

RESIDENTIAL Floor Slabs

Introduction

Producing a good concrete floor slab is very easy if some simple rules are followed. Concrete used in residential slabs is often the most abused material we come across. This information is intended to assist builders produce a high-quality product at little additional cost to the prevalent practices which at present give disappointing results. The cost of rework is very high. Follow these suggestions and save money and time.

Questions are regularly asked about the use of concrete for residential flooring and this information answers some of the more commonly asked questions and gives guidance on good practice. It is not intended to replace the use of NZS 3604, or any other related Standard.

What concrete strength should I use for the slab?

- NZS 3604:1999 refers to slabs on grade in Section 7 of the Standard.
- Section 4 of NZS 3604:1999 explains the various zones that comprise the exposure maps for New Zealand.
- Most of the country's population is based in Exposure Zone 1, which requires reinforced concrete with 50mm cover to the steel to have a 20 MPa strength "when exposed to weather".
- The alternative approach allowed by NZS 3101:1995 is to use 17.5 MPa concrete with 65mm cover to the steel.
- NZS 3604 requires a concrete strength of 17.5 MPa for all concrete used in residential housing work in Zone 2 and 3.
- All concrete within 500 metres of high tide, and in certain coastal zones on the west coast of the South Island and a band on the west coast north of Auckland require 25 MPa concrete when exposed to weather.

As a general rule, we recommend using 20 MPa or 25 MPa concrete for improved performance at little additional cost, especially if the concrete is to be exposed in use, in areas such as garage floors and areas to be tiled.

Do I need to extend the damp-proof membrane (DPM) under the perimeter footings?

- The use of DPM is mandatory under all living areas. We also recommend it be used for the garage area.
- The role of the DPM is to stop the passage of water vapour from the sub-base into the slab, where increased moisture will damage base plates of walls, floor coverings, etc.
- Granular fill material is required under the DPM to prevent ground water being drawn up to the underside of the slab by capillary action.
- Polythene DPM needs to be carefully placed on a layer of sand or on a layer of building paper to prevent accidental puncturing of the membrane.
- All penetrations and laps need to be taped or sealed to prevent unintended moisture ingress.

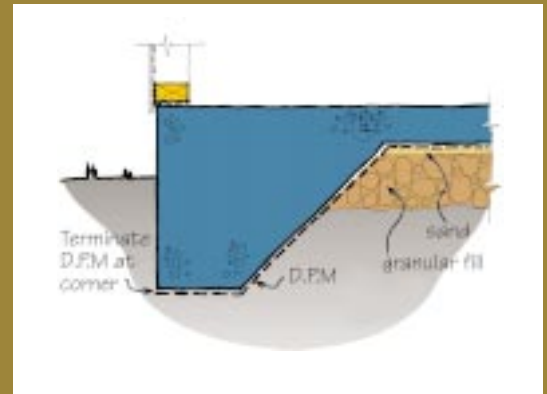


Figure 1: Damp-proof membrane stopped at foot of foundation wall

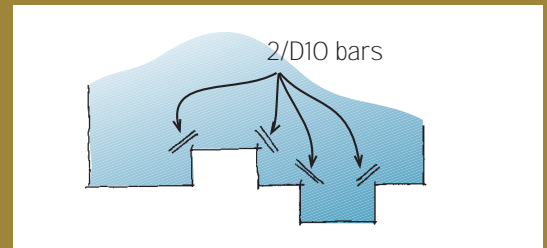


Figure 2: Additional reinforcing at bays or insets

- On well-drained sites the DPM can terminate at the outer edge of the footing (the risk of moisture migrating in from the untreated outer face of the footing is low). See Figure 1. Bulletin 333 from BRANZ gives more detailed guidance on this.
- In damp sites with high water tables the DPM must be extended under the footing and up the outside face of the perimeter beam.

What are the reinforcement requirements for slabs on grade?

- NZS 3604 covers reinforcement detailing in Section 7.

- It is important to place the correct number of bars as detailed in the plan:
 - ensure that they are placed with the correct amount of cover
 - ensure the steel is well tied to prevent accidental displacement during the concrete placing operation.
- NZS 3604 permits slabs to be either unreinforced, fibre reinforced or steel reinforced, usually with mesh. Careful selection of the type of reinforcement is necessary otherwise excessive cracking of the slab may occur. Even slabs described as “unreinforced” require steel reinforcing to be installed at internal corners (see Figure 7:17 in NZS 3604:1999 for details) and will require control joints.
- Two-storey houses must have a reinforced ground slab.

