RESIDENTIAL CONCRETE

SLAB-ON-GROUND FLOORS

Producing a quality concrete slab on ground is easy if some basic rules are followed. This leaflet is intended to assist builders to produce a quality slab. The cost of rework is very high, so follow the suggestions in this leaflet to save time and money.

CCANZ
concrete answers

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CERTAIN STRENGTH

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CONTENTS

CCANZ concrete answers

Questions are regularly asked about the use of concrete for residential flooring. This leaflet answers some of the more commonly asked questions and gives guidance on good practice. It is not intended to replace the use of clause 7.5 *Concrete slab-on-ground floors for timber buildings* of NZS 3604:2011 *Timber-framed buildings* or any other related Standard. Please refer to the Standards for full details.

FINISHED SLAB LEVELS

NZS 3604:2011 Figure 7.11 gives the minimum finished floor levels above the outside surface finish for concrete slab-on-ground construction for timber-framed buildings. This also provides guidance when lightweight steel framing is used. Where masonry construction is used refer to NZS 4229:1999 *Concrete masonry buildings not requiring specific engineering design* Section 7.

WHAT CONCRETE STRENGTH SHOULD BE USED FOR SLAB-ON-GROUND CONSTRUCTION?

- Clause 4.2 of NZS 3604:2011 defines the various exposure zones (to wind-driven sea salt) for New Zealand.
- NZS 3604:2011 paragraph 4.5.2 requires as a minimum:
  - 17.5 MPa concrete for concrete that is protected from the weather, or exposed to the weather in zone B
  - 20 MPa concrete for concrete that is exposed to the weather in zone C
  - 25 MPa concrete for concrete that is exposed to the weather in zone D
  - specific engineering design (SED) for concrete in geothermal areas

- NZS 3604:2011 paragraph 4.5.1 specifies minimum cover of:
  - 75 mm for concrete placed directly on or against the ground
  - 50 mm when placed against formwork and the strength requirements above are complied with
  - 30 mm for the top of an exposed slab protected from the weather
  - 50 mm for any slab surface exposed to the weather
- An alternative approach, followed in NZS 4229:1999, is to use 17.5 MPa concrete throughout but provide 75 mm of cover instead of the 50 mm specified.
- Where significant areas of concrete are directly exposed it is recommended that 20 MPa or 25 MPa concrete be used.

DOES THE DPM NEED TO BE EXTENDED UNDER THE PERIMETER FOOTINGS?

- The use of a DPM is mandatory under slabs on ground for all habitable spaces and under slabs such as garages or ancillary buildings that may in the future become used as habitable spaces.
- The role of the DPM is to stop the passage of water vapour from the ground and granular base into the slab, where increased moisture could damage bottom plates of walls and floor coverings.
- Compacted granular fill material is required under the DPM to reduce the risk of groundwater being drawn up to the underside of the slab by capillary action and as a drainage layer. (Note: SED is required if the granular-base layer is greater than 600 mm deep.)
- The DPM needs to be carefully placed on a thin 5–25 mm layer of sand to prevent accidental puncturing.
- All DPM penetrations and laps need to be taped or sealed to prevent moisture ingress.
- On a well drained site, the DPM can terminate at the outer edge of the footing, as the risk of moisture migrating in from the untreated outer face of a well compacted slab edge or foundation wall is low (see Figure 1). BRANZ Bulletin 469 *Damp-Proof Membranes to Concrete Slabs* gives more detailed guidance on this.
- On a damp site with a high water table, the DPM must be extended under the footing and up the outside face of the perimeter beam and must be protected from damage, for example, by installing a protective sheet material.

WHAT ARE THE REINFORCEMENT REQUIREMENTS FOR A SLAB-ON-GROUND?

From 1 August 2011, in response to slab performance in the Christchurch earthquakes, amendment 11 to B1/AS1 requires that all NZS 3604:2011 concrete floor slabs constructed on 'good ground' must be reinforced with a minimum of 2.27 kg/m^2 of grade 500E reinforcing mesh fabric that conforms with AS/NZS 4671:2001 *Steel reinforcing materials* and all perimeter foundations are required to be tied to the concrete slab with reinforcing steel (see Figure 2).

