THE HIGHWAYS AGENCY HD 32/94

THE SCOTTISH OFFICE DEVELOPMENT DEPARTMENT

THE WELSH OFFICE
Y SWYDDFA GYMREIG

THE DEPARTMENT OF
THE ENVIRONMENT FOR NORTHERN IRELAND

Maintenance of Concrete Roads

Summary:

REGISTRATION OF AMENDMENTS

Amend No	Page No	Signature & Date of incorporation of amendments	Amend No	Page No	Signature & Date of incorporation of amendments

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VOLUME 7	PAVEMENT DESIGN AND MAINTENANCE
SECTION 4	PAVEMENT MAINTENANCE METHODS

PART 2

HD 32/94

MAINTENANCE OF CONCRETE ROADS

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Chapter

1. INTRODUCTION

General

1.1 Proper maintenance of rigid and rigid composite pavements is important if the structure is to have a reasonable expectancy of remaining in a satisfactory condition and achieving the design life. To assess the need for maintenance and repair work a standard procedure of regular inspection and fault recording is necessary, as described in HD 29 (DMRB 7.3.2) and HD 30 (DMRB 7.3.3). This should ensure correct diagnosis of the various types of defect that may be encountered.

1.2 This Part gives recommendations for maintenance, repair and structural strengthening of concrete slabs in rigid and rigid composite pavements based on current experience using methods which are tried and proven. In most instances a more detailed description of faults and advice on treatments is given in Mildenhall and Northcott (1986). Procedures for maintenance and repair are given in Annex 1 unless referred to in the Specification (MCHW1).

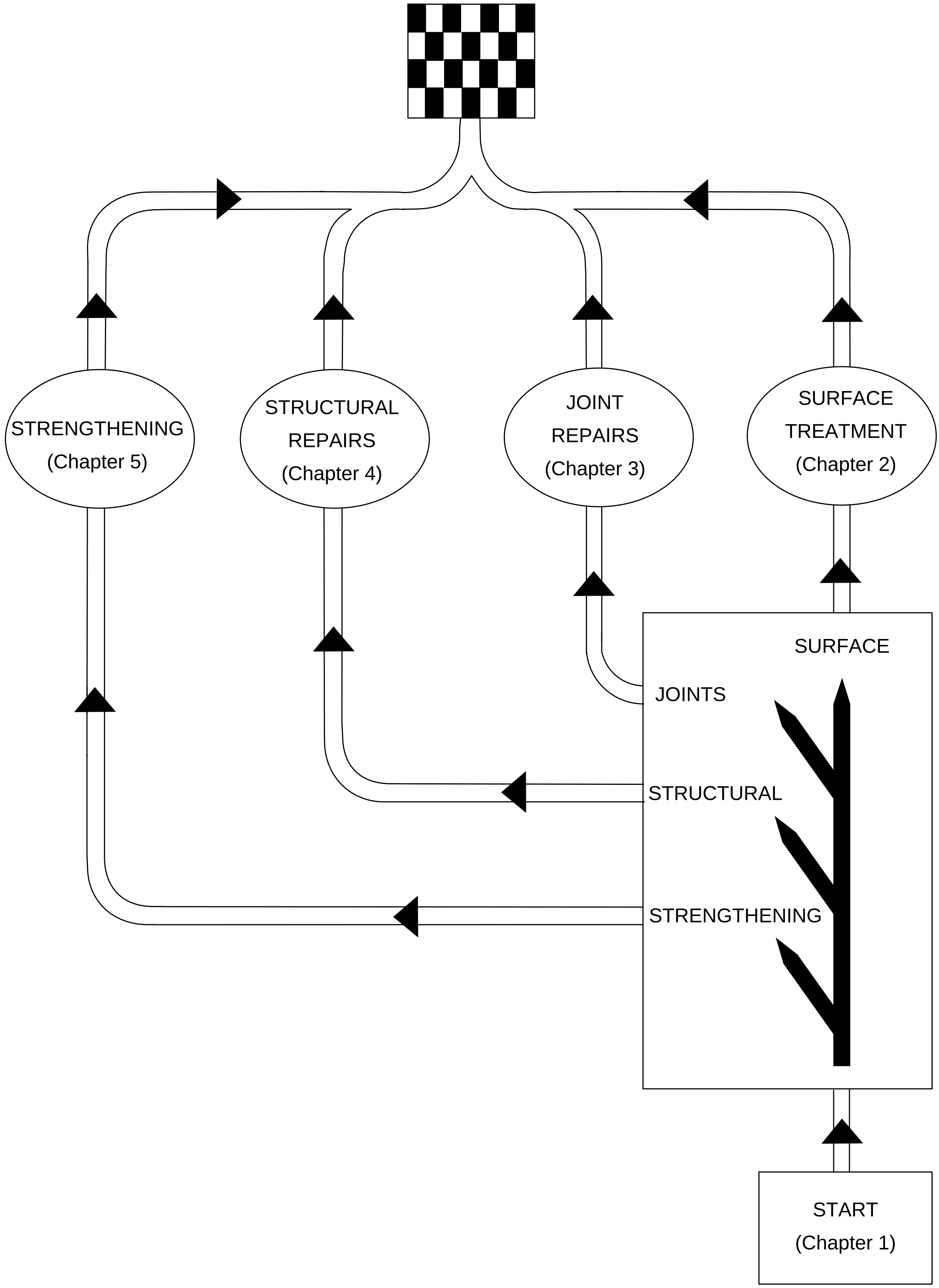
1.3 In addition, some methods of treatment are discussed which have had little use to date, such as, Cracking and Seating of concrete pavements, Thin-bonded Concrete Overlays and Continuously Reinforced Concrete Overlays. Consequently the latest advice should be sought from the Overseeing Department if such methods are to be considered. Maintenance of the bituminous surfacing in rigid composite pavements is covered in HD 31 (DMRB 7.4.1).

Implementation

1.4 This Part shall be used forthwith on all schemes for the improvement and maintenance of trunk roads including motorways, currently being prepared provided that, in the opinion of the Overseeing Department this would not result in significant additional expense or delay. Design organisations should confirm its application to particular schemes with the Overseeing Department.

Mutual Recognition

1.5 The construction and maintenance of highway pavements will normally be carried out under contracts incorporating the Overseeing Department's Specification for Highway Works (MCHW1). In such cases products conforming to equivalent standards and specifications of other member states of the European Community and tests undertaken in other member states will be acceptable in accordance with the terms of the 104 and 105 Series of Clauses of that Specification. Any contract not containing these Clauses must contain suitable clauses of mutual recognition having the same effect regarding which advice should be sought.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2. SURFACE TREATMENTS

2.1 HD 28 (DMRB 7.3.1) discusses the assessment of skidding resistance using the SCRIM machine or Portable Pendulum Tester, although SCRIM only measures skidding resistance at low speed (50km/hr).

