ISSUE535 BULLETIN

REPAIRING CRACKS IN CONCRETE

June 2011

- A satisfactory repair requires correct diagnosis of the cause, together with an understanding of the repair materials and processes.
- Repairs should be carried out by experienced operators. Some materials only give you one chance at getting it right.
- This *Bulletin* replaces *Bulletin* 363 of the same name.

1.0 INTRODUCTION

1.0.1 This bulletin:
- explains how minor non-structural crack repairs may be carried out by builders
- identifies those repairs that should be carried out by specialist operators.

1.0.2 Concrete usually contains many fine 'hair' cracks and these are not normally serious enough to warrant any action. The acceptable width of larger cracks depends on the structure, the crack size and the environment.

1.0.3 Cracks may not be acceptable if they:
- are unsightly
- are likely to weaken the structure
- allow the ingress of water
- may lead to further deterioration of the concrete.

1.0.4 This Bulletin updates and replaces Bulletin 363 of the same name.

1.1 CAUSES OF CRACKING

1.1.1 There are many reasons for concrete to crack. The most common are:
- incorrect reinforcing distribution
- drying shrinkage
- incorrect mix (too wet)
- poor curing
- incorrectly placed shrinkage cuts
- mechanical overload.

1.1.2 Surface cracking can occur before the concrete sets. This is called plastic cracking, and is caused by the concrete drying out too quickly, as might happen on a hot or windy day.

1.1.3 Shrinkage cracking of concrete can occur if:
- the mix has too high a water content or is too weak
- there are insufficient joints to allow for drying shrinkage, thermal expansion and contraction
- sawcuts in floor slabs are poorly configured or timed
- the concrete is not cured properly and excess water evaporates too fast
- there is built-in restraint which results in unintentional tension stresses in the concrete.

1.1.4 Structural cracking can occur as a result of over-loading caused by:
- failure of the subgrade due to improper compaction or incorrect analysis of the sub-soil condition
- inadequate design of the structure for the in-use loads
- mishandling of precast units such as tilt-up walls.

1.1.5 Corrosion of the reinforcing resulting from water penetration is a common cause of poor concrete durability. It is caused by:
- inadequate quality of the concrete
- insufficient thickness of the concrete cover to the reinforcing.

1.1.6 Rust has a volume approximately three times that of the steel and its expansion exerts enormous pressure on the adjacent concrete. The first signs of corrosion are small cracks and rust stains on the surface. Once this has started, the concrete cover will eventually spall off and corrosion will rapidly increase. From a corrosion viewpoint, less risk is posed to reinforcing steel by narrow cracks crossing the reinforcing at right angles, whereas cracks parallel to and immediately above the bars suggest that reinforcing corrosion has started.

1.2 ASSESSMENT OF CRACKS

1.2.1 Assess the seriousness of the cracking, and the need for repair, by considering:
- is the crack structural?
  - is the movement that caused the crack on-going, or has it stabilised?
  - has the reinforcing fractured?
- does the crack allow water penetration?
  - will it compromise the durability of the reinforcing?
  - will it affect internal finishes?
- is the crack cosmetic?

1.2.2 If there is any uncertainty about the cause or the seriousness of cracking, seek advice from a structural engineer. An incorrect analysis could lead to a serious problem. Generally, structural repair techniques will depend on the nature of the cause, and are outside the scope of this Bulletin.

1.2.3 Waterproofing repairs, or repairs to correct appearance (cosmetic repairs) can usually be carried out by an experienced building contractor.

1.3 WHAT CRACKS ARE ACCEPTABLE?

1.3.1 The maximum acceptable width of cracks in reinforced concrete depends on the exposure to which the structure is subjected. Table C 2.1 of NZS 3101: Part 1:2006 lists the maximum allowable surface width of cracks for different structures and various types of exposure.

1.3.2 As a simple guide, crack widths should not exceed:
- 0.3 mm in an in-ground exterior environment
- 0.4 mm for a ground floor slab protected by a damp-proof course
- 0.4 mm for other elements fully enclosed within a building.