The common practice of not chairing the mesh but simply lifting the mesh as the concrete is placed means much of the steel is in the wrong position or simply ends up back on the bottom. Mesh with a 300mm grid is preferable to standing on mesh with a smaller grid.

Reinforced or unreinforced – which is the best option for me?

Reinforcing in most residential slab-on-ground is there to control crack widths and to allow for a slightly larger spacing of the joints. Reinforcing mesh allows bay sizes to extend to 6m. Polypropylene fibre extends bay sizes to 4m and unreinforced slabs cannot exceed 3m. Two-storey structures must have a reinforced slab on grade.

Crack control is primarily catered for by the use of control joints. The choice of mesh type and control-joint location should be detailed on the drawings. Any decisions that have to be made on site on these items should be discussed with the designer first.

Unreinforced slabs with separate reinforced perimeter foundation

- If the presence of construction joints on a 3m-grid is acceptable then unreinforced slabs will be satisfactory. This is certainly the case when the slab is to be completely covered with carpet.
- The maximum plan dimension between construction or shrinkage joints for unreinforced slabs must not exceed 3m, with maximum bay dimensions of length:width (aspect ratio) not exceeding 1.3:1.
- Internal corners need additional reinforcing bars (2 No. D10's, each 1.2m long) see Figure 2. The additional steel must not cross shrinkage-control joints. Where they would cross shrinkage-control joints, leave them out.

Fibre-reinforced slabs with separate reinforced perimeter foundation

- Polypropylene fibre, (added at the rate of not less than

0.7 kg /m³) permits the maximum plan dimension between construction or shrinkage joints for unreinforced slabs to be increased to 4m, with maximum bay dimensions of length:width: width (aspect ratio) not exceeding 1.5:1.

- Additional steel is needed for internal corners as covered in the unreinforced slab section. Where they would cross shrinkage-control joints, leave them out.

Steel reinforced slabs on grade with thickened edges

- The use of steel reinforcing mesh permits the maximum plan dimension between construction or shrinkage joints to be increased to 6m, with maximum aspect ratio being 2:1. (CCANZ recommends that bay sizes are no larger in any dimension than 5m, and should not exceed 6m under any circumstance). Internal corners need additional reinforcing bars (2 No. D10's, each 1.2m long.) The additional steel must not cross shrinkage-control joints. Where they would cross shrinkage-control joints, leave them out.
- Reinforcing mesh needs to be placed in the top portion of the slab with a minimum cover to the top surface of 30mm. The mesh requirement is 2.27kg/m².
- It 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.
- Where tiles or other special finishes are being applied, consider reducing bay sizes to a 1:1 ratio. Specific engineering design is recommended for these applications to minimise the risk of uncontrolled cracking.
- It is important to accommodate the additional stresses brought about by perimeter restraint when reinforced slabs are tied into the perimeter foundation, especially where visible floor areas can be up to 6m or more in each direction. Edge restraint will almost certainly guarantee cracks developing unless the bay is divided in two in both directions. Consider using proprietary crack inducers to isolate garages and in areas to be tiled.

Masonry walls

- For walls that are non-retaining, starter bars should be placed in the centre of the wall and at 800 mm centres along the length of the wall, **but** you need to set out the position of doorways and windows.
- The starting point for the first bar at a corner is 100 mm.
- Starter bars are needed on each side of every window opening, even if the window is not at slab level.
- The finishing point for the last bar will always be 100 mm from the corner.
- If the wall is a retaining wall, you must check the position of the bars both for position within the

thickness of the wall and for centres along the wall because they may be set out at 200, 400 or 600mm. The starting and finishing point remains at 100mm from the edge of the corner.

If in doubt, get a registered structural mason to set out the starter bars (see Figure 3).

Should I tie the slab into the perimeter foundation? Won't this restraint increase the probability of cracking?

- Tying steel, connecting the perimeter footing, and localised thickenings to the slab all increase the likelihood of early-age thermal cracking and restrained shrinkage. For single-storey construction, no tying steel is needed from the slab to the foundation perimeter, provided the detail shown in Figure 4 is used.

How can I minimise the risk of cracking?

Granular fill

- The granular fill should be well compacted 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 construction drawings and strictly followed by the builder.
- More flexibility for bay layout is possible when the slab is steel reinforced because of the maximum dimension between joints of 6m.
- Remember that you cannot have a slab dimension greater than 18m without having a free control joint which has no steel going through it (i.e. you can only have three bays of 6m that are tied).
- 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 possible to provide a guarantee that a crack will form at this location, so you ignore them at your peril (see Figure 5).
- Think carefully about penetrations and box-outs. 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 if areas of the slab are to be tiled or covered with thin floor coverings, such as vinyl, and in uncovered garage floors. In instances such as these the 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.

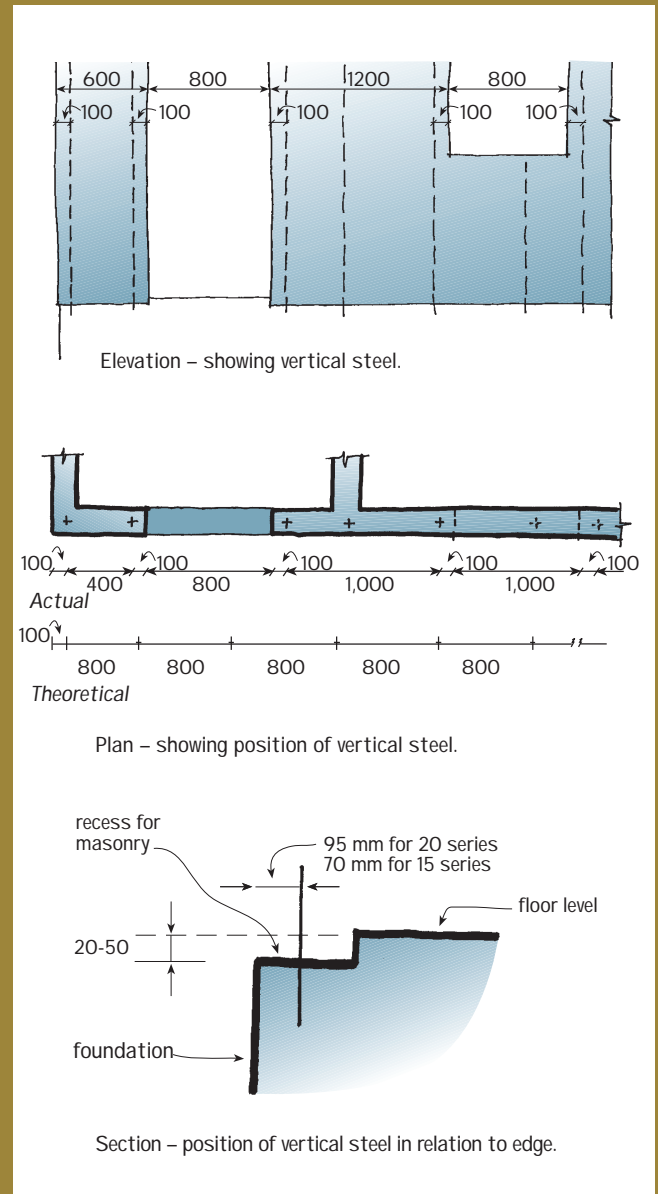


Figure 3: Layout of vertical steel for concrete masonry

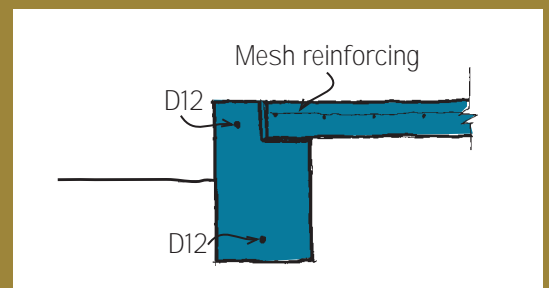


Figure 4: Slab confined by foundation wall

The concrete

- The risk and extent of cracking occurring can be minimised by ensuring a low-water content mix is used.
- Use a 19mm structural mix rather than a 12mm pump mix.
- The second option is to use a superplasticiser which significantly reduces water content. Seek advice from your readymix supplier on this.
- There will be far less bleeding when using a superplasticiser. Watch for plastic cracking with this type of mix.
- Adding water on site to increase slump for the ease of the placer and pump operator will increase the chances of shrinkage.

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 re-application on windy days. If you do not maintain a damp look to the surface it will dry out. This can be achieved by using a water blaster aimed above the slab.
- If the concrete does not appear to be bleeding you are at risk of plastic cracking occurring.

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 mean many slabs crack overnight.
- To significantly reduce the risk of an early-age thermal crack developing, 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.
- Many cracks will be seen within the first 48 hours. (These cracks look exactly like a drying shrinkage crack.)
- Sawcutting has been the traditional technique for forming control joints. Sawcutting of the slab to initiate shrinkage-induced movement should be carried out as soon as the concrete can withstand the process and within 24 hours.
- Carry out any sawcutting within 12 to 18 hours using traditional sawcutting equipment, particularly where the slab is exposed to high temperature changes or drying winds.
- Consider the use of early-entry saws (within the first few hours of placing the concrete). However, this option may not be available in all locations.
- Failure to carry out sawcutting of the joints within this timeframe significantly increases the probability of uncontrolled cracking in the slab.

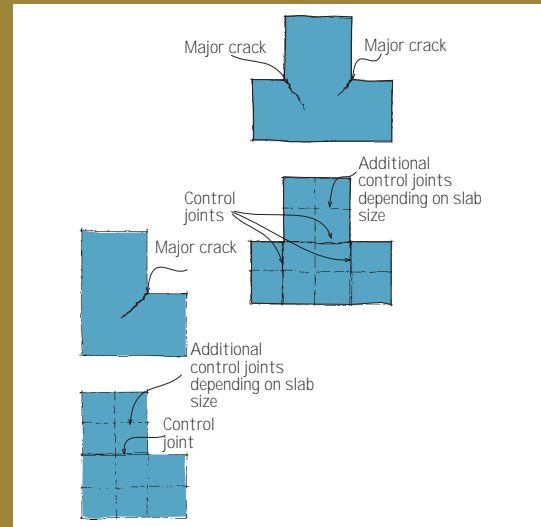


Figure 5: Positioning of crack control joints

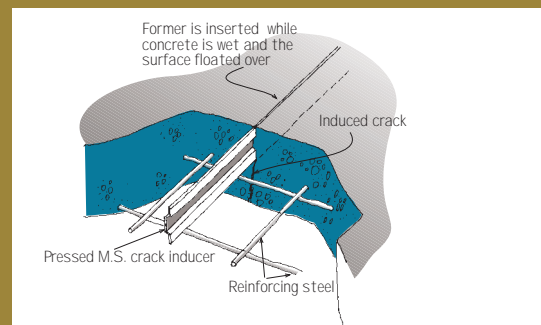


Figure 6: Crack inducer (for reinforced or unreinforced slabs)

Drying shrinkage

- Drying shrinkage becomes noticeable after two weeks at the earliest and will continue to widen for several months
- Shrinkage cracking is controlled by the correct positioning of control joints.

Do I need to vibrate the concrete?

Yes. This is very important.

- Poorly compacted concrete, with air voids within it, will be significantly weaker and could result in expensive call-backs and remedial work.
- Even pump mixes, which appear to be very easily moved and compacted by the screeding process, must be vibrated.
- Special attention needs to be paid to compacting concrete in locally thickened regions, such as perimeter beams (see Figure 7).

What are the concrete placement options?

- It is becoming the norm for the concrete to be pumped into residential slabs. Though this is quick and easy, the shrinkage potential for these pump mixes is higher than a conventional mix.
- For critical areas, consider using a structural concrete mix with a 19mm aggregate, rather than the 13mm maximum aggregate pump mixes usually supplied for residential slabs.

What is the effect of water addition on site?

- Increasing the water content of a concrete mix will reduce the potential strength that the concrete will be able to achieve. If you require 120mm slump for placing then order it so that a mix designed for the higher slump is delivered.
- It will also increase the shrinkage movement that it will undergo as it finally dries out after the curing process is completed.
- Water added to the mix without the approval of the readymix supplier places the onus of responsibility for all aspects of the performance of the concrete on the person adding the water.
- It also transfers liability for any financial consequences for this action to that person.

Do not add any water to the concrete mix unless the readymix supplier approves it. The driver should carry out the water addition, but only on the instructions of the batcher.

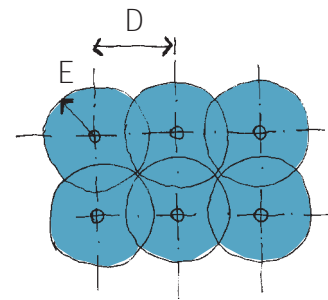
How should I finish the slab?

- Section D1/AS1 of the Building Code describes acceptable finishes for different applications. Wet areas, such as driveways, should not be steel-trowel finished (Class U3, NZS 3114:1987 specification for concrete surface finishes) as this process produces slabs with a poor skid resistance. This may also be a consideration in areas subjected to intermittent wetting, such as 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 2mm to 3mm (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 to improve the ease of finishing. Either technique will lead to a dusting surface, or one that will delaminate as the slab dries after wet curing.
- In winter, be prepared for significant delays between placing and finishing.

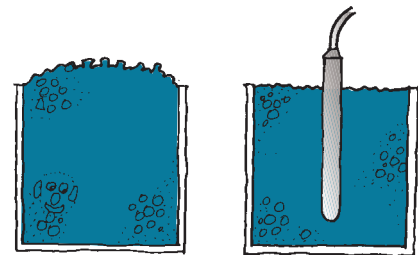
The common practice of squeegeeing the bleed water from a slab presents two problems. First, if the day has any wind this bleed is protecting the slab from plastic cracking. Second, if the removal process mixes any water into the remaining paste then this paste will be severely weakened. Correct finishing procedures will produce a very hard, long-lasting surface. For more details on correct finishing procedures contact CCANZ.

How should the concrete be cured?

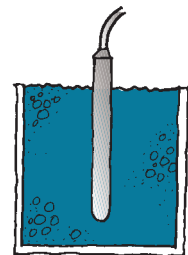
It is very important that concrete is not allowed to dry out in its early life. Apply the curing as soon as the concrete can withstand the



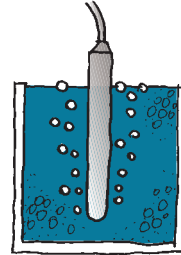
E = The effective range of the immersion vibrator. 180mm to 360 mm
D = The distance between immersion is approx 150 mm



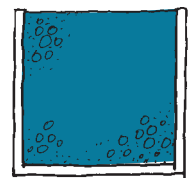
Stage 1. The form is surcharged with concrete.



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



Stage 2. Trapped air is expelled.



7-15 seconds.

Total time for both stages, 10-20 seconds.

Figure 7: Centres for insertion of poker vibrator and the process of compaction

process. The most effective method for curing concrete is by water spraying or ponding (see Figure 9). Plastic sheeting is very good, as long as it is held in place and does not permit any wind to get between the slab and the plastic sheet. Curing membranes, if complying with NZS 3109:1997 (typically only wax-based membranes and some acrylics meet the standard), and applied at the correct rate, can also be effective. Improperly applied membranes, and membranes that do not meet the Standard, are usually ineffective. Membranes, however, are not suitable if tiles or vinyl are to be placed on the floor. Points to remember:

- Poor curing of floor slabs can reduce concrete strength by 50%, resulting in 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 three days. Longer is better, and can be accommodated with good planning.

What you should see happening on site if you are using a specialist subcontractor

There are 9 key steps that are important if a good quality slab is to be produced. These are:

1. Sub-base correctly formed and compacted.
2. Sub-base blinded with sand then DPC carefully installed and taped.
3. Steel reinforcing (where used) placed, tied and spaced to within 30mm of top surface of slab with trimmer bars placed at all re-entrant corners; crack inducers (if used) positioned and fixed together with any starter reinforcement for masonry walls.
4. Concrete of correct specified strength delivered to site in accordance with NZS 3604:1999 Section 4.8 (No water added without the permission of the supplier). Concrete placed and compacted with the use of immersion vibrators.
5. Concrete finished only after all bleed water has evaporated from the surface.
6. Antivap sprays used (applied more than once if necessary) to control evaporation rate to prevent plastic shrinkage cracking.
7. Curing process started immediately finishing operations are completed.
8. Joints cut immediately (using early-entry saws) or within 12 to 18 hours if using traditional sawcutting equipment.
9. Wet curing or covering the concrete with black plastic sheeting continued for three to seven days if a membrane system is not used.



Figure 8: Power floating



Figure 9: Curing concrete using a sprinkler



A coloured concrete floor with cut joints

Where can I get more information?

New Zealand Ready Mixed Concrete Association (www.nzrmca.org.nz).

New Zealand Registered Structural Masons (www.mtrb.org.nz)

Cement and Concrete Association of New Zealand has produced two floor design guides that are an excellent source of more detailed information. Visit the website (www.cca.org.nz) or phone on 04 4998820.

BRANZ Bulletin 333: June 1995. *Damp-proof membranes to concrete slabs.*

BRANZ *Good Concrete Floors and Basements Practice*, October 2002. Visit BRANZ website (www.branz.co.nz) or phone 0800 80 80 85.

This document was prepared by the *Cement and Concrete Association of New Zealand*, on behalf of the *New Zealand Ready Mixed Concrete Association*.