2.2 There are several different methods of restoring skidding resistance to concrete roads, but the most suitable depends on the type of road, speed of traffic, the risk factor and the aggregate used in the concrete. Some methods will restore macrotexture while others only improve microtexture, and some do both. The following gives some general comments:-

a) **Surface dressing**
- Restores microtexture and macrotexture
- Type dependent on road

b) **Transverse grooving**
- Suitable for high speed roads
- Restores braking force and macrotexture
- Prevents aquaplaning

c) **Mechanical roughening**

Flailing-transverse
- Improves macrotexture and removes polish from aggregates.

Bush hammering
- Improves macrotexture
- Removes polish of exposed aggregate
- Risk of damage to surface and microcracking of the matrix

Grit blasting
- Removes surface polish
- Short term improvement of micro-texture
- Suitable for roads with lighter traffic with less polishing effect

d) **Thin bonded surface repairs**
- Restores microtexture and macrotexture
- Time consuming and relatively expensive
- Suitable for damaged slabs and local areas

Methods b) and d) above are detailed in the Specification (Series 1000) and are not discussed further in this Part.

SURFACE DRESSING

2.3 Design of bituminous surface dressings, including those on concrete roads, is covered in Section 4, Part 1, which in turn refers both to Road Note 39 (1992) and the Specification (Series 900) for further details.

2.4 A very high level of low speed skidding resistance can be achieved by the application of a surface dressing consisting of an epoxy resin based binder and highly abrasion resistant calcined bauxite chippings. Its comparatively high cost is likely to limit its use to small areas. However, the performance of this type of treatment on concrete may not be as good as on bituminous surfaces because of the difficulty of obtaining good bond between the binder and the concrete surface over large areas. The main reason for bond failure is the different coefficients of thermal expansion for concrete and resin.

2.5 Surface dressings may not have a very long life where turning heavy commercial traffic is likely to scour the surface. An advantage of bituminous surface dressing is the speed at which it can be applied, but it is a weather susceptible operation which is restricted to a limited season. Care must be taken in the selection of the right binder to suit the circumstances and control applied to achieve an even distribution of binder and chippings. Traffic control measures are extensive and complex because of the need for controlled slow speed trafficking of newly applied dressing, followed by sweeping to dislodge and remove any loose chippings. Surface dressing is likely to need renewing at least once during the structural life of the slab.

MECHANICAL ROUGHENING

2.6 Improved skidding resistance can be achieved by roughening the worn surface by the use of abrasive blasting, scabbling, grinding or milling equipment. Abrasive blasting is effective in restoring slow speed skidding resistance and equipment is available which is suitable for treating both large and small areas.

2.7 The effectiveness of the surface texture produced by scabbling and milling will be influenced by the the properties and characteristics of the coarse aggregate in the concrete that is exposed.

2.8 Any retexturing treatment gives an increase in high speed skidding resistance resulting from a greater depth of texture. Treatments are likely to be accompanied by some increase in the amount of tyre noise, the nature of which will depend on the type of treatment that is adopted.

3. JOINT REPAIRS

3.1 Concrete slabs expand and contract as the temperature rises and falls. They also warp, or curl, when the temperature of the slab surface is substantially different from the underside. Longitudinal and transverse joints enable the different types of movement to occur and it is therefore essential that they are both well constructed and maintained in an effective working condition.

DEFECTIVE JOINT SEALS

Consequences

3.2 Defective joint seals allow silt, grit, stones and water to enter between the slabs and infiltrate the lower levels of the pavement. An accumulation of detritus can prevent the joint closing and lead to spalling of concrete or, if several slabs are affected, "blow-up" expansion type slab compression failures. Penetration of water into the joint can lead to softening of the sub-base or subgrade, and corrosion of steel dowels and tie-bars, especially in the presence of de- icing salt. The presence of water is also a contributory factor in the disruptive alkali-silica reaction, that can occur within concrete composed of certain reactive aggregates.

Types

3.3 The life expectancy of most joint seals is short compared with that of the concrete pavement, since they tend to harden and become brittle with age. Consequently, joint seals have to be replaced regularly, and a guide to the main types, relative life and usage is given in Table 3.1.

3.4 The type of seals given in the Specification (MCHW1) are expected to have a life of up to 10 years. On some older roads a bituminous sealant was used, with which the present specified hot applied sealants are incompactible. Therefore, it may be preferable and speedier to rake out and top up the joint with the short life bituminous seal at more frequent intervals, than have the expense of sawing out the joint and resealing with new materials. The choice would be made on economic grounds.

Classification	Chemical	Physical Type	Life	Type of Joint	Compliance
Hot Applied	PVC/pitch polymer	Elastomeric	Medium	All	BS2499 (1993)
	Polymer/Bitumen	Elastomeric	Medium	All	BS2499 (1993)
Cold Applied	Polysulphide	Elastomeric	Medium	All	BS5212 (1975) and BS4254 (1983)
	Polyurethane	Elastomeric	Medium	All	BS5212 (1990)
	Silicone	Elastomeric	Medium	Warping	BS5889 (1989)
Compression	Polychloropene	Elastomeric	Longest	All	BS2752 (1990) and ASTM D2628

TABLE 3.1 Main Types of Joint Sealing Material

3.5 Either hot or cold applied elastomeric materials or compression seals are permitted for general re-sealing, but gun grade cold applied materials are probably the most appropriate when small quantities of material are involved. At some locations, e.g. bus lay-bys or parking areas, a fuel resistant sealing material should be used. At joints between concrete and bituminous pavements only hot applied polymer modified bituminous sealants, Type N1 to BS2499 (1993) or preformed polymer modified bituminous strips shall be used.

3.6 Sealants of the hot applied type can become brittle if overheated at the time of application. Inadequate mixing of cold applied sealants or the use of incorrect proportions of components will result in poor performance.

3.7 Overbanding materials shall not be used to seal joints or cracks in concrete pavements. The seal tends to crack along the joint and that remaining on the surface hides defects in the joint arrises.

3.8 For fast-track construction, compression type seals can be installed as soon as the groove is sawn. If hot or cold applied sealants are to be used they can be applied after the concrete has reached sufficient strength for grit blasting without damage occurring to the joint grooves. Refer to the Specification (MCHW1) Series 1000 and to HD27 (DMRB 7.2.4.3).