1.3.3 The acceptability of cracks will relate not just to a building's function and durability, but also how the owner wants the building to look.

1.4 MEASUREMENT OF CRACK MOVEMENT

1.4.1 The known history of the structure can help determine if there is any continuing movement in the crack. For example, the crack may have been caused by a recent earthquake, a vehicle impact, or recurring movement every cold or hot day.

1.4.2 Where continuing movement is not obvious, it can be determined by:

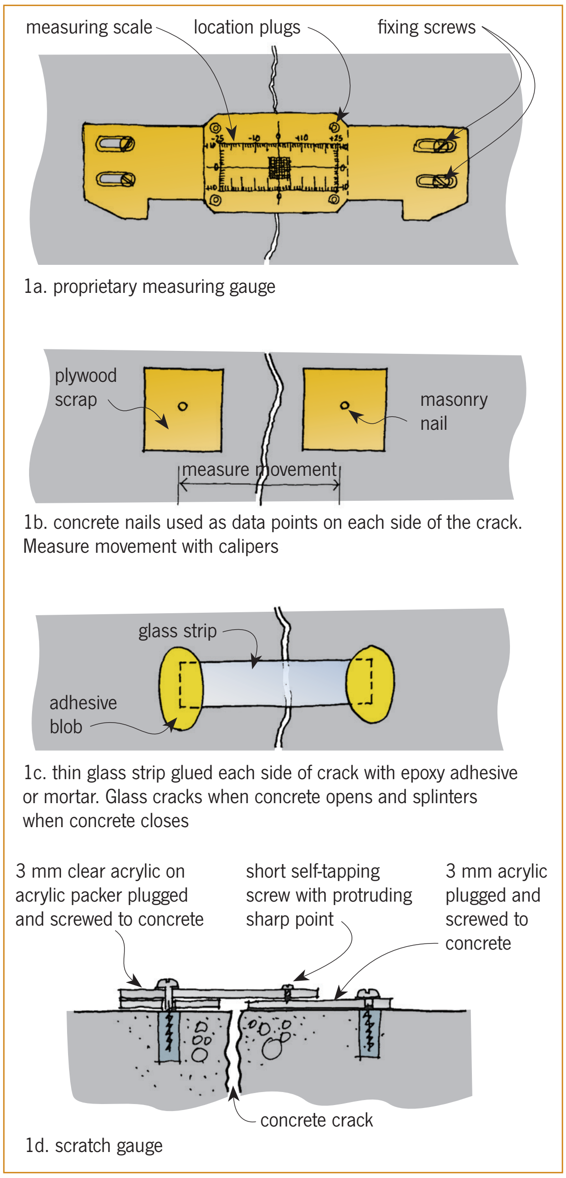


Figure 1. Monitoring crack movement

- using a proprietary monitoring gauge with calibrated base plate and cross hair bezel. These gauges are bolted or glued in place. The crack movement is read off the plate and recorded on a monitoring sheet (Figure 1a)
- placing tape across the crack; it will wrinkle when the crack closes and split when it opens
- using a crack width measuring gauge, or an automotive-type feeler gauge, at different times of day
- using concrete nails on each side of the crack as data points, and measuring the movement with calipers at specified times of day over a fortnight (Figure 1b)
- fixing a piece of thin glass across the crack with a dab of fast-setting adhesive or cement mortar on both sides of the crack. The glass will crack when the gap opens and splinter when it closes (Figure 1c)
- fitting a scratch gauge (Figure 1d). This can be made from two pieces of 3 mm clear acrylic sheet fixed to opposite sides of the crack. One of the pieces is fitted with a sharp scriber which records movement by scratching the other piece.

2.0 METHODS OF REPAIR

2.0.1 It is generally easier to repair cracks while they are new. With time, cracks become filled with debris and algae which may be impossible to remove, making adhesion of the repair material unlikely.