This requirement also applies to NZS 4229:1999 floor slabs. The **Canterbury Earthquakes Damage** section of this leaflet outlines design solutions, listed by the Department of Building and Housing, for ground defined as 'poor ground' in NZS 3604:2011, with a particular emphasis on liquefaction.

FIGURE 1

Damp-proof membrane terminated at the outer face of the foot of the foundation wall.

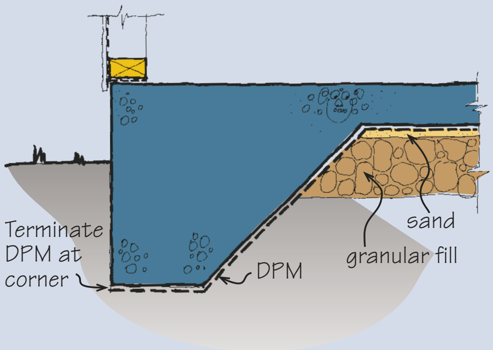
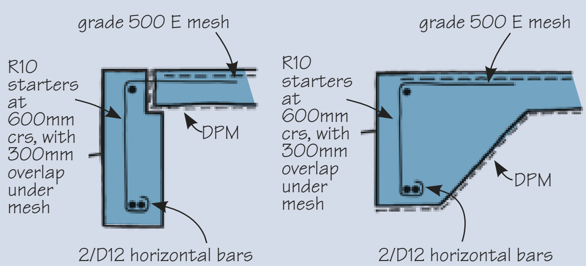


FIGURE 2

Slab reinforcing tied to foundation wall.



Note that the grade 500N 665 and 668 mesh that has been used in the past does not comply with the requirements of amendment 11 to B1/AS1.

Reinforcing bars/mesh must be supported on chairs to ensure reinforcement position and 30 mm top cover is maintained. The common practice of lifting the mesh as the concrete is placed can result in much of the steel being in the wrong position or simply ending up at the bottom of the slab. Mesh with a 300 mm grid is preferable to mesh with a smaller grid as it is less likely to be pushed out of position.

CONTROL JOINTS – WHICH IS THE BEST OPTION?

Crack control is primarily catered for by the use of control joints. The choice of mesh type and location of control joints should be detailed on the drawings and contract documents. Decisions relating to these matters should not be made on site – they should be discussed with the designer beforehand.

NZS 3604:2011 paragraph 7.5.8.6 sets out the requirements for shrinkage-control joints.

CAN I USE AN UNREINFORCED CONCRETE SLAB ANYWHERE IN NZ?

- Unreinforced concrete slab-on-ground floors are NOT permitted by B1/AS1 amendment 11, which came into force on 1 August 2011.
- The amendment modifies the requirements of NZS 3604:2011 to exclude unreinforced slabs and requires all perimeter foundations to be tied to the concrete slab with reinforcing steel.

ADDITIONAL REINFORCING TO INTERNAL SLAB CORNERS

Internal corners of slabs that do not have shrinkage-control joints radiating from them need additional reinforcing bars across the corner – two 1.2 m lengths of D10 (see Figure 3). The additional steel must have sufficient cover from the slab edge and must not cross shrinkage-control joints. Where they would cross shrinkage-control joints, they can be left out.

FIBRE-REINFORCED SLAB WITH SEPARATE REINFORCED PERIMETER FOUNDATION

- The practice of adding polypropylene fibres to increase the dimension between shrinkage-control joints is **no longer** acceptable. While polypropylene fibre can still be used to reduce the risk of early age surface cracking, it can only be used in slabs that already include the minimum requirement of 2.27 kg/m^2 of Grade 500E reinforcing mesh.
- Steel fibre-reinforced concrete slabs may be used, but they must be the subject of SED.