3.9 Joint seals suffer from adhesion failure between the seal and the groove, cohesion failure causing transverse or longitudinal cracking within the seal, and extrusion. In each case the seal must be replaced. Possible causes of these defects are given in Table 3.2, and the correct amount of sealant to apply is shown in Figure 3.1.

3.10 Preparation and sealing of joint grooves shall be in accordance with the relevant British Standard for hot or cold applied sealants and with the Specification (MCHW1) and manufacturer's recommendations for compression seals.

Preparation of the sealing groove

3.11 For the seal to function properly it must adhere to the sides of the sealing groove. This necessitates use of an appropriate primer, ensuring that the sides of the sealing groove are scoured by abrasive blasting, clean, dry and not too cold at the time of application. Some sealants are incompatible with others (e.g. hot applied bituminous based and pitch modified materials) and this may adversely affect adhesion if some of the old sealant remains in the groove.

3.12 Hot applied sealants shall not be applied when the temperature in the groove is less than 7°C. Heating the concrete to raise its temperature is not recommended because the effect will be temporary and it will cool very quickly causing moisture to condense on the surface. However, the application of hot air through a lance may be used to dry surface water from within the sealing groove.

Sealing groove dimensions

3.13 The groove dimensions must be appropriate both for the amount of movement that is expected to take place at the joints, which is a function of the distance between them, and the type of sealing material that is used. A width to depth ratio of between 1:1 and 2:1 shall be

Type of defect	Causes	Remedies
Adhesion failure (lack of adhesion between the seal and the sides of the sealing groove)	Inadequate preparation of the sealing groove Faulty or inappropriate sealing material Incorrect sealing groove dimensions Chilling effect of cold concrete Moisture in sealing groove	Remove old seal, thoroughly clean out, prepare groove and re-seal
Cohesion failure (cracks within the seal either transverse or parallel to the joint groove)	Age Faulty or inappropriate sealing material Incorrect sealing groove dimensions Lack of bond breaking strip beneath seal	- do -
Extrusion	Overfilled sealing groove Lack of compressible caulking strip in bottom of sealing groove Incorrect sealing groove dimensions	- do -

TABLE 3.2 Joint Seal Defects : Causes and Remedies

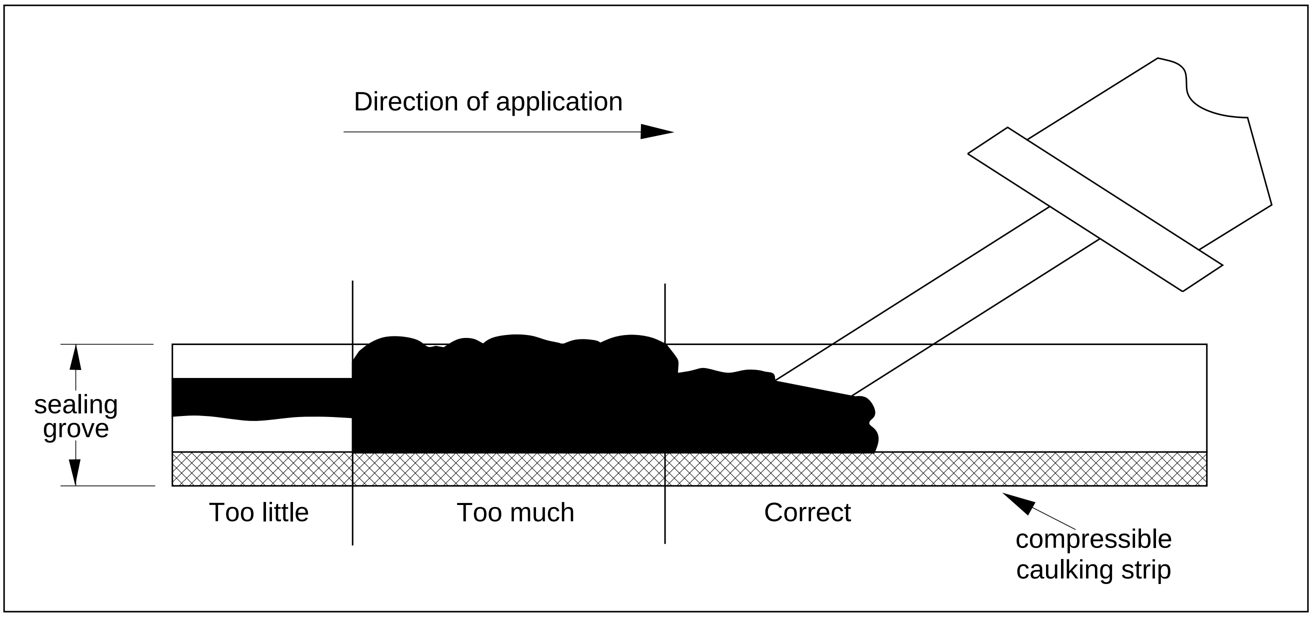


FIGURE 3.1 Application of Gun Grade Cold Applied Sealant

used for plastomeric materials and from 1:1 to 1:1.5 for elastomeric materials, with a minimum depth of seal of 15mm.

3.14 The dimensions of grooves appropriate to hot and cold applied sealing materials are given in the Specification (MCHW1) Series 1000. The uncompressed width of compression seals and the initial width of the sealing groove are related to the distance between joints, and in accordance with the manufacturer's recommendations, so that when inserted into the sealing groove they remain in compression at all times.

3.15 During hot summer weather, seals which have been applied at a cooler time of the year may be extruded from the joint. If this happens, the seals may be damaged by traffic and can be lost altogether. Joint seals shall therefore initially be not less than 5mm below the surface of the slab, except in the case of cork seals.

SHALLOW SPALLING

3.16 Spalling of the arrises of joints (or the edge of slabs) is likely to impair the effectiveness of the joint seal. Possible causes are given in Table 3.3.

3.17 Spalling due to the ingress of incompressible material into the joint groove usually occurs suddenly and is often in the form of 'wedge' shaped pieces of concrete which typically taper towards the back and sides.

3.18 Shallow spalling should be repaired before the joint seal has been affected to the extent that it will permit an appreciable amount of surface water etc to penetrate into the joint groove. It is likely that this would happen if the spalling is more than approximately 20mm deep.

3.19 Correct identification of this defect is very important because it can appear to be very similar to the early stages of deep spalling, the causes and remedy of which are very different.