2.0.2 However, in new concrete – especially floors – ongoing drying shrinkage may mean that cracks continue to widen for up to 2 years, and very early repairs may fail. Depending on the circumstances, it may be wise to wait until shrinkage has finished before making any repair.

2.1 PREPARING THE CRACK

2.1.1 Clean cracks with water blasting and compressed air to remove dust and debris. Clean other contaminants such as oil or grease from in and around the crack using a solvent. Algae or bacterial growth can be removed with a detergent or herbicide.

2.1.2 For most repairs, let the area dry before proceeding. The crack can be dried using a hot-air blower such as a paint-stripping device. Take care not to overheat the concrete.

2.1.3 It is important to assess the depth of the crack before starting filling. If the crack penetrates the full thickness of the concrete, filling material will run through. If practical, the other side of the crack may be stopped up with a temporary sealant or putty which can be removed on completion.

2.2 MATERIALS FOR CRACK REPAIR

2.2.1 Repair materials can be grouped in the categories:
- Portland cement-based
- polymer-modified cement-based
- rigid setting resins, such as epoxies
- elastomeric sealants which set to a rubbery consistency.

2.2.2 The choice of material will depend on the size and nature of the crack, the reasons for the repair, and the water resistance of the material.

2.3 FILLERS

2.3.1 Inert fillers can be added to the repair material to:
- alter its workability. This may vary between a flowing mix which can be poured, to one which must be trowelled into position
- make the mix thicker so that it will not run out of cracks which penetrate right through the concrete
- reduce the quantity of material used in order to lower the cost of the repair.

2.3.2 Fillers suitable for repair include:
- fine graded and dried sand for mixing with Portland cement for cracks of 10 mm and upwards
- calcite (a finely ground limestone with a particle size below 600 microns) for cracks between 5 mm and 10 mm

- talc (with a particle size below 55 microns) for cracks below 1 mm
- kaolin or bentonite clays (with a particle size below 45 microns) for cracks below 1 mm.

2.3.3 Follow manufacturers' recommendations on the use and mix proportions of fillers.

2.3.4 Many specialist repair products are available ready-mixed. Seek advice on their use from the manufacturer or supplier.

3.0 PORTLAND CEMENT

3.1 ORDINARY PORTLAND CEMENT

3.1.1 Ordinary Portland cement is the cheapest basic material for repair work and has the advantage of being similar to the concrete being repaired. It is used to improve appearance, or to waterproof a crack where no further movement is expected. It is especially suitable for the repair of shrinkage cracks in horizontal, or near horizontal, newly placed concrete surfaces such as floors.

3.1.2 Cracks between 5 and 10 mm wide may be filled with a neat cement grout. It is preferable to try a slurry mix of 1 part cement:1 to 2 parts of filler for gaps from 10 to 50 mm wide.

3.1.3 If cement grout or slurry is used, the surface of the slurry or grout is then brushed with a dry 1:2 cement:sand mix. The completed repairs must be cured in the same way as new plasterwork by keeping them damp for seven days.

3.1.4 Colour matching may be improved by replacing some of the grey cement with white cement or finely ground pumice in wider cracks. Experiment with colour matching before carrying out the final work. Fifty per cent white cement is suggested as a start.

3.1.5 Proprietary cement-based products are available. Some consist of cement and fine fillers while others contain fillers and expansive additives.

3.2 POLYMER MODIFIED CEMENT REPAIRS

3.2.1 'Polymer modified cement' describes cement gauged with a fluid consisting of water and acrylic-polymer or styrene butadiene mix which improve the quality of the repair mortar and enhance adhesion, density and durability.

3.2.2 These materials are suitable for repairing narrow cracks that require waterproofing, are not subject to hydrostatic pressure, and are not expected to move in the future. These cracks may be filled with a thin slurry based on acrylic resins and Portland cement and possibly other fillers. Designed as a waterproof surface coating, this mixture can be readily pumped or poured into cracks.

3.2.3 Styrene butadiene-based material is used for waterproofing narrow cracks, but is generally not as resistant to sunlight as acrylic-based material. Manufacturers' recommendations should be followed when choosing a material for exterior situations.