SLAB-ON-GROUND DIMENSIONS AND BAY SIZES

- The maximum plan dimension between construction or shrinkage-control joints for steel mesh reinforced slabs is 6 m, with the maximum aspect ratio being 2:1. (CCANZ recommends that bay sizes are no larger in any dimension than 5 m and should not exceed 6 m under any circumstance.)
- Reinforcing mesh fabric shall be grade 500E that conforms with AS/NZS 4671:2001 and needs to be placed in the top portion of the slab with a minimum cover to the top surface of 30 mm. Reinforcing mesh of a minimum 2.27 kg/m^2 is required as a minimum for all slabs.

- The reinforcing mesh needs to be well supported on reinforcement chairs that will not puncture the DPM when the concrete is being placed and compacted. If the mesh is not well supported in the top section of the slab, it will be ineffective in controlling shrinkage cracking.
- Where tiles or other special finishes are being applied, consider reducing bay sizes to a 1:1 ratio while accommodating the selected tile size and joint layout. SED is recommended for these applications to minimise the risk of uncontrolled cracking.
- It is important to accommodate the additional stresses induced by perimeter restraint when reinforced slabs are tied into the perimeter foundation, especially where visible floor areas can be up to 6 m or more in each direction. Edge restraint will almost inevitably mean cracks will develop unless the bay is divided in two in both directions. Consider using proprietary crack inducers to isolate garages and in areas to be tiled. (Co-ordinate flexible tile joints with the movement control joint.)

MASONRY WALLS

- For walls that are non-retaining, vertical starter bars should be placed in the centre of the wall and at the required centres along the length of the wall (see NZS 4229:1999 for non-specific design), but the positions of doorways and windows need to be set out – vertical starter bars are needed on each side of every window and door opening, even if the window is not at slab level.
- The starting point for the first bar at a corner is typically 100 mm.
- The finishing point for the last bar will always be 100 mm from the corner.

FIGURE 3

Additional reinforcing at bays or insets where there are no shrinkage control joints.

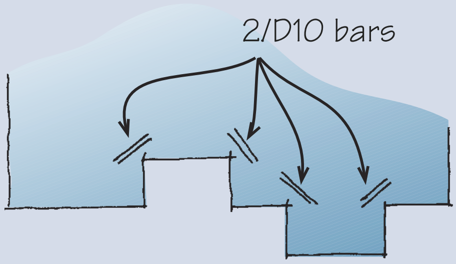
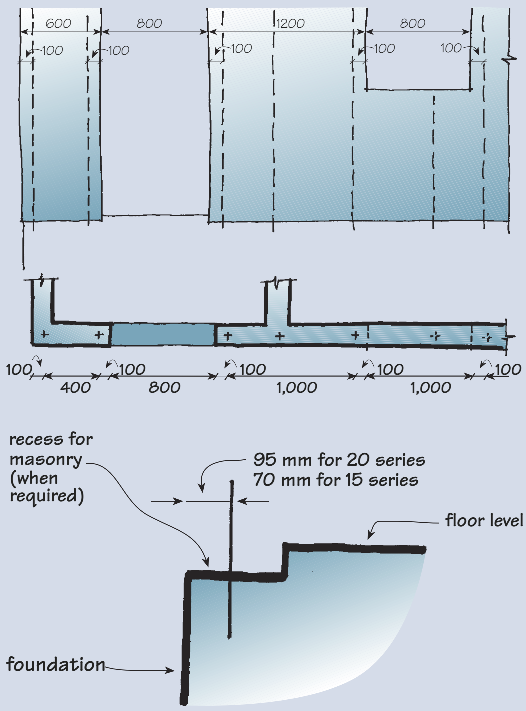


FIGURE 4

Schematic of layout of vertical steel adjacent to openings for concrete masonry.



- If the wall is a retaining wall or a specifically designed wall, you must check the placing of the bars both for position within the thickness of the wall and for centres along the wall as they may be set out at 200, 400 or 600 mm. The starting and finishing point remains at 100 mm from the edge of the corner.

If in doubt, get a registered structural mason or licensed building practitioner (blocklaying) to set out the starter bars (see Figure 4).

HOW CAN THE RISK OF CRACKING BE MINIMISED?