Thin Bonded Arris Repairs

3.20 Removing the old joint seal and groove former at the commencement of a thin bonded arris repair enables the full extent of shallow spalling to be determined. This can be confirmed by tapping with a steel rod, a hollow sound indicating the presence of cracked material, whilst a ringing tone indicates intact concrete.

3.21 Wherever possible thin bonded arris repairs should be carried out using either cement mortar or fine concrete depending upon the depth of the repair. The practical minimum depth is approximately 10mm. Cement mortar should be used for repairs up to 20mm deep and fine concrete for thicknesses greater than this.

Type of defect	Causes	Remedies
Shallow spalling of transverse and longitudinal joint arrises or the edges of slabs	Weak concrete lacking in durability or compaction Infiltration of silt or other fine material into the joint groove Penetration of stones into the joint groove Tilted joint groove formers Mechanical damage caused by removal of formwork etc	Minor spalling should be removed by widening the joint groove locally by sawing up to 40mm wide at transverse joints and 30mm wide at longitudinal joints in conjunction with flat grinding as necessary Spalling which cannot be dealt with in this way should be rectified by means of a thin bonded arris repair

TABLE 3.3 Shallow Spalling : Causes and Remedies

3.22 The use of epoxy concrete, or other 'concretes' having different thermal properties and strengths from the existing concrete, is not recommended, since debonding of the repair or further cracking of the existing concrete often ensues. They may however, be used with care on small repairs.

3.23 Thin bonded repairs to surfaces of slabs and to joint arrises shall be carried out in accordance with the Specification (MCHW1) Series 1000. Thorough preparation, attention to detail and good workmanship are essential for this type of repair.

3.24 The procedure requires a delineating groove to be chased out rather than sawn in order to provide a roughened vertical edge around the repair, against which the repair material can be properly bonded (Figure 3.2). Sawing produces a polished surface which inhibits good bond and there is also an undesirable tendency for sawn grooves to be extended into the slab beyond the corners of the repair. However if required, a shallow delineating groove may be sawn to start with and subsequently chased out to the full depth.

3.25 The success of thin bonded arris repairs depends largely upon developing good bond at the interface between the repair material and the existing concrete. This is best achieved by compacting the repair material against a freshly scabbled, clean surface. The finished repair must be flush with the existing slab surface and must not bridge the joint.

DEEP SPALLING

3.26 Deep spalling usually extends to at least half slab depth and possible causes are given in Table 3.4. One cause, dowel bar restraint, may be due to misalignment and/or excessive bond along the length of the bar which should be free to move in one of the slabs.

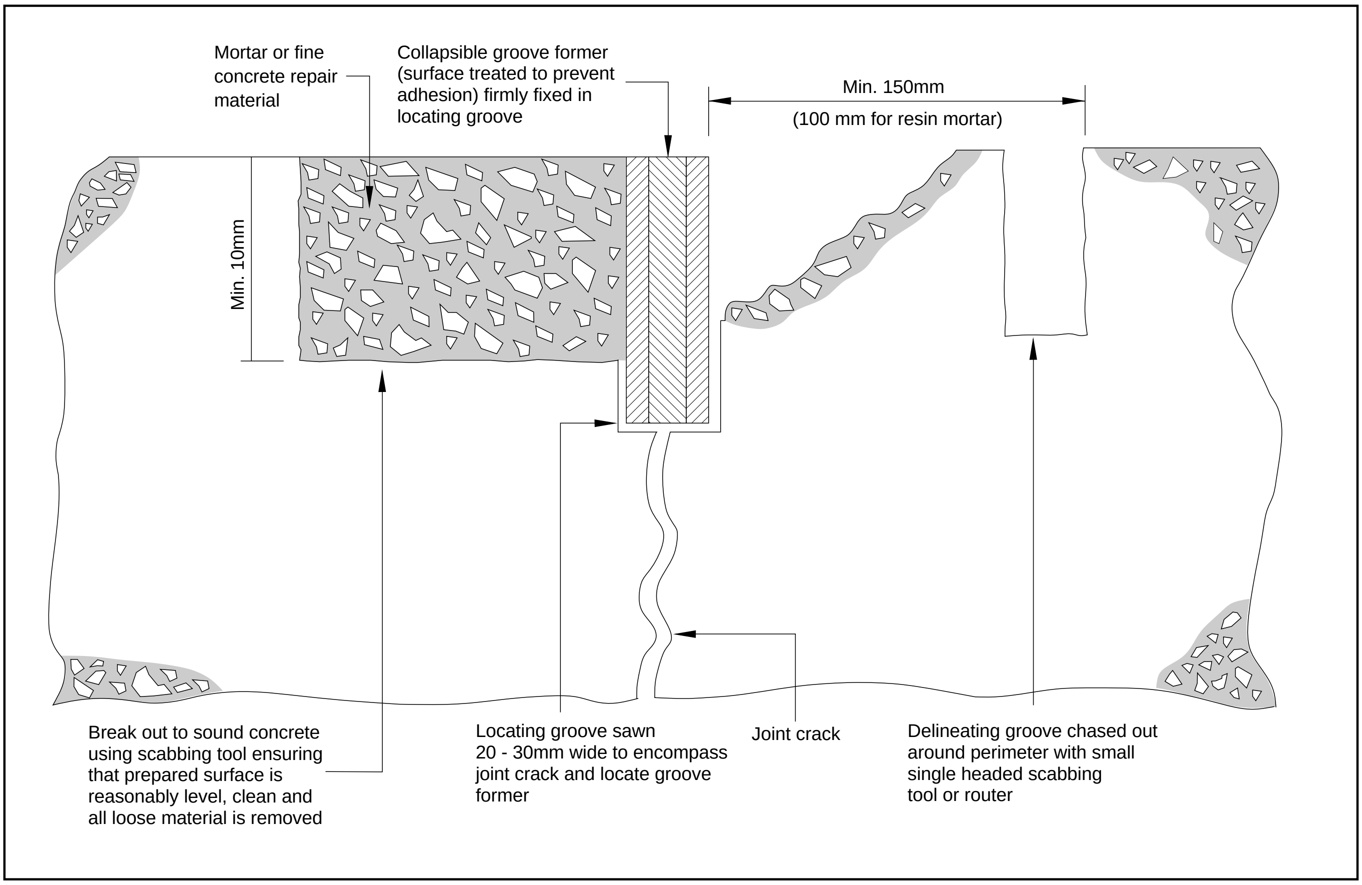


FIGURE 3.2 A Thin Bonded Arris Repair

Type of defect	Cause	Remedy
Deep spalling at contraction and expansion joints	Dowel restraint Ingress of solids into the joint crack	Transverse full depth repair
Deep spalling at the corners of bays	- do -	Full depth corner repair

TABLE 3.4 Deep Spalling : Causes and Remedies

Full Depth Repair

3.27 Full depth repairs shall be carried out in accordance with the Specification (MCHW1) Series 1000. Full depth repairs form small bays which should be at least equivalent to the main slab in all respects (Figures 3.3 and 3.4). Irrespective of whether the main slab is reinforced or not, it is advisable to reinforce the repair and this <u>must</u> be done when the ratio of the longest to the shortest dimension is greater than 2 which will often be the case. Either square or long mesh reinforcement of appropriate weight may be used. In the case of the latter, the main bars shall be positioned parallel to the longest dimension and if square mesh reinforcement is used, its weight per m^2 shall be approximately twice that of the long mesh reinforcement.