3.2.4 Single fine cracks are sealed by pouring the material with a squeeze bottle along the line of the crack. This is repeated until no more material is accepted in the crack.

4.0 EPOXY RESIN

4.0.1 Epoxy resins are especially suitable for:
- structural repairs to concrete that has been overstressed during handling or accidental overloading
- waterproofing cracks, especially if hydrostatic pressure is present.

4.0.2 Small cracks are repaired with unfilled resins, but resins for cracks in excess of 3 mm usually contain fillers.

4.1 STRUCTURAL REPAIRS AND MAJOR WATERPROOFING

4.1.1 Small jobs can be done by building contractors using epoxy resin products, but structural repairs or major waterproofing should be carried out by a specialist operator. Manufacturers or suppliers of epoxy resins may be able to advise the names of firms that undertake this type of work.

4.2 MINOR REPAIRS

4.2.1 A range of epoxy resins is available for different conditions, and it is essential to choose the correct one for each job. They include products ranging from heavy mortar consistency to a free-flowing liquid (Figure 2). Some require the surface of the concrete to be dry, while others can be applied to wet surfaces or even under water. The size and expected movement of the crack is critical when choosing a suitable filler, and the advice of the manufacturer should be sought.

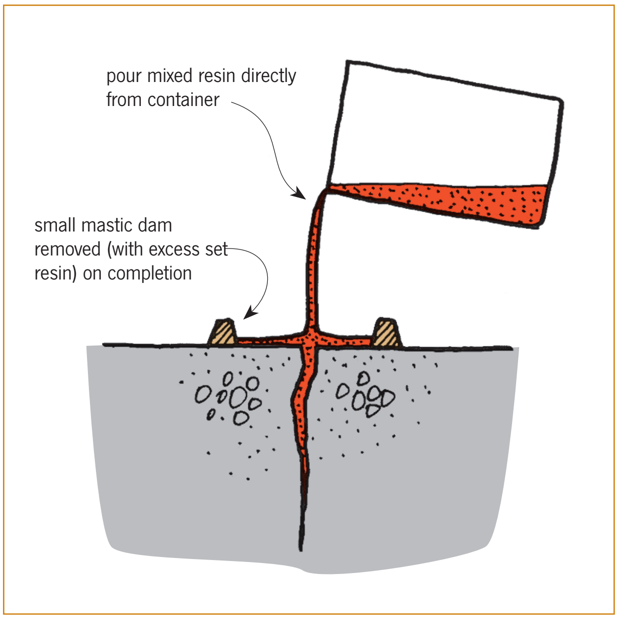


Figure 2. Filling large cracks in horizontal surfaces using free-flowing resin

4.2.2 Most epoxy resins are a two-part formula, and accurate proportioning and mixing of the constituents is important. Both pot life and curing times are sensitive to temperature. High temperatures make the resin more workable, but shorten pot life and curing times. In cold weather, pot life and curing time are increased. Application difficulties are likely to occur below 5°C and above 30°C, but the formula can be modified to adjust pot life and curing time. The manufacturer should be consulted for temperatures outside this range.

4.2.3 Crack repair on horizontal or near horizontal surfaces is normally carried out by pumping resin directly into the crack. A temporary surface seal with inlet ports is formed along the crack to contain the injected resin. It is removed on completion. Resins for small cracks up to 1 mm wide should be free flowing. As the width of the crack being filled increases, the resin should be made more viscous by the addition of fillers. Cracks up to 5 mm wide can be filled by this method. The resin for larger cracks may be the consistency of mortar. A surface seal will not be necessary.