GRANULAR FILL

- The granular fill should be well compacted (in 150 mm maximum layers) and level. An uneven surface will restrict slab shrinkage movement.

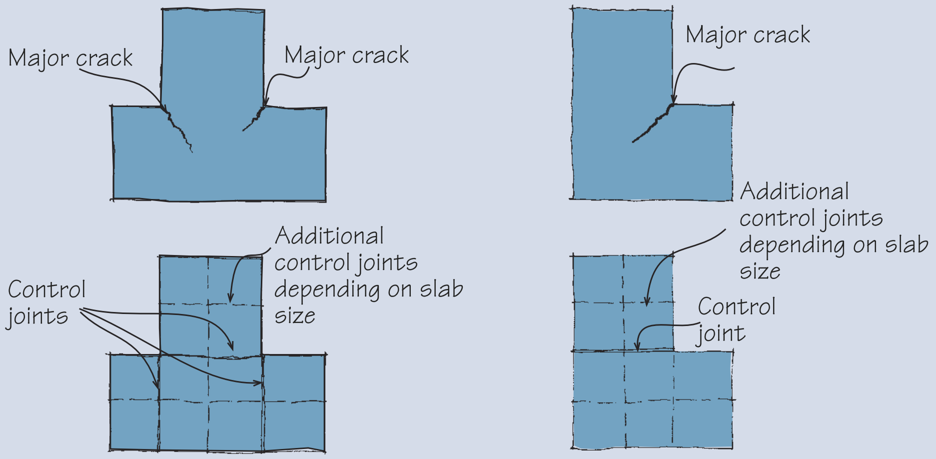
JOINT LAYOUT

- Shrinkage-control joints need to be positioned to coincide with major changes in plan.
- Square bays are less prone to shrinkage cracking.
- Sensible layout of the joints will greatly reduce the chance of random cracking.
- The layout of joints should be shown on the consented drawings and strictly followed by the builder.
- Limit the overall slab dimension to no greater than 18 m when using 2.27 kg/m^2 500E mesh. A maximum slab dimension of 24 m can be achieved using a recommended 3.02 kg/m^2 500E Mesh. Where the slab length exceeds 24 m, a free joint must be created using the Department of Building and Housing's recommendations or specific engineering design. Tied control joints are to be formed between the free joints at a spacing not exceeding 6 m (CCANZ recommends 5 m).




FIGURE 5

Location of crack control joints. Note that NZS 3604:2011 allows the use of angled control joints from an internal corner.



- When planning the joint layout, first look for internal corners. These increase the stress in the slab and are the most common position that cracks propagate from. It is almost impossible to provide a guarantee that a crack will not form at this location, so you ignore them at your peril (see Figure 5).
- Think carefully about penetrations and boxouts. If square shaped, these can create sharp re-entrant corners that trigger cracks. Circular blockouts reduce the risks of cracks developing.
- Wrap compressible materials, such as polystyrene or semi-rigid foam, around cast-in formers to minimise the risk of restrained shrinkage cracking developing.
- Crack control needs to be considered, particularly if areas of the slab are to be tiled or covered with thin floor coverings, such as vinyl, and in exposed garage floors. In instances such as these, careful layout of saw cuts is essential – saw cuts need to be positioned to ensure that any movement occurs beyond the areas to be covered with vinyl or tiles. Consider locating these saw cuts under internal walls where they will be hidden from view.

THE CONCRETE

- Order a 100 mm slump concrete mix from the ready mixed concrete supplier.
- Use a 19 mm maximum size aggregate mix rather than a 12 mm pump mix.
- Adding water on site to increase slump for the ease of the placer and pump operator is not recommended as it will increase the chances of shrinkage and reduce strength.

PLASTIC CRACKING

- Plastic cracks normally appear on the day the concrete is being placed.
- To avoid these cracks, the concrete must be protected from evaporation of the bleed water from the moment it is screeded until it is hard enough to finish and cure. This is when it is most at risk. This is best achieved by using either a water mist or alcohol-based membranes (antivaps) sprayed on the screeded concrete at the rate specified by the manufacturer. These membranes may require reapplication on windy days. If you do not maintain a damp look to the surface, the concrete will dry out. This damp look can be achieved by using a waterblaster aimed above the slab.
- If the concrete does not appear to be bleeding, plastic cracking can occur.