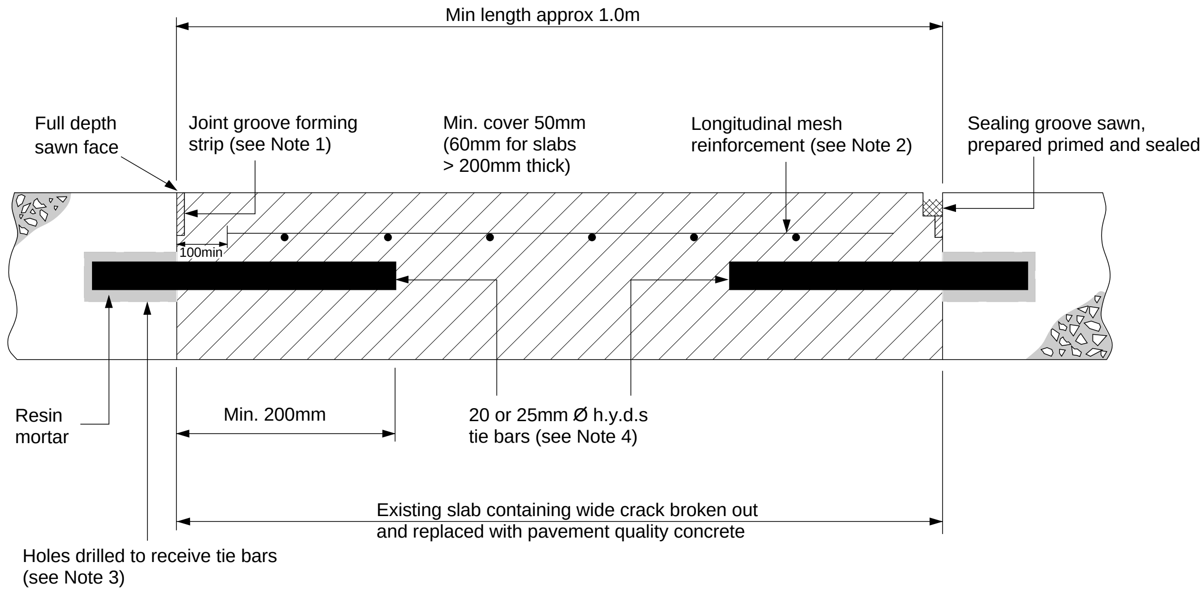
3.28 Small bays of 1m length (along the carriageway) constructed over a granular sub-base may fail around the dowel bars and settle due to heavy traffic loading and lack of compaction of the sub-base. It is recommended that when the existing sub-base is granular the length of bay is increased to at least 2m so that recompaction of the sub-base is easier and the traffic load is spread over a longer bay, so eliminating the punch down effect on a short bay.

3.29 It is essential that the corners of the repair are broken out either to a sharp right angle, or a 45º chamfer in the case of corner repairs, and that the sides are vertical and dressed smooth, otherwise it will be difficult to fix the expansion material in position and any "bridging" or projections in the corners are likely to result in spalling. Longitudinal sides of repairs shall not occur along the wheelpaths. In transverse full depth repairs the expansion material shall be extended around the corners to ensure complete separation at these locations. Expansion material shall be provided around the entire perimeter of full depth corner repairs.

3.30 When undertaking all types of full depth repairs every effort should be made to prevent slurry from sawing, repair material and other debris from entering any joint cracks and grooves in the sides of the repair. Prior to placing the repair material, joint cracks and grooves should be cleaned out using oil free compressed air if necessary and taped over with adhesive masking tape.

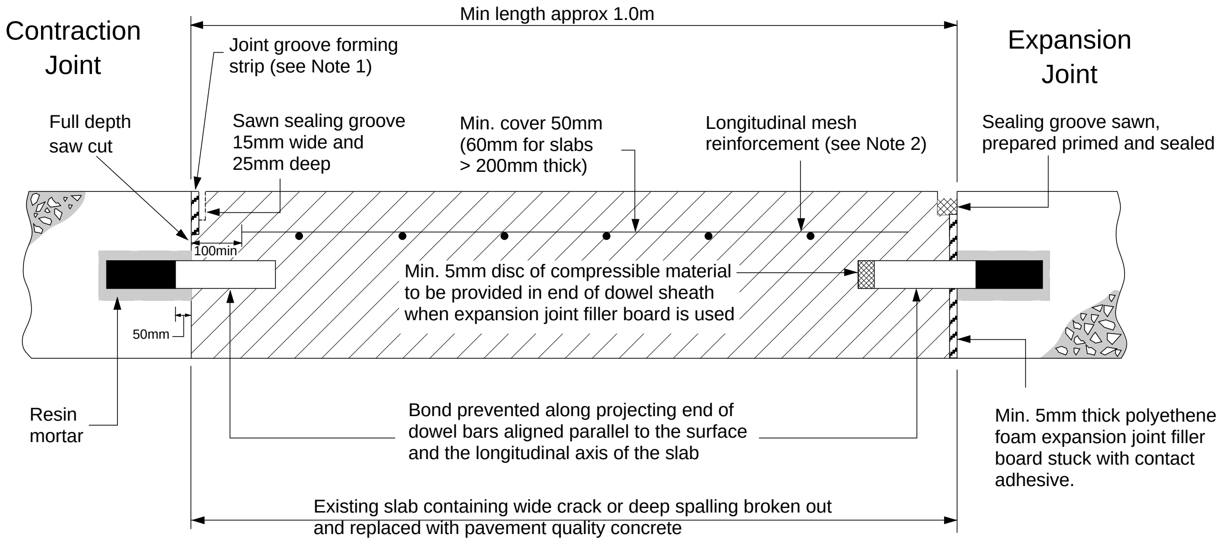
Removal of Slabs

3.31 As repairs are mainly carried out in summer, removal of slabs or parts of slabs can cause additional cracking due to the compressive stresses during high temperatures being concentrated on less than half the width of slab, once saw cuts are made. This may cause longitudinal cracking or localised compression failures at joints.