4.3 EPOXY INJECTION

4.3.1 For repair of vertical and horizontal cracks it is necessary to inject the resin into the crack under pressure.

4.3.2 Kitsets are available for small projects. They come with instructions which should be followed closely.

4.3.3 The procedure is:
- clean the crack and adjacent surfaces as described in paragraph 2.1.1
- bond the injection-ports centrally over the crack, using the adhesive supplied with the kit, at centres at least equal to the crack depth
- seal the crack between the ports with sealing compound and allow it to cure for the specified period
- if the crack extends right through the concrete, it must be sealed on both sides. Injection ports can be applied to either or both sides
- mix the resin as instructed and, after fitting the injector cartridge in the sealant gun, connect the sealant gun hose to the lowest port and begin injection
- when resin begins to flow out of the adjacent higher port reconnect the hose to that port and, after plugging the first port, repeat the process until the entire crack is full
- allow the resin to cure for the specified time
- remove the ports and grind or peel off the sealing compound (Figure 3).

4.3.4 When using any injection material, the operator must protect skin against contact with the resin. Wear protective clothing and goggles. Mix in a well-ventilated space. The effects of skin contact can be serious. Resin or hardener should be washed off immediately and thoroughly with soap and water.

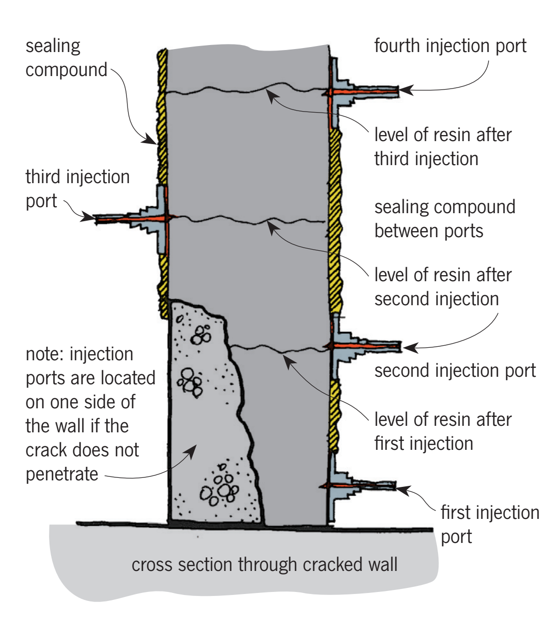


Figure 3. Epoxy resin injection into cracked wall

5.0 SPECIALIST INJECTION TECHNOLOGY

5.0.1 A wide range of specialist repair and waterproofing techniques has been developed. These techniques require expertise and can only be carried out by specialist firms.

5.0.2 The technology involves high and low pressure injection systems using specialised equipment, and a range of products, including:
- epoxy resins
- cement-based minerals
- polyurethane resins and foams
- acrylic gels
- methyl methacrylate resins.

5.0.3 Vacuum induction involves sealing the cracks as you would for injection, but the resin is introduced via the lowest port, with a vacuum pump being attached to an upper port. It is particularly suited to repairing delaminated faces where the added pressure of an injection system could cause failure of the delaminated section.

5.1 EPOXY RESINS

5.1.1 Epoxy resins are used for dry structural or rigid repairs. Resins with very low viscosity can be injected into extremely fine cracks. The viscosity of the resins used will vary with the width of the crack to be filled.

5.2 CEMENT-BASED SYSTEMS

5.2.1 Cement-based products can be injected into wet cracks down to 1 mm wide. (The minimum particle size of Portland cement is 200 microns. Some mineral-based injection materials have a maximum particle size of 16 microns.)

TABLE 1. SUITABILITY OF INJECTION PRODUCTS FOR VARIOUS SITUATIONS						
	Dry conditions			Wet conditions		
	Structural repair	Rigid sealant	Flexible sealant	Structural repair	Rigid sealant	Flexible sealant
epoxy resins	✓	✓				
cement-based systems	✓	✓		✓	✓	✓
polyurethanes		✓	✓		✓	✓
acrylic gels					✓	✓

5.3 POLYURETHANES

5.3.1 Injection systems based on polyurethane resins can be used to waterproof structures which are only accessible from one side. Even cracks leaking water under pressure can be sealed with fast-flowing water-stopping polyurethane. Two-part polyurethane injection kits are available. Follow the instructions carefully to achieve acceptable results.

