) for cement mortars (M2, M3, M4 or similar)—

$$f'_{ms} = 0.20 \text{ MPa}$$

- (ii) for lime mortars (M1 or similar)—

$$f'_{ms} = 0.10 \text{ MPa}$$

- (c) In vertical shear planes other than those described in Item (a)—

- (i) with neither wire ties nor masonry header units crossing the shear plane—

$$f'_{ms} = 0$$

- (ii) with wire ties complying with AS 3700 intersecting the shear plane—

- (A) for cement mortars (M2, M3, M4 or similar)—

$$f'_{ms} = 0.20 \text{ MPa}$$

- (B) for lime mortars (M1 or similar)—

$$f'_{ms} = 0.10 \text{ MPa}$$

- (iii) through masonry in ordinary running bond or with the shear plane intersected by masonry header units complying with AS 3700—

$$f'_{ms} = 1.2r_h \text{ MPa; or}$$

$$= 0.60 \text{ MPa, whichever is less,}$$

where r_h is the proportion of the area of a vertical mortar joint in a member that is intersected by masonry header units.

Higher values for f'_{ms} may be used if these are confirmed by an in situ shear test.

NOTE: For an example of an in situ shear test, see Appendix E.

- (iv) for reinforced masonry—

$$f'_{ms} = 0.25 \text{ MPa.}$$

NOTE: For commentary on this Clause, see Paragraph D3.3.6 of Appendix D.

3.3.7 Shear factor Unless substantiated by appropriate tests, the shear factor (k_v) used in design shall be as follows:

- (a) At mortar bed joints, k_v shall not exceed 0.30.
- (b) At membrane-type damp-proof courses, flashings and similar locations, k_v shall be less than or equal to 0.20.

NOTE: For commentary on this Clause, see Paragraph D3.3.7 of Appendix D.

3.3.8 Elastic properties of masonry In the absence of in situ test data, the following elastic properties of the masonry can be assumed:

- (a) Short-term modulus of elasticity (E_s) $700f'_m$.
- (b) Long-term modulus of elasticity (E_l) $450f'_m$.
- (c) Shear modulus (G) $300f'_m$.
- (d) Poisson's ratio (ν) 0.20.

NOTE: For commentary on this Clause, see Paragraph D3.3.8 of Appendix D.

3.4 OTHER EXISTING MATERIALS The strength values for other existing materials and diaphragms shall be either—

- (a) as given in Table 1; or
- (b) determined from appropriate tests on samples taken from the structure or from another acceptable source.

NOTE: For commentary on this Clause, see Paragraph D3.4 of Appendix D.

TABLE 1
STRENGTH VALUES FOR OTHER EXISTING MATERIALS AND DIAPHRAGMS

Material	Strength value (see Note 1)	Capacity reduction factor, ϕ
Concrete	$f'_c = 10$ MPa (plain) $f'_c = 15$ MPa (reinforced)	(See Note 2)
Grout in masonry cores or cavities	$f'_c = 10$ MPa	(See Note 2)
Timber	Stress Grade F11 (hardwood) Stress Grade F5 (softwood)	(See Note 2)
Reinforcing steel	$f_{sy} = 200$ MPa	(See Note 2)
Structural steel	$f_{sy} = 200$ MPa	(See Note 2)
Bolts in structural steel	$f_{sy} = 200$ MPa	(See Note 2)
Roof and floor diaphragms:		
(a) Roofs with straight butted timber boarding and roofing applied directly to the boarding.	6 kN/m	0.7
(b) Roofs with diagonal boarding and roofing applied directly to the boarding.	15 kN/m	0.7
(c) Floors with straight tongue and groove timber boarding.	6 kN/m	0.7
(d) Plywood or particle board diaphragms.	4.8 kN/m	0.7
Wall and ceiling diaphragms (See Note 3):		
(a) With wood lath and plaster, one side.	3 kN/m	0.7
(b) Plasterboard and gypsum, fixed with clout nails at 150 mm centres around sheet perimeters, one side.	1.5 kN/m	0.7
(c) Plasterboard and gypsum, fixed with clout nails at 75 mm centres around sheet perimeters, one side.	3 kN/m	0.7
(d) Timber boarding or sheeting, fixed with clout nails at 50 mm centres around sheet perimeters, one side.	6 kN/m	0.7

NOTES:

- 1 The strength values in the Table are lower bound estimates to allow for the uncertainty in the material properties due to ageing.
- 2 For value of ϕ , see relevant Standard.
- 3 Walls may be either steel or timber framing.

3.5 NEW MATERIALS The properties of new materials and systems shall be determined from appropriate tests or from the relevant material Standard or other technical information for new construction.

NOTE: For commentary on this Clause, see Paragraph D3.5 of Appendix D.

3.6 COMBINATION OF EXISTING AND NEW MATERIALS

3.6.1 Existing linings removed Where existing linings of timber boarding or sheeting, plaster sheeting and other linings are non-existent or have been removed, and new structural diaphragms are fixed using the existing framing, the strength of the new system shall be assessed as for new materials (see Clause 3.5).

NOTE: For commentary on this Clause, see Paragraph D3.6.1 of Appendix D.

3.6.2 Existing timber linings retained Where existing linings of timber boarding or sheeting, plywood or particle board are left in place and new structural diaphragms are fixed over the existing linings, the strength of the new system shall be assessed as for new materials, as if the existing linings did not exist (see Clause 3.5).

NOTE: For commentary on this Clause, see Paragraph D3.6.2 of Appendix D.

3.6.3 Existing plaster linings retained Where existing plasterboard or gypsum linings are retained and new diaphragms are fixed over the existing linings, the strength of the combined system shall be taken as that of the plaster-based lining alone, with due regard to the increased nail fixings.

NOTE: For commentary on this Clause, see Paragraph D3.6.3 of Appendix D.

3.6.4 Connections Anchor bolts used in connections to masonry or concrete walls shall be of the following types:

- (a) *Bolts embedded in masonry or concrete walls* Bolts embedded in masonry or concrete walls shall have an embedment depth that will provide the required connection. The tensile and shear strength values of the anchors shall be determined from site testing or from industry data on similar wall material, using a reduction factor as given in Table 2.

Consideration shall be given to the location of bolts from edges, corners or tops of walls.

- (b) *Bolts passing through masonry or concrete walls* Bolts passing entirely through masonry or concrete walls shall be secured with a $150 \times 150 \times 8$ mm plate or equivalent on the far side of the wall. The tensile and shear strength values of the anchors shall be determined from site testing using a capacity reduction factor of 0.75, or from first principles as follows:

- (i) For masonry walls, the tensile strength of the anchors shall be determined from first principles, this being the lesser of the load causing shear failure through the bed joints or the tensile strength of the bolt.

The shear strength of the anchors shall be determined from first principles, this being the lesser of the load causing bearing failure of the masonry or the shear strength of the bolt.

- (ii) For concrete walls, the tensile strength of the anchors shall be determined from first principles, this being the lesser of the load causing cone failure mode in the wall or the tensile strength of the bolt.

The shear strength of the anchors shall be determined from first principles, this being the lesser of the load causing bearing failure of the concrete or the shear strength of the bolt.

Consideration shall be given to the location of bolts from edges, corners or tops of walls.

NOTE: For commentary on this Clause, see Paragraph D3.6.4 of Appendix D.

TABLE 2
CAPACITY REDUCTION FACTORS
FOR ANCHORS EMBEDDED IN
MASONRY OR CONCRETE WALLS

Strength determined from	Capacity reduction factor, ϕ
Site testing	0.75
Industry data	0.65

SECTION 4 ANALYSIS AND DESIGN

4.1 ANALYSIS OF EXISTING BUILDINGS Before analysing the building, the load paths shall be established by examining the building structure. The load paths shall form the basis of the analysis.