Notes:-
1. Polyethylene foam joint groove forming strip 5mm wide x 40mm deep stuck along top edges of remaining slab.
2. Appropriate longitudinal mesh reinforcement, main bars parallel to longitudinal dimension.
3. Hole drilled 150-200mm deep to receive tie bars at 600mm c/c.
4. Tie bars to be 20mm dia. for slabs up to 225mm thick.

FIGURE 3.3 Longitudinal Full Depth Repair - Jointed Slabs



Notes:-
1. Polyethylene foam joint groove forming strip 5mm wide x 40mm deep stuck along top edges of remaining slab.
2. Appropriate longitudinal mesh reinforcement, main bars parallel to longitudinal dimension.
3. Hole drilled 150-200mm deep to receive 20 or 25mm Ø x 400mm burr free dowel bars in Grade 250 steel at 300mm c/c.
4. Tie bars to be 20mm dia. for slabs up to 225mm thick.

FIGURE 3.4 Transverse Full Depth Repair

3.32 To reduce this risk:-

a). Saw full depth cuts at cooler periods of the day (ie. at night or early morning).

b). Saw along the joint before making cuts each side to eliminate a badly spalled joint.

c). Cool the concrete with water.

d). If a series of repairs is required make intermediate cuts to relieve stress at intervals rather than cutting sequentially along the road.

3.33 Saw cuts should not be extended into adjacent slabs. To ease removal of the slab in the corners and prevent under-cutting or breakout where the saw cannot reach, holes can be drilled full depth.

3.34 When removing an old joint in one lane and forming new joints at new positions staggered with those in other lanes, the new slab should be isolated from adjacent slabs longitudinally. No tie bars are necessary and a separating compressible material should be placed along the longitudinal joint.

OTHER CRACKS AT JOINTS

3.35 The main types of these cracks, their likely causes and appropriate remedies are summarised in Table 3.5. The two types of stitched crack repair are shown in Figure 3.5, and procedures described in Annex 1.

3.36 The reason for carrying out a stitched crack repair is to convert the crack into a tied warping joint which will allow the slab to "hinge" at that point whilst preventing the crack from becoming wider.

3.37 The use of resin mortar to bond-in the tie bars is recommended to try to ensure that the repair material hardens before movement at the crack disrupts the repair. It may be necessary to use a purpose made crack saw to cut the sealing groove along the line of a meandering crack. If the crack occurs within the middle third of the length of the tie bars at a longitudinal joint, it will not normally be necessary to install new 'staple' tie bars and only the sawing and sealing of a groove along the crack will usually be required.

Type of Defect	Cause	Remedy
Transverse or diagonal cracks at transverse joints	Dowel restraint - gross misalignment Late sawing of joint groove Misaligned top and bottom crack inducers	Transverse full depth repair
Longitudinal cracks at transverse joints	Compression failure Ingress of incompressible material into joint crack Edge restraint	Transverse, longitudinal or corner full depth repairs as appropriate
Longitudinal cracks at longitudinal joints	Misaligned top and bottom crack inducers Omission of bottom crack inducer	Longitudinal full depth repair or Stitched crack repair