If it's a good day to get washing dry, then beware of plastic cracking!

EARLY-AGE THERMAL MOVEMENTS

- Temperature changes in the freshly placed concrete can cause slabs to crack overnight.
- To significantly reduce the risk of an early-age thermal crack, all joints should be in position before the first night. This entails the use of crack inducers (see Figure 6), tooled joints or early-age saws.
- Cracks can be seen within the first 48 hours. (These cracks look exactly like a drying shrinkage crack.)

- Saw-cutting has been the traditional technique for forming control joints. Saw-cutting of the slab to initiate shrinkage-induced cracking should be carried out as soon as the concrete can withstand the process and generally within 24 hours. Where the slab is exposed to high temperature changes or drying winds cutting with traditional saw cutting equipment should be carried out within 12–18 hours.
- Consider the use of early-entry saws (within the first few hours of placing the concrete). However, this option requires special machines that are not always available.
- Failure to carry out saw-cutting of the joints within this timeframe significantly increases the probability of uncontrolled cracking in the slab.

DRYING SHRINKAGE

- Drying shrinkage cracking typically becomes noticeable after 2 weeks at the earliest, and cracks can continue to widen for months.
- Shrinkage cracking is controlled by the use of reinforcement, the correct positioning of control joints, compaction and using the appropriate concrete mix.

THE CONCRETE MUST BE VIBRATED

- Good vibration to compact the fresh concrete is a key aspect of concrete quality. Poorly compacted concrete with air voids, particularly when exposed to the weather, will be significantly weaker and less durable. This could result in expensive call-backs and remedial work.
- Pump mixes can appear to be more readily moved by the screeding process, but even they must be vibrated.
- Pay special attention to compacting concrete in locally thickened regions, such as perimeter beams and thickenings under loadbearing walls (see Figure 7).

WHAT ARE THE CONCRETE PLACEMENT OPTIONS?

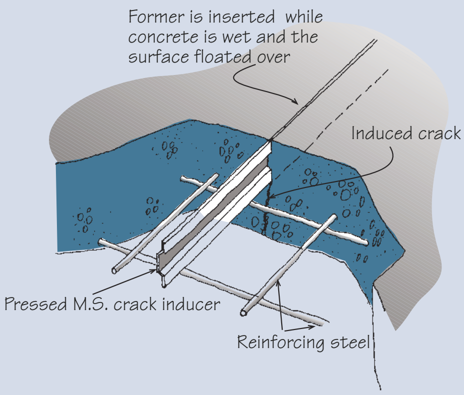
- It is relatively common for concrete to be pumped into residential slabs. Although this is quick and easy, the shrinkage potential for pump mixes is higher than a conventional mix, and extra care on the location of control joints is needed.

WHAT IS THE EFFECT OF ADDING WATER ON SITE?

- Increasing the water content of a concrete mix will reduce the strength of the concrete. If a 120 mm slump is required for placing, order it so that a mix designed for the specified slump is delivered.
- Adding water during delivery and placement will also increase the shrinkage movement in the concrete as it dries out when the curing process is completed.
- If water is added to the mix, the conditions stipulated in NZS 3109:1997 A1 *Concrete construction* paragraph 9.4.2.1 must be strictly adhered to. That is to say, for normal concrete the

FIGURE 6

Crack inducer.



slump on site can be adjusted to its nominal value by the addition of water up to 10 litres per m³. The final slump is measured and total amount of water added are both written on the delivery docket.

HOW SHOULD THE SLAB BE FINISHED?