Where the existing load paths to the foundations do not provide sufficient strength to meet the threshold load values specified in Clause 2.4.2, the building shall be interconnected and re-analysed using the revised load paths.

NOTES:

- 1 Diaphragms may be assumed to be rigid in transferring induced loads to the resisting elements.
- 2 For the distribution of loads and for the determination of relative stiffnesses, all sections may be assumed to be uncracked.

Gravity effects shall be considered to act in resisting effects from the induced loads.

A rational analysis shall be carried out.

The strength of the existing materials shall be in accordance with Clauses 3.3 and 3.4.

NOTE: For commentary on this Clause, see Paragraph F4.1 of Appendix F.

4.2 DESIGN OF STRENGTHENING ELEMENTS Strengthening elements shall be designed to resist the threshold loads appropriate to the type of the existing part inducing the load, as specified in Clause 2.4.

If new in-plane resisting elements are added, the loads shall be apportioned between new and existing parts by taking into account their relative stiffness.

NOTE: Diaphragms may be assumed to be rigid in transferring induced loads to both new and existing elements.

The strength of the new materials shall be determined in accordance with Clause 3.5.

NOTE: For commentary on this Clause, see Paragraph F4.2 of Appendix F.

APPENDIX A

BACKGROUND INFORMATION

(Informative)

There are many existing buildings that may be vulnerable to infrequent events such as earthquakes, because of their original design, or previous alterations, or deterioration of materials. That these buildings have existed for a long time is not an assurance that they are safe from these events. The return period for a damaging earthquake may be measured in hundreds of years, and is significantly greater than the life of most buildings. When the event does occur, as demonstrated at Newcastle in December 1989, the risk to life and the disruption to society can be significant.

This Standard requires that buildings be capable of withstanding the prescribed loads induced by earthquakes. These loads are less than those required for the design of new buildings, as the Committee considered that it is appropriate to accept a higher level of risk for existing buildings than that acceptable for new buildings.

It provides methods for the assessment of the condition of an existing building, the establishment of its material properties and the level of earthquake loads for design. Once these are established, the relevant material and loading Standards can be used to analyse and design the structure. No calculations, however, are required for buildings which are within the deemed to satisfy provisions given in Appendix C.

This Standard is intended for the strengthening of existing buildings for earthquake so as to minimize the risk of loss of life and injury from structural collapse or damage. It is not intended to prevent damage to the building. It is noted that although there was extensive damage to Class 1 and Class 10 buildings which include dwellings in the Newcastle earthquake, there was no total collapse and no lives were lost. Such buildings are generally small and have been excluded from this Standard, which applies to larger buildings. A different approach may be required which could be the subject of a separate housing Standard. Whilst this Standard does not apply to Class 1 and Class 10 buildings, there is no restriction on its application to such buildings.

Acceptability of risk is very difficult to define. The Committee has recognized that the likelihood of the potentially damaging event is not high, and that there is considerable disruption and cost in strengthening existing buildings. The Committee also considered that, in many cases, it is difficult to bring an existing building to the same level of strength as an equivalent new building. It could have been built of inappropriate materials and there could be a general deterioration of material strength as the building has aged. Many existing buildings are vulnerable to earthquake. To leave what may be a significant proportion of building stock in a potentially hazardous condition is to invite large-scale damage and, hence, risk to life and safety should the damaging event occur.

The Committee has made its judgements taking such considerations into account, and has set load criteria at appropriate levels to reduce the risk to life and safety to acceptable levels.

The owners of some buildings, e.g. heritage buildings, may elect to go further and aim to protect the building itself. Minimizing the hazard to life will involve ensuring that the overall structure will not collapse, and that excessive parts of the structure will not break away and fall. The structure may still be left with considerable cracking and secondary damage however, and if this damage extends to irreplaceable parts of the building fabric, a higher degree of protection may be considered desirable. This may be achieved by assessing whether the building, including its parts, can withstand a load level higher than that set out in the Standard.