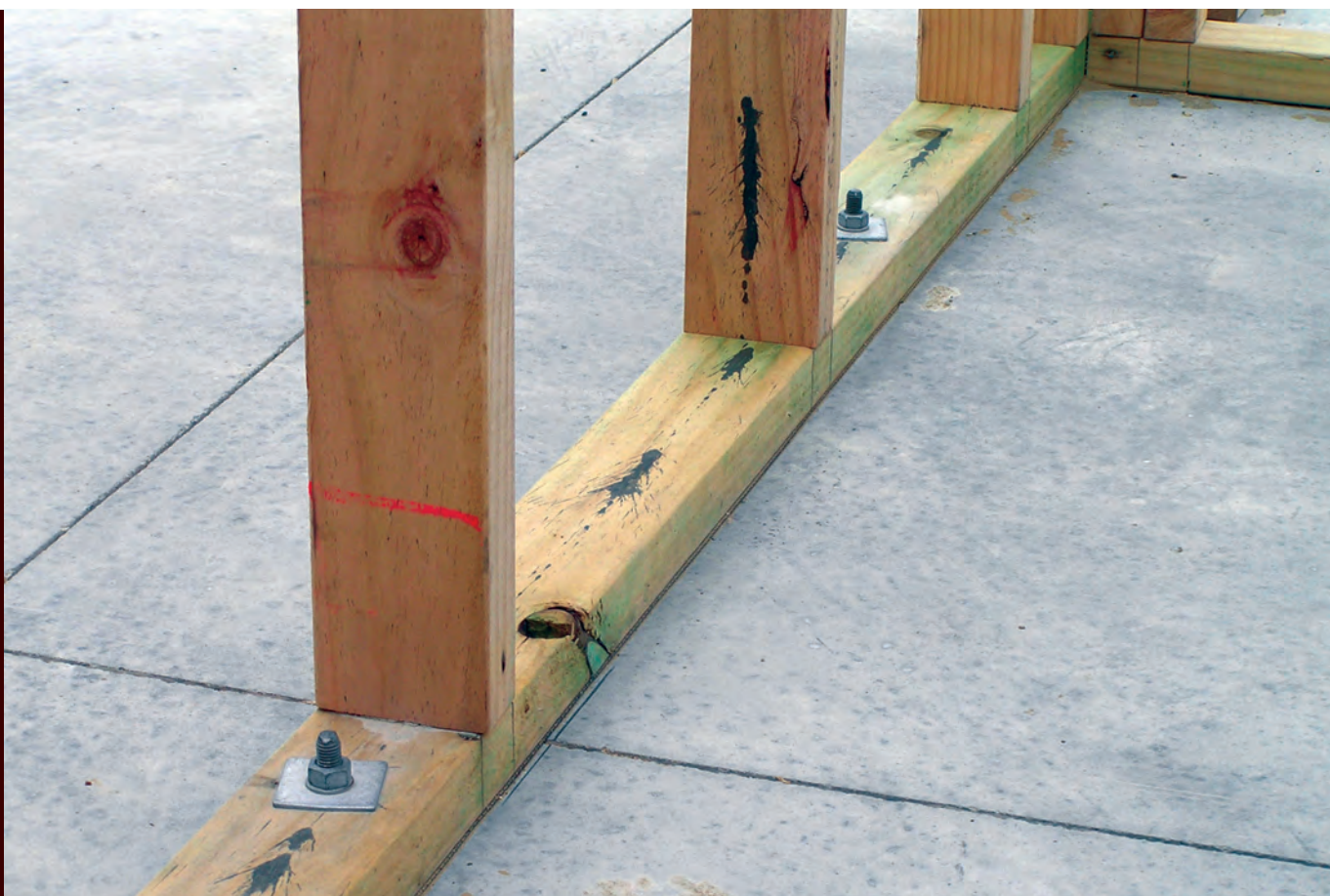


ISSUE 541

BULLETIN



CONCRETE FLOOR SLABS

December 2011

■ This Bulletin describes the general requirements for on-grade concrete floor slabs as described in NZS 3604:2011 *Timber-framed buildings*.

■ Also discussed are important changes to New Zealand Building Code Compliance Documents for clause B1 *Structure*.

■ This Bulletin complements Bulletins 491 *Embedded floor heating* and 498 *Preparation for concrete floor slabs*.

1.0 INTRODUCTION

1.0.1 This Bulletin describes the general requirements for the design and construction of on-grade concrete floor slabs as described in NZS 3604:2011 *Timber-framed buildings*.

1.0.2 Also discussed are important changes (Amendments 10 and 11) to New Zealand Building Code Compliance Documents for clause B1 *Structure*. Amendment 11 modifies NZS 3604:2011, NZS 4229:1999 *Concrete masonry buildings not requiring specific engineering design*, and NZS 4299 *Earth buildings not requiring specific design*.

1.0.3 The choice to build with a slab as opposed to a suspended floor will depend on several factors:

- On-grade slabs are easy to construct, durable, and are generally cheaper than timber floors on flat sites or where limited excavation or cut and fill is possible
- Slabs eliminate the need for subfloor bracing
- Concrete slab floors can offer a practical option for basement construction where concrete or concrete masonry walls footings can easily be tied in to slabs.
- The thermal mass of concrete can absorb solar energy during the day and re-radiate heat into the home at night.

2.0 BUILDING CODE REQUIREMENTS

2.0.1 Concrete floor slabs placed directly on the ground are required to comply with the following clauses of the New Zealand Building Code:

- **B1 STRUCTURE** – the performance of concrete floors should take into account the combination of all loads likely to be encountered during construction and for the duration of a building's existence. The objective of the clause is to protect people from injury and loss of amenity caused by structural failure.
- **B2 DURABILITY** – concrete must be sufficiently durable to withstand the elements, and protect the framing, for the life of the building.
- **E2 EXTERNAL MOISTURE** – the slab must be constructed to meet or exceed minimum distances to finished ground level. E2/AS1 also requires that the 'moisture contained in the building structure at the completion of construction shall not be permitted to damage the building elements'.
- **E3 INTERNAL MOISTURE** – provision needs to be made for floor slabs to dry properly to safeguard people against illness, injury or loss of amenity from the accumulation of internal moisture.
- **H1 ENERGY EFFICIENCY** – floor slabs as part of the building's thermal envelope are taken into account in energy efficiency calculations whether or not they have under-slab insulation.

3.0 BUILDING CODE B1 CHANGES

3.0.1 Changes to Building Code Compliance Document B1/AS1 require that concrete floor slabs around the whole country must be constructed in

accordance with the recently updated NZS3604:2011, except as modified by Amendment 11.

3.1 AMENDMENT 10

3.1.1 Amendment 10 was introduced by the Department of Building and Housing (DBH) in May 2011 to require better performance from floor slabs in the Canterbury earthquake region. Significant failures occurred during the Canterbury earthquakes (Photograph 1), including severe cracking of floor slabs both unreinforced and mesh-reinforced. Some slabs with 665 and 668 mesh reinforcing cracked, due to limited mesh ductility. Liquefaction also gave rise to differential movement between foundations and slabs which may not have occurred if the slab reinforcing had been physically tied into the foundation reinforcing.



Slab cracking after the Canterbury earthquakes

3.2 AMENDMENT 11

3.2.1 Amendment 11 modifies the requirements of NZS 3604:2011 (all references to NZS3604 below are to the 2011 version), and also NZS 4229:1999 *Concrete masonry buildings not requiring specific engineering design*. The Amendment was introduced to extend the requirement for stronger foundations to the whole of New Zealand from 1st August 2011.

3.2.2 Concrete floor slabs must now be reinforced with ductile steel (Grade 500 E) mesh, and the mesh must be tied into the perimeter foundation with R10 starter bars at 600 mm centres. Details in NZS 3604 which show no ties between slab and foundation wall (Figures 7.13(A), 7.14(A), 7.15(A) and 7.16(A)) may no longer be used.

3.2.3 Unreinforced floor slabs and polypropylene fibre-reinforced floor slabs are no longer covered by NZS 3604:2011.

3.2.4 Ground subject to liquefaction is excluded from the definition of 'good ground' in the Canterbury earthquake area. The definition of good ground which applies in Canterbury has not yet been extended in the B1 compliance document to include the whole country. Land subject to liquefaction and/or lateral spread requires considerably more robust foundations. Advice should be sought from a chartered professional (CPEng) engineer.

3.2.5 A guidance document for using NZS 3604 with ground with potential for liquefaction has been issued by DBH. It is being revised as this Bulletin goes to press.

3.2.6 Further changes to national building Standards are likely to follow as a result of experience gained from the recent Canterbury earthquake events.

4.0 FLOOR SLAB-ON-GRADE GENERAL REQUIREMENTS

4.0.1 NZS 3604 Clause 7.5 describes requirements for concrete slab-on-ground floors for timber-framed buildings with occupancy loading of up to 3 kPa, and with a maximum dimension of 24 m (either between free joints or between free joints and slab edges).

4.1 CONCRETE

4.1.1 Clause 2.6 requires concrete to comply with NZS 3104 Specifications for concrete production for manufacture, and with NZS 3109 *Concrete construction*.

4.2 FINISHED FLOOR LEVELS AND FOUNDATION EDGE CONSTRUCTION

4.2.1 The height of the finished floor level above ground must comply with NZS 3604 Clause 7.5.2.1

or E2/AS1 Table 18:

- If the adjoining ground is permanently paved:
 - no less than 100 mm for masonry veneer (Figure 1), and 150 mm for other claddings (Figure 2)
- or, if the adjoining ground is unpaved:
 - no less than 150 mm for masonry veneer (Figure 3), and 225 mm for other claddings (Figure 4)

4.2.2 Building Code clause E2 *External moisture* also requires that the floor level must be set above the final finished ground level, and the building consent authority (BCA) may check relative heights on code compliance inspection. The ground directly adjacent to the building must be sloped no less than 1:25 for at least 1m to carry water away from the building.

4.2.3 Designs must also meet the minimum cladding to finished ground clearances specified by E2/AS1.

4.3 FOOTINGS

4.3.1 Footing widths for in situ concrete and for masonry foundation walls (for single and two storey construction) are given in NZS 3604 (Figures 7.13 (B), 7.14 (B, C), 7.15 (B) and 7.16 (B, C)).

4.4 GRANULAR HARDFILL

4.4.1 The slab should be based on well graded fill to NZS 3604 clause 7.5.3. The maximum permitted thickness of compacted granular fill under slabs is 600 mm (the minimum is 75 mm). Engineering advice must be sought if the thickness of granular fill exceeds 600 mm. Granular fill must be compacted in layers not exceeding 150 mm. Provision should be made for waste pipes, piped services, and under-floor heating cables. Trenches for services are normally excavated after initial placement and compaction of hardfill, with hardfill re-compacted as appropriate after installation.

4.5 DAMPPROOF MEMBRANES

4.5.1 Ground moisture is prevented from entering the concrete slab by an approved impervious membrane. Compacted granular fill also helps prevent

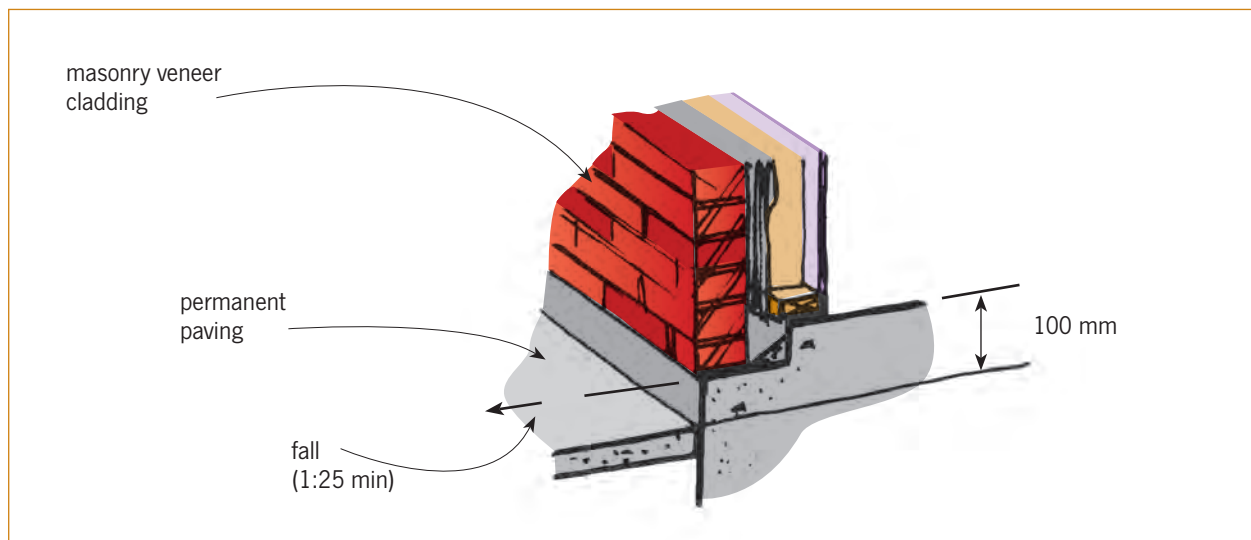


Figure 1. Masonry veneer with permanent paving

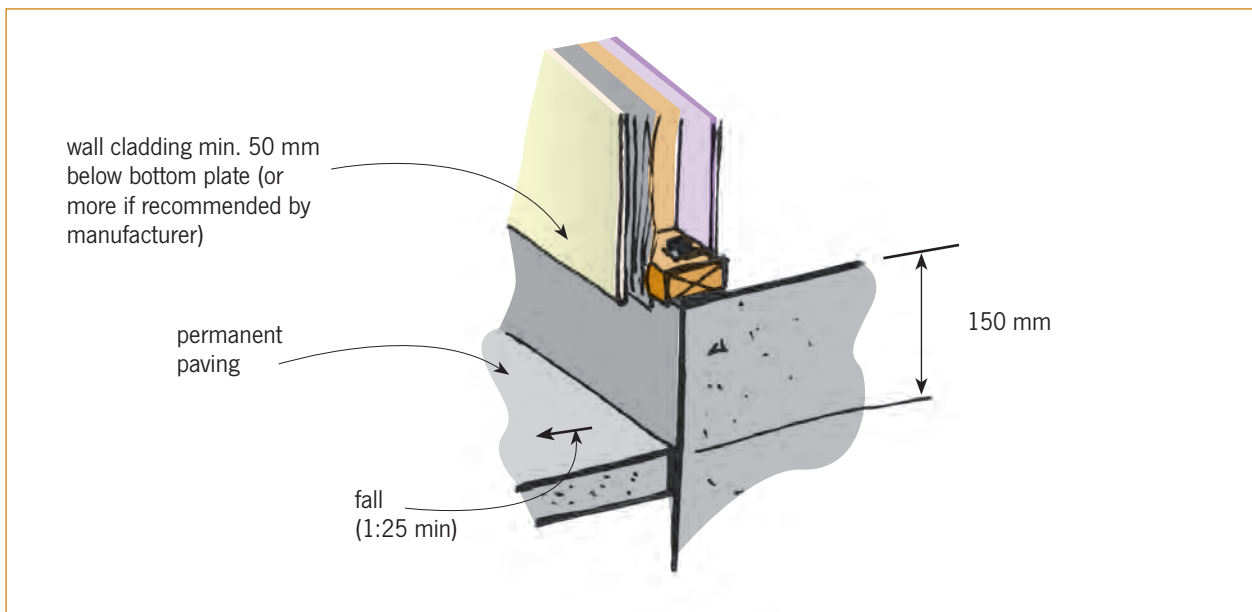


Figure 2. Non-masonry cladding with permanent paving

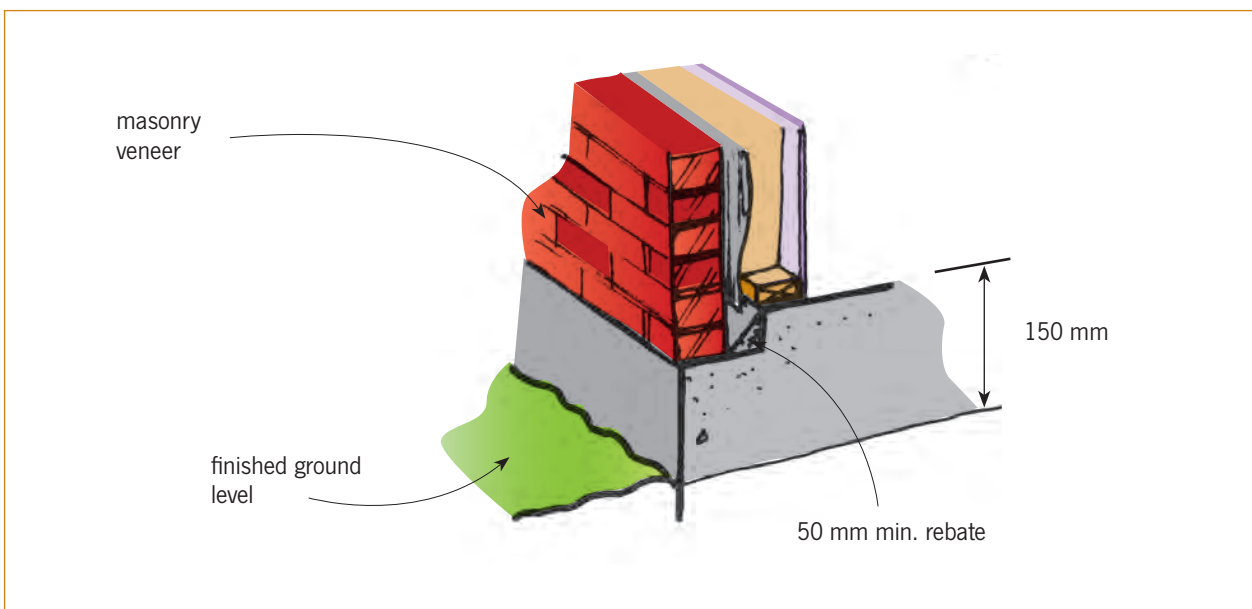


Figure 3. Masonry veneer unpaved ground

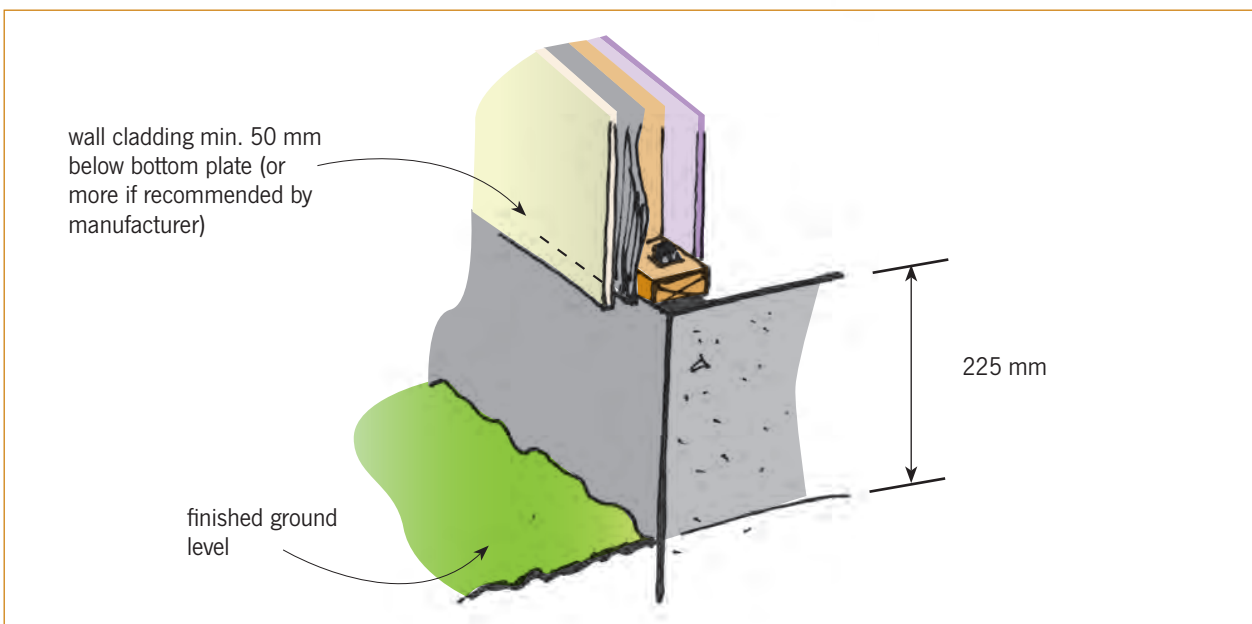


Figure 4. Non-masonry cladding and unpaved ground

groundwater from being drawn under the slab by capillary action. The dampproof membrane or DPM (which is mandatory under habitable areas, and recommended for garages) is usually placed over a 25 mm layer of compacted sand blinding to prevent puncturing of the membrane. Joints are sealed or taped.

4.5.2 A commonly used material for membranes for residential slabs is 250 micron (0.25 mm) polythene. The properties of acceptable DPM materials are specified in NZS 3604 clause 7.5.

4.6 REINFORCING – CHANGES

4.6.1 B1/AS1 (incorporating Amendment 11) lists several important changes and deletions to NZS 3604:2011 clauses dealing with concrete slabs.

- As already noted, use of unreinforced slabs is deleted from NZS 3604:2011.
- All reinforcing steel including mesh is required to be Grade 500 E with a minimum of 2.27 kg/m² conforming to AS/NZS 4671:2001 *Steel reinforcing materials*. The use of 665 mesh (a longstanding standard practice in the past) is no longer permitted.
- Reinforcing mesh fabric lap requirements are given in B1 clause 3.1.9.
- Polypropylene fibre reinforcing for concrete floor slabs is deleted from NZS 3604:2011.

4.6.2 B1/AS1 clause 3.1.3 replaces NZS 3604 clause 7.5.2.3 with new wording. This requires slab reinforcing to be tied to the foundation wall reinforcing (with R10 tie rods bars at 600 mm centres as shown in NZS 3604 Fig 7.15 (b)).

4.6.3 Details within NZS 3604 that show unreinforced slabs or slabs not tied to foundations are deleted by Amendment 11 of B1/AS1, clause 3.1.5.

4.6.4 Two D 12 bars are now required in the bottom of the foundation wall or footing – the options for single bars have been taken out.

4.7 SLAB THICKNESS

4.7.1 Slab thickness, except under loadbearing elements such as walls or posts:

- 100 mm when laid over DPM and properly compacted hardfill
- 50 mm topping slab over DPM on 75 mm reinforced concrete slab
- 75 mm topping slab on rubber emulsion DPM on 50 mm concrete slab.

4.8 SLAB DIMENSIONS

4.8.1 NZS 3604 specifies no maximum sizes for concrete slabs, provided the building floor plan limits cited in clause 1.1.2(l) are not exceeded, and provided the slab is divided into panels with free joints at the maximum spacings cited in clause 7.5.1.

4.8.2 B1/AS1 (Amendment 11) clause 3.1.13 adds a new paragraph (clause 7.5.8.8) to NZS 3604, which describes the new requirements for free joints using dowel bars within concrete slabs on ground.

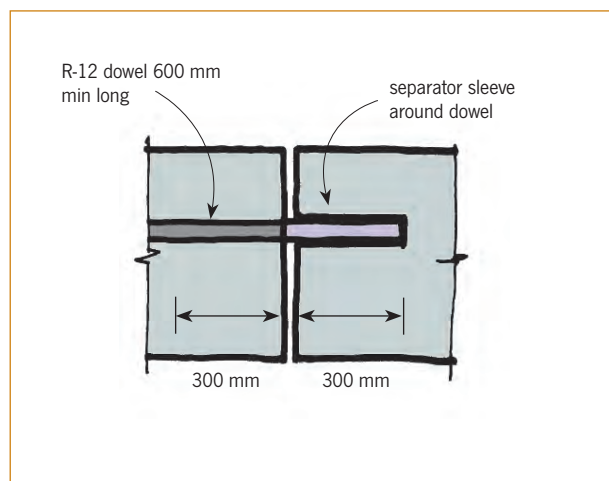


Figure 5. Free joint

4.8.3 Free joints (Figure 5) are defined as a construction joint that has no reinforcing passing through it and the faces of the concrete at the joint must not be in bonded contact. However, Amendment 11 now requires dowel bars as shown in Figure 5.

4.9 SHRINKAGE CONTROL JOINTS

4.9.1 Typically, control joints to prevent random cracking are achieved by saw cuts to a depth of $\frac{1}{4}$ of the slab thickness, or by casting-in a crack inducer. The potential for shrinkage cracking increases with the size of the slab area, and is affected by the shape of the slab. The layout and spacings of shrinkage control joints (for reinforced concrete slabs) are prescribed in NZS 3604 Cl. 7.5.8.6.4 and as indicated in Fig 7.19.

4.9.2 Saw cutting of the slab should be carried out within 24 hours after placement, or as soon as the concrete surface can endure the saw cutting process.

4.9.3 Half of the shrinkage occurs within four months, but concrete will continue shrinking at a reduced rate, depending on drying conditions, for a year or more.

4.9.4 Consideration should be given to floor finishes and wall layouts when setting out slab panel sizes and shrinkage control joints. Joints in tile layouts, for instance, should be at no more than 4.5 m centres. It might be advantageous in many cases for shrinkage control joints to be hidden beneath wall plates. (See NZS 3604 clauses 7.5.8.6.4 for bay sizes and ratios.)

4.10 CURING

4.10.1 Concrete must be properly cured to achieve optimum strength and to minimise shrinkage cracking during initial drying. While a large volume of water is required to make concrete workable, very little (around 25% of the weight of the cement) is required for hydration, the chemical reaction drying process which occurs when water is added to cement.

4.10.2 The risk of shrinkage cracking can be minimised by using low water content in the mix, or using 19 mm aggregate rather than smaller aggregate

sizes in the concrete mix. The use of a super-plasticiser may also be considered. (Adding water to the mix on site for ease of placing and working of concrete is not recommended as it reduces concrete strength.) Failure to correctly apply curing methods can cause up to 50% reduction in compressive strength, reduced durability and abrasion resistance and other serious problems.

4.10.3 The method given for measuring the moisture content of concrete floors, before laying flooring, is to use a flooring hygrometer. Other measuring devices are not referenced in E2/AS1. Under E2/AS1, the maximum recommended hygrometer reading before installing fixed floor coverings is a relative humidity of 75%. (BRANZ recommends 70% for timber due to the hygroscopic nature of the material and its intolerance of slabs that are too wet when the flooring is laid.)

4.10.4 The setting of concrete is a chemical process, not a drying process, and it requires water to occur. The surface of concrete slabs should therefore be kept moist for several days after pouring. This process is called curing. Curing should begin as soon as possible after concrete has been compacted (usually with a needle vibrator) and screeded off. The rate of curing is very much dependent on weather conditions (wind, direct sun, ambient temperature and humidity).

4.10.5 Postpone concrete pours if temperatures below freezing are expected in the next 7 days.

4.10.6 The curing process is usually achieved by ponding, using a fine spray of water, covering the slab with wet hessian or polythene sheet, or using a chemical (evaporation retardant) compound. The compatibility of such chemical retardants should be taken into account when considering floor finishes such as staining, sealing, and so on.

4.10.7 Minimum curing times (which are dependent on exposure classifications) are set out in NZS 3101 Concrete Construction. Typically, concrete slabs should be cured for a minimum of seven days when the mean temperature exceeds 10°C. In certain inland exposure zones (A1 interior or A2 inland), the curing time can be reduced to a minimum of three days.

4.11 CONCRETE STRENGTH

4.11.1 The minimum concrete strength (at 28 days) permitted in NZS 3604 (Clause 4.5.2) is dependent on exposure zones (clause 4.2) as follows:

- Zone B: 17.5 MPa for concrete protected from or exposed to the weather
- Zone C: 20 MPa for concrete exposed to the weather
- Zone D: 25 MPa for concrete exposed to the weather
- geothermal areas require specific engineering design.

4.11.2 Where a direct wearing concrete floor is required, Table 5.3 in NZS 3101 should be used.

4.11.3 10 MPa concrete can be used for unreinforced concrete in mass foundations.

4.12 CONCRETE COVER

4.12.1 Concrete cover to steel reinforcement is specified in clause 4.5:

- 75 mm when placed on or against the ground
- 50 mm when against formwork
- 30 mm from the top of a wall or slab in a closed area
- 50 mm from the top of a wall or slab in an exposed area.

4.13 INTERNAL LOADBEARING WALLS AND SLABS

4.13.1 Internal loadbearing walls must be adequately supported with thickenings of the slab. NZS 3604 Fig 7.20 shows a section detail with a thickening to 200 mm deep. The thickening is not required where only the roof on a single storey building is supported.

4.14 FIXING OF PLATES

4.14.1 Bottom plates to perimeter walls with direct-fixed claddings must overhang the slab edge to prevent the ingress of water by capillary action. (An overhang is not necessary for cavity construction.)

4.14.2 Bottom plates must be fixed to the slab by either:

- cast-in M12 anchor fixings (Figure 6) as specified and as set out in clause 7.5.12.1
- proprietary post-fixed anchors of minimum capacity as specified and as set out in clause 7.5.12.2 spaced at 900 mm centres. A 600 mm spacing is required where header blocks are used to form the edge of the slab.

4.14.3 Bracing wall elements must be fixed with anchors of the load bearing capacity specified by the bracing panel manufacturer.

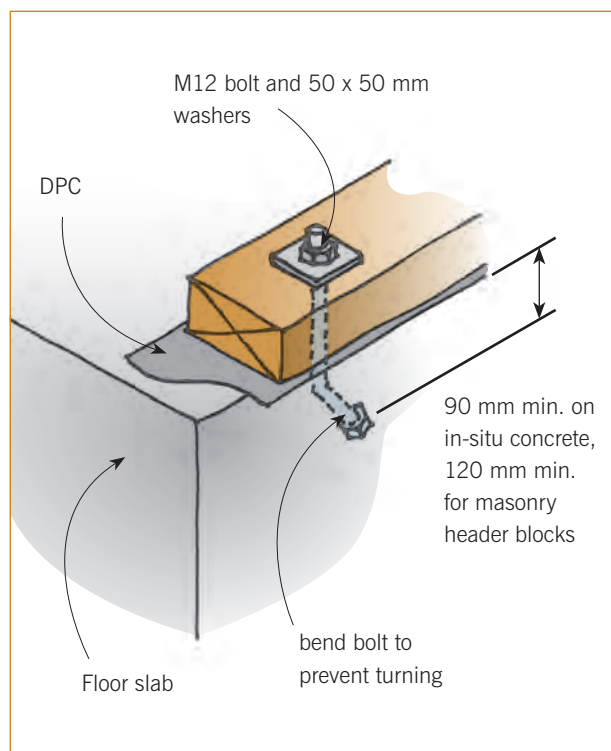


Figure 6. Fixing of bottom plate to slab with cast-in bolts

5.0 FLOOR SLAB INSULATION

5.0.1 Insulation is important for energy efficiency. It is recommended to exceed Building Code clause H1 Energy efficiency minimum requirements where possible.

5.0.2 Consult tables 1, 2(a) and 2(b) in H1/AS1 for minimum thermal resistance requirements for unheated floors (with required R-values of between R1.3 and R1.5). H1/AS1 requires (for the Schedule or Calculation Method) a minimum thermal resistance of R1.9 for heated floors.

5.1 UNDER-SLAB INSULATION

5.1.1 Thermal insulation in the form of XPS (extruded) or EPS (expanded) polystyrene, typically 50mm thick, is laid over the DPM and placed immediately before placing of steel reinforcement.

5.1.2 R values of 1.32-1.39 can be achieved with 50 mm XPS, although XPS is more expensive than EPS. The compressive strength of under-slab insulation should be considered if thicker insulation is used.

5.2 EDGE INSULATION

5.2.1 It is important to continue thermal insulation under the floor slab and around the perimeter to avoid forming thermal bridges. Edge insulation is highly recommended for a heated slab, and especially for slabs where the water table is high. Approximately 80% of heat loss from a floor slab occurs at the perimeter. There is no clear consensus, however, on the best way to achieve slab edge insulation.

5.2.2 A strip of timber (often detailed as 90 x 45 mm H3.2-treated timber on edge) between the slab and the foundation wall provides an adequate thermal barrier, but is difficult to implement, especially now that slab reinforcing must be tied into the perimeter foundation. It would be difficult to thread a large number of reinforcing rods through holes or slots in the timber edge. The rods also act as a thermal bridge, which reduces the effectiveness of the timber as insulation.

5.2.3 Insulation on the external face of the perimeter foundation improves thermal performance, but the insulation must be protected from the weather and physical damage. EPS blocks used here should be protected by a plaster finish or durable rigid sheet.

5.2.4 For structural reasons it is not recommended that insulation be installed under edge beams.

5.2.5 A range of proprietary under-slab insulation and edge insulation systems are available (including various types of EPS formwork). Protection of exposed polystyrene is required in all cases.

6.0 IN-SLAB HEATING

6.0.1 Embedded floor heating – hot water circulated through pipes ('hydronic system') or electric cables – is described in detail in BRANZ Bulletin 491 *Embedded Floor Heating*.

7.0 FURTHER READING

7.0.1 Publications/books:

- BRANZ Bulletin 469 *Damp-proof membranes to concrete slabs*
- BRANZ Bulletin 491 *Embedded floor heating*
- BRANZ Bulletin 498 *Preparation for Concrete floor slabs*
- BRANZ *House Building Guide* (3rd edition)
- CCANZ *Designing Comfortable Homes- Guidelines on the use of glass, mass and insulation for energy efficiency*.
- CCANZ *Residential Concrete Slab on Ground Floors*

7.0.2 Relevant Standards

- NZS 1170 Part 5 *Structural design actions- Earthquake actions New Zealand*
- NZS 3101 *Concrete structures standard*
- NZS 3104:2003 *Specification for concrete production*
- NZS 3109: *Concrete construction*
- NZS 3604:2011 *Timber-framed buildings*
- NZS 4229:1999 *Concrete masonry buildings not requiring specific engineering design*
- NZS 4429:2001 *Concrete masonry buildings*

7.0.3 Useful websites:

- BRANZ: www.branz.co.nz
- New Zealand Ready Mixed Concrete Association: www.nzrmca.org.nz
- Cement and Concrete Association of New Zealand: www.ccanz.org.nz
- Department of Building and Housing: www.dbh.govt.nz

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