- Building Code Acceptable Solution D1/AS1 describes acceptable finishes for different applications. Wet areas should not be steel-trowel finished (Class U3, NZS 3114:1987 *Specification for concrete surface finishes*) as this process produces slabs with a poor slip resistance. This may also be a consideration in areas subjected to intermittent wetting, such as exposed concrete kitchen and bathroom floors or garage floors.
- Finishing operations must not begin until the slab has stopped bleeding and has taken on a dull grey appearance, with no visible surface moisture. It will be stiff enough to walk on and only leave a foot imprint of 2–3 mm (see Figure 8).
- Finishing operations must be timed to ensure that the surface can be worked without the addition of water or cement to the surface. Either of these will lead to a dusting surface or one that will delaminate as the slab dries.
- In winter, be prepared for significant delays between placing and finishing.

The common practice of squeegeeing the bleed water from a slab presents two problems:

1. If it is windy, bleed water protects the slab from plastic cracking.
2. If the removal process mixes any water into the remaining paste, this paste will be weakened.

Adding cement to the surface to remove water is not recommended as it can lead to delamination. Correct finishing procedures will produce a very hard long-lasting surface. For more details on correct finishing procedures, contact CCANZ.

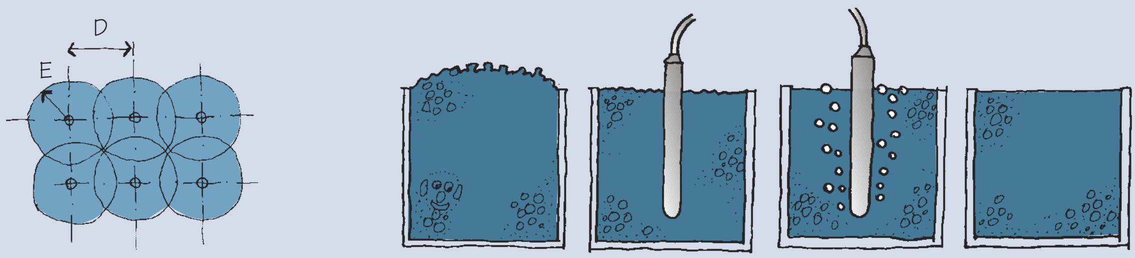
HOW SHOULD THE CONCRETE BE CURED?

It is very important that concrete is not allowed to dry out in its early life. Apply the curing as soon as the concrete can withstand the process. The most effective method for curing concrete is by water spraying or ponding (see Figure 9). The length of the curing period is stipulated in NZS 3109:1997 paragraph 7.8.4 and in NZS 3101:2006 Section 3. See KEY POINTS overleaf.

Using plastic sheeting is a very good method, as long as it is held in place and does not permit any wind to get between the slab and the plastic sheet. Where exposed special decorative finishes have been created a curing membrane method is recommended rather than plastic sheeting.

Curing membranes can also be effective. They must comply with AS 3799:1998 *Liquid membrane forming curing compounds for concrete* and ASTM C309 *Standard specification for liquid membrane forming compounds for curing concrete*. Poorly applied membranes and membranes that do not meet the standards are usually ineffective.

FIGURE 7
Centres for the immersion of a poker vibrator and the process of compaction of concrete.



E = The effective range of the immersion vibrator. 180mm to 360 mm
D = The distance between immersion is approx 150 mm

Stage 1. The form is surcharged with concrete.

Liquification of the concrete. It slumps and fills the form (3-5 seconds.)

Stage 2. Trapped air is expelled.

7-15 seconds.

Curing membranes are not suitable if tiles or vinyl are to be adhered to the floor.

KEY POINTS

- Poor curing of floor slabs can reduce concrete strength by up to 50%, resulting in lower strength and a greater risk of random shrinkage-induced cracking, despite control joints being saw-cut.
- Effective curing will improve the durability and the abrasion resistance of the concrete.
- The curing period should be at least 3 days, but 7 days is better. A longer period may be required, or shorter period feasible, as prescribed in NZS 3101:2006 or as intended by the designer.

ON-SITE SPECIALIST SUBCONTRACTOR – BEST PRACTICE

There are 11 key steps that are important if a good quality slab is to be produced:

1. Granular fill is correctly formed and compacted.
2. The top surface of the granular fill must not puncture the DPM, which must be carefully installed and taped.
3. Steel reinforcing is placed, tied and spaced to within 30 mm of the top surface of slab, with trimmer bars placed at all re-entrant corners. Crack inducers (if used) are positioned and fixed in conjunction with any starter reinforcement for masonry walls.
4. Concrete of correct slump, air content and specified strength is delivered to site in accordance with NZS 3604:2011 paragraph 4.5.2.
5. No water is added without the conditions stipulated in NZS 3109:1997 A1 paragraph 9.4.2.1 being strictly adhered to.
6. Concrete is placed in accordance with NZS 3109:1997 and compacted with the use of immersion vibrators.
7. Concrete is finished only after all bleed water has evaporated from the surface.
8. Antivap sprays can be used (and applied more than once if necessary) to control the evaporation rate to prevent plastic shrinkage cracking.
9. The curing process is started immediately finishing operations are completed.
10. Joints are cut immediately (using early-entry saws) or within 12–18 hours if using traditional saw-cutting equipment.
11. Wet curing or covering the concrete with black plastic sheeting is continued for a minimum of 7 days (unless otherwise stipulated) if a curing membrane is not used.

SPECIAL SYSTEMS AND FINISHES

- Proprietary waffle slab systems are also available, providing an alternative to the concrete slab construction discussed in this leaflet.
- Decorative finishes can be incorporated into the concrete such as texture and colour. Sometimes this is a process involving the material at the ready mixed concrete plant, and other times it is an applied technique carried out during the wet stages of the concrete operation. It is important to ensure the appropriate skills of the concrete placer meet the requirements of the special finish supplier.

FIGURE 8
Power floating.

CANTERBURY EARTHQUAKES DAMAGE

Following the September 2010 Darfield earthquake, which resulted in significant building damage, the Department of Building and Housing published *Guidance on house repairs and reconstruction following the Canterbury earthquake*, which outlines a number of repair options where there had been land damage. This publication was 'revised' in December 2011.

The DBH document summarises the effects of liquefaction, lateral spreading and bearing capacity failure resulting from the earthquake. The document attributes most of the building damage that occurred to the effects of liquefaction of the underlying soils, which gives rise to:

- differential settlement (vertical) effects giving rise to sagging or dishing (the centre of the slab becomes lower than the outside), hogging (the centre of the slab is higher than the outside), an abrupt change (the slab has cracked) or racking/twisting where the settlement around the building has been uneven
- uniform settlement – where the building sinks into the ground
- tilt settlement – where the whole foundation tilts as one
- lateral spreading or stretching, which tears the building apart – the latter being the most damaging to buildings.

Concrete foundation and slab-on-ground damage reported from the earthquake predominantly occurred in areas that suffered from liquefaction, and typically consisted of:

- cracks in slabs and foundation walls
- out-of-level floors
- floors on a lean
- humps or hollows in floors
- reduction in slab to ground clearances where the building had settled.

If the Territorial Authority deems that the ground is 'poor', the designer will need to use specific engineering design for the floor slab and foundations. In effect, the recommendations in *Revised Guidance on House Repairs and Reconstruction Following the Canterbury Earthquake* outline design solutions for housing built on ground designated as 'poor ground' in NZS 3604:2011.

FIGURE 9
Curing concrete using a sprinkler.




WHERE YOU CAN GET MORE INFORMATION

- BRANZ Bulletin 469: Damp-Proof Membranes to Concrete Slabs (2006) – **www.branz.co.nz**
- BRANZ Good Practice Guide: Concrete Floors and Basements (2012) – **www.branz.co.nz**
- Cement and Concrete Association of New Zealand (CCANZ) – **www.ccanz.org.nz**
- Revised Guidance on House Repairs and Reconstruction Following the Canterbury Earthquake (December 2011) – **www.dbh.govt.nz**
- New Zealand Ready Mixed Concrete Association – **www.nzrmca.org.nz**
- New Zealand Registered Structural Masons and Registered Master Bricklayers – **www.mtrb.org.nz**

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