5.4 ACRYLIC GELS

5.4.1 These are a low viscosity, high speed reaction product which can be pumped into the fill around tunnels and on the fill side of retaining walls to form a permanent seal against water. They only function in perpetually damp conditions.

5.5 METHYL METHACRYLATE RESINS

5.5.1 These are ultra-low viscosity resins used largely for dry structural or rigid repairs, and can be adjusted to give any desired cure rate from very fast to very slow. They are suitable for static impregnation of fine cracks in floor slabs, and pressure injection or vacuum induction in wall slabs.

5.6 TECHNICAL SOLUTIONS

5.6.1 A range of solutions to complex construction repair problems is available. Polyurea resins, for example, are typically fast-curing and tough, but retain good flexibility. They are good for repairs in high-use areas where cure times may be restricted by operational needs.

5.6.2 While these techniques are often expensive, and some should only be used by specialist operators, in many cases they are the best or the only viable solution. Table 1 shows the suitability of these products.

6.0 ELASTOMERIC SEALANTS

6.0.1 Where design provisions for thermal or moisture movement have been insufficient, cracks may occur. These cracks change in width as temperatures and moisture content of the concrete change. Where it is necessary to repair them, they must be filled with a sealant that remains flexible and prevents water entry.

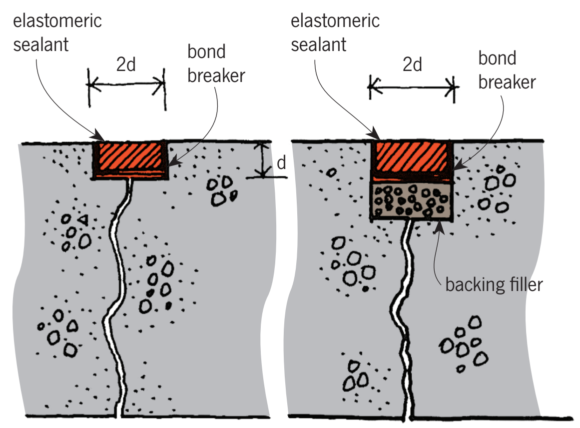
6.0.2 Elastomeric sealants remain flexible after curing and are suitable for sealing joints which are subject to movement. A wide range of sealants is available including acrylic, polyurethane, polysulphide and silicone-based products. It is important to select the correct sealant for each situation. Ask for the manufacturer's advice.

6.0.3 Elastomeric sealant repairs are not suitable for restoring structural strength.

6.1 PREPARATION OF THE CRACK

6.1.1 Before applying a sealant, the cracks must be correctly shaped. An abrasive disc in a portable saw can be used for fairly straight cracks; irregularly shaped cracks can be widened with an offset grinder.

6.1.2 The cracks must be chased so that they conform to the following:
- a width of at least 5 mm to make sealant application practicable
- the width of the cut crack must be at least 6 times the expected movement across the crack
- the sealant depth should be approximately half its width. If the crack is cut to a greater depth, the additional space should be filled with backing material.



joint cut and elastomeric sealant applied. Proportion of depth to width is most important

use a backing filler if joint is cut too deep

Figure 4. Elastomeric sealant joint

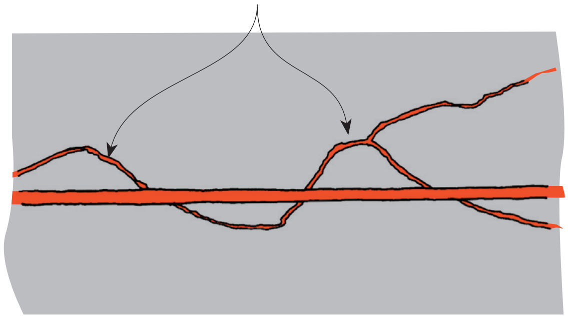


Figure 5. Cutting a new expansion joint through irregular cracks

6.2 SEALANT APPLICATION

6.2.1 The selected sealant joint can be constructed by these steps:

- clean out and dry the joint as described in paragraphs 2.1.1 and 2.1.2
- apply a bond-breaking tape to prevent the sealant from adhering to the bottom of the chase. This is important because if adhesion occurs the sealant may split
- fix masking tape on both sides of the chase to protect the face of the concrete
- use a primer (if recommended) on the sides of the chase
- gun the sealant in and tool to the required shape.

6.2.2 If the sealant is to be painted, ensure that the product used will accept paint. Even with a paintable sealant, there will be a tendency for paint to wrinkle or crack if the joint moves.

6.3 IRREGULAR CRACKS

6.3.1 If the concrete has cracked in an irregular line and is still subject to movement, it is sometimes possible to fill it with an epoxy resin, as described in 4.2.3, and then to cut a new flexible sealant-filled movement joint (Figure 5). This must only be done after an engineering analysis.

7.0 CRACKS IN INDUSTRIAL FLOORS

7.0.1 Epoxy filling and elastomeric joints may be acceptable for domestic or light commercial floors. Soft flexible joints are not suitable for industrial situations where the edges of the joint are likely to spall off due to hard-wheeled handling equipment.

7.0.2 In these situations, always seek specialist advice. The following is a basic repair method (Figure 6):

- make a saw cut on either side of the crack or damaged joint so that all the spalled part is removed
- clean out the crack and apply primer (if recommended)
- fill the joint with high-strength epoxy mortar
- form the movement joint in the mortar using a pull-out slip or saw cut when the mortar has fully cured
- apply a bond breaker to the movement joint and fill with a semi rigid epoxy.

7.0.3 Some proprietary systems include the insertion of metal strips or angles to protect the edges of the joint.

8.0 CONCLUSION

8.0.1 The essential requirements for success in concrete crack repair are:

- correct diagnosis
- an understanding of the materials and processes used
- thoroughness - if the work is skimped, the result is likely to be unsatisfactory
- having experienced persons work on the repairs.

9.0 CODES AND STANDARDS

- *Guide to Concrete Repair and Protection 1996*. A joint publication of ACRA, CSIRO, Standards Australia and Standards New Zealand.
- Standards New Zealand Wellington NZS 3109 *Specification for concrete construction* and NZS 3101 *Code of practice for the design of concrete structures Part 1.*

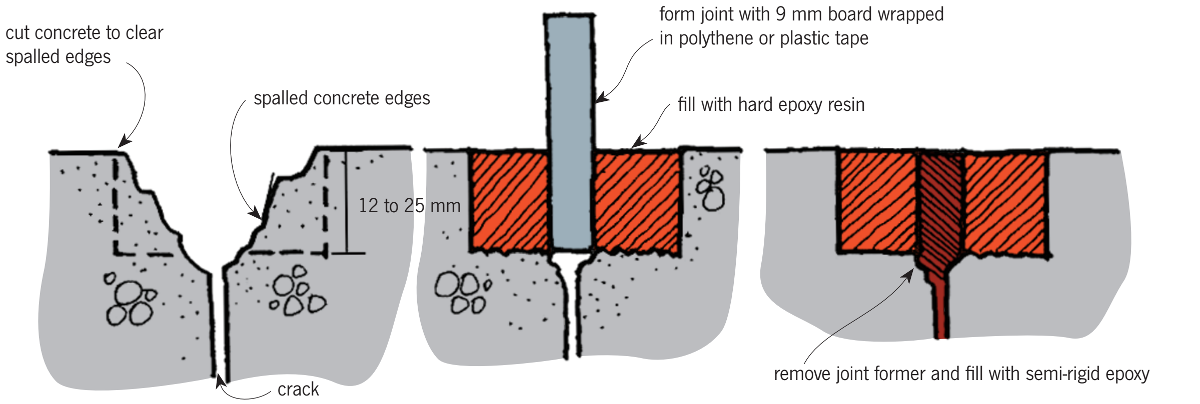


Figure 6. Repair of joint in floor with heavy duty use

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