TABLE 3.5 Other Cracks at Joints : Causes and Remedies

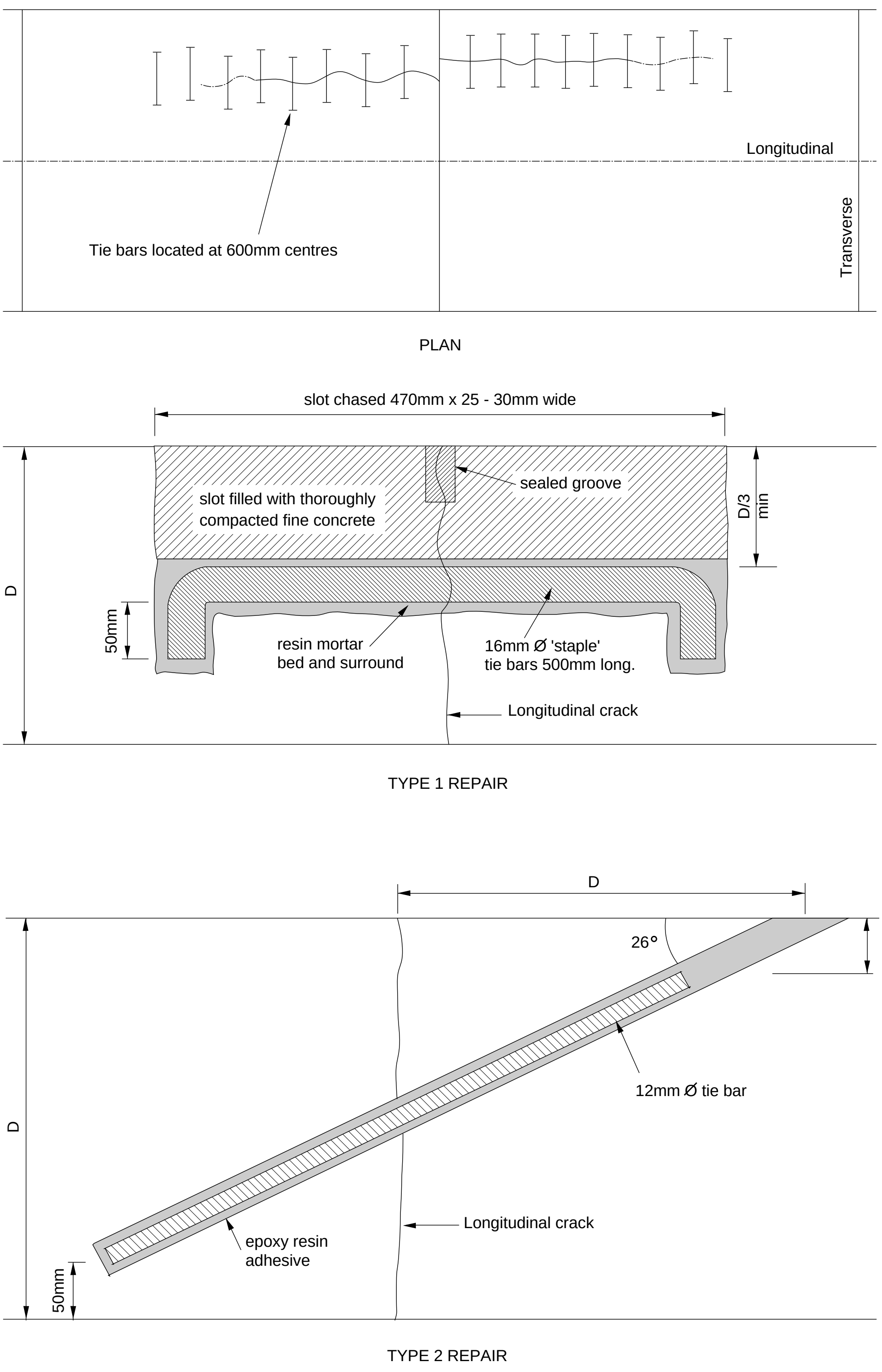


FIGURE 3.5 Stitched Crack Repairs

4. STRUCTURAL REPAIRS

4.1 Structural defects manifest themselves mainly in the form of various types of cracks in the slab but settlement or movement at joints may also occur which, without remedial action, can lead to the development of cracks and subsequent failure. Also considered as structural defects are compression failures of the 'blow-up' expansion type. Due to the unique features of continuously reinforced slabs and roadbases they are dealt with separately in paragraphs 4.32 to 4.36.

4.2 Structural cracks are classified according to their severity which is defined in terms of the unspalled width of the crack measured on the surface of the slab in cold weather (see Table 4.1).

TRANSVERSE AND LONGITUDINAL CRACKS

4.3 Narrow transverse cracks are a normal feature of all reinforced slabs and roadbases. They are considered to be structurally insignificant, are not expected to deteriorate any further, and consequently are not likely to require any remedial treatment. However, longitudinal cracks are not expected and may well deteriorate and develop further unless some remedial action is taken. Where longitudinal and transverse cracks cross there is a risk of spalling occurring, particularly if they cross obliquely. Reinforcement at medium transverse cracks may not have yielded completely and action should be taken to prevent the ingress of water, brine etc which could lead to corrosion and spalling. When sealing cracks, a sawn groove is preferred to one that is chased out by a router or single headed scabbing tool, because it is much more regular and can be made narrower. The reinforcement at wide cracks will almost certainly have yielded. In effect the cracks are likely to be acting as either undowelled or untied joints and consequently require at least a full depth and perhaps a bay replacement repair.

4.4 No cracks of any type are expected to occur between the joints in unreinforced slabs and, although narrow transverse cracks may not require any immediate treatment, it is quite likely that in this type of slab they will become wider in a fairly short time. Consequently at the very least they need to be regularly inspected. Medium and wide cracks should be treated in the same way as similar cracks in reinforced slabs.

4.5 The most likely cause and appropriate remedies for structurally significant cracks are given in Table 4.2.

Crack Definition	Width (mm)	Condition Assumed
Narrow	< 0.5	Full aggregate interlock and load transfer
Medium	0.5 - 1.5	Partial load transfer. Permits ingress of water
Wide	> 1.5	No load transfer. Permits ingress of water and fine detritus

TABLE 4.1 Crack Classification

Type of defect	Cause	Remedies
Transverse cracks	Excessive bay length Dowel bar restraint at joints Late sawing of joint grooves Inadequate reinforcement lap Sub-base restraint (lack of separation layer or excessive irregularity of sub-base)	Medium width cracks - form a groove and seal Wide cracks - transverse full depth repair
Longitudinal cracks	Excessively wide bays Omission of bottom crack inducer at longitudinal joint Compression failure Settlement	Narrow cracks in reinforced slabs require no immediate action Narrow cracks in unreinforced slabs and medium cracks in slabs of all types should be remedied by means of a stitched crack repair Wide cracks in all slabs should be remedied either by a longitudinal full depth repair or by means of a bay replacement repair

TABLE 4.2 Transverse and Longitudinal Cracks : Causes and Remedies

Bay Replacement

4.6 Prior to breaking out the affected bay a full depth saw cut shall be made around the perimeter of the repair to minimise damage to the surrounding slab. This shall include the existing transverse joints, care being taken to ensure that the saw cuts do not extend into adjacent bays. The concrete may then be sawn into smaller pieces before being broken up and removed from the bay. The concrete that remains in the corners of the repair after saw cutting shall be broken out carfefully to avoid undercutting the remaining slab.

4.7 Any reinstatement of the sub-base that is necessary shall be undertaken before the new dowel and tie bars are fixed at the transverse and longitudinal joints respectively. Particular care is necessary to ensure that any new sub-base material is fully compacted especially in the corners, and a heavy plate vibrator shall be used to compact either granular or cement bound sub-base material.

4.8 An existing cement bound subbase may be reinstated and regulated as necessary using sand/cement mortar, fine concrete or fine cold asphalt.

4.9 If an existing granular sub-base is to be replaced with cement bound material, any potential deleterious effect, due to creating a discontinuity in the underslab drainage, should be considered and appropriate action taken.

4.10 To avoid surface water ponding in the repair, it should either be prevented from entering by the use of sand bags or provision made for it to drain away.

4.11 The procedure for bay replacement is given in Annex 1. Note should be made of Chapter 3, paragraphs 3.31 to 3.34 regarding removal of slabs in summer.

DIAGONAL AND CORNER CRACKS

4.12 The term diagonal cracks is intended to include all multi- directional full depth cracks in the slab which are neither generally transverse, nor longitudinal, nor across the corners of bays. Corner cracks include single, full depth cracks varying in length from approximately 0.3 m to 2 m across the corners of bays, which, if not repaired, may lead to localised deterioration of the sub-base and perhaps subsequent mud pumping. The most likely causes and appropriate remedies are given in Table 4.3.

4.13 If a repair to the full width of a slab is not appropriate then a corner repair is carried out. When undertaking corner repairs it is desirable that as large a 'chamfer' as possible is provided across the corner to reduce the risk of a crack subsequently developing across the slab from that point. This means that it may not be possible to extend the saw cuts that are made around the corners of the repair through the full depth of the slab necessitating quite a lot of careful breaking out to the smooth vertical face that is required in the corners. Particular care should be taken to avoid damaging the remaining top edges of the slab.

4.14 It is essential that the repaired slab should not inhibit either contraction or expansion movement in the existing slab. For this reason it is recommended that no dowel or tie bars are provided in the edge which is parallel to the longitudinal axis of the slab, and that a 5mm thick expansion filler board is provided around the perimeter of each repair.

CRACKS AT MANHOLES AND GULLIES

4.15 If recesses in the slab which house surface water gullies or manholes etc are incorrectly positioned relative to transverse or longitudinal joints, cracks are likely to develop across the slab. Similar cracks are also likely to occur if the slab is 'propped' or resting on the gully or manhole construction. To ensure this does not happen, either the recess must be made sufficiently large to encompass the shaft of the structure and any concrete surround to it, or the top of the shaft and surround, must not be brought closer than 200 mm to the underside of the sub-base.

4.16 To reduce the risk of these cracks occurring, the recesses should be positioned in the corners of the bays, either astride or alongside a transverse joint, and have 'chamfered' corners. When this is not possible, an additional warping joint should be constructed from the centre of the recess across the slab to the nearest longitudinal joint and/or edge of the slab.

VERTICAL SLAB MOVEMENT

4.17 Vertical movement of the slab may develop either in the form of dynamic movement which occurs under passing traffic or permanent movement in the form of settlement of the slab or 'stepping' at joints or cracks.

4.18 Dynamic movement may be associated with mud-pumping, the usual signs of which are muddy stains on the surface of the slab which, unless remedied, is likely to eventually result in multiple cracking of the slab. Mud-pumping is probably also indicative of poor pavement or sub-soil drainage which should be corrected before any remedial work to the slab is undertaken. Seepage of water up through joints or along the edges of the slab may also indicate poor drainage.

Type of defect	Cause	Remedies
Diagonal Cracks	Settlement or heave of the sub-base or subgrade	Narrow cracks in unreinforced slabs and medium cracks in all slabs will need to be either sealed or remedied by means of a stitched crack repair Wide cracks will necessitate either a bay replacement repair or a full depth repair
Corner Cracks	Lack of load transfer at joints Dowel bar restraint near edge of slab Ingress of solids into joint at edge of slab Acute angles in non-rectangular slabs Loss of sub-base support	Corner or transverse full depth repair as appropriate

TABLE 4.3 Diagonal and Corner Cracks : Causes and Remedies

4.19 Dynamic movement may be measured as deflections of the slab at joints or cracks under a static or dynamic load. A dynamic load may be applied by a moving lorry, Deflectograph or Falling Weight Deflectometer. In each case, high absolute deflection or relative deflection across joints or cracks is indicative of poor support and possible voiding.

4.20 Settlement is most likely to occur as a result of consolidation or compaction of the fill material in embankments, particularly in the back-fill behind structures or when the pavement is constructed on ground which has a low bearing capacity. It may also occur where there are shallow mine workings etc.

4.21 `Stepping' in the form of permanent relative vertical movement at joints and wide cracks is a phenomenon which can occur in slabs where there is no effective load transfer in the form of dowel or tie bars at joints, and in which the reinforcement, if any, has yielded the cracks.

4.22 These defects, their likely causes and appropriate remedies are described in Table 4.4. However, it should be noted that the remedy for the immediate problem may not remove the original cause, eg. ground softening due to water ingress. It is essential that the cause is understood before ordering repairs.

Slab Lifting

4.23 Raising the level of slabs by slab lifting is a very controllable process in which the slab is connected to a lifting frame which straddles the bay and is raised to the required level in increments of a few millimetres at a time by the operation of hydraulic jacks (Procedure given in Annex 1). Whilst the slab is still connected to the lifting frame, the void that has been created underneath should be filled by either pressure or vacuum grouting. When slab lifting is undertaken over a long length, it may be necessary to install stitched tie bars across the longitudinal joint to prevent this from opening subsequently.

Type of defect	Cause	Remedies
Dynamic movement at joints and cracks	Lack of support from sub-base Lack of, or ineffective, load transfer dowels or tie bars at joints	Pressure or vacuum grouting
Mud-pumping	Poor pavement or sub-soil drainage	Renew or improve existing surface water and/or sub-soil drainage as necessary
Settlement	Compaction or consolidation within the sub-soil drainage Movement in underlying ground	Localised settlement may be remedied by means of slab lifting in conjunction with either pressure or vacuum grouting Severe settlement can be remedied either by reconstruction of the slab or by the construction of an overlay as described in 7.4.2.5.
Stepping at joints and cracks	Lack of effective load transfer dowels and tie bars at joints	Slab lifting undertaken in conjunction with either pressure or vacuum grouting and/or bump cutting

TABLE 4.4 Vertical Slab Movement, Mud Pumping and Settlement : Causes and Remedies

4.24 Slab lifting can also be used on continuously reinforced concrete pavements, but requires longitudinal saw cutting between lanes in order to isolate each section of pavement. In contrast to other types of concrete pavement, both the slab and the underlying cement bound sub-base should be cut through if lifting is to be successful, as a result of the bonding created between these two layers.

Pressure grouting

4.26 Pressure grouting is used either to fill small voids and stabilise dynamic movement of the slab or to fill the voids that are created when slabs are raised to correct settlement or stepping at joints and cracks (Procedure given in Annex 1). As well as cementitious and resin grouts a dry mix mortar may also be used to fill voids, but it may be necessary to raise the slab initially to a slightly higher level than is actually required to allow for future compaction once trafficked. Fluid grout is more suitable for the filling of smaller voids under the slab.

Vacuum grouting

4.26 In this process, normally a low viscosity resin grout is induced to flow into voids beneath the slab by the application of a vacuum. Holes approximately 30 mm in diameter are drilled through the slab on 1 m x 1 m grid to provide the vacuum suction and grout injection points (see Annex 1, Figure 1.1).

4.27 The advantages of this process are that any water beneath the slab is drawn off before the grout is injected and the use of low viscosity grout enables very small voids to be penetrated. There is also little danger of inadvertently filling service ducts.

4.28 Care should be taken never to grout up expansion joints, particular care is necessary when operating during colder weather. Preventing free movement of slabs could lead to compression type "blow-up" failures.

4.29 The unit of measurement of grout in both pressure and vacuum grouting should be the litre.

COMPRESSION FAILURES

4.30 Compression failures can occur in concrete pavements either in the form of longitudinal cracks, or as a series of short longitudinal and transverse cracks close to a joint giving a 'crazed' appearance, or as "blow-up" expansion failures in which the slab is crushed and may buckle as part of it lifts up from the sub-base. These defects occur as a result of excessively high compressive stresses which develop in the concrete due to restrained expansion of the slab during periods of hot weather, the effects of which may be accentuated by a high moisture content in the concrete.

4.31 Among the defects found at joints where "blow-ups" have occurred are defective joint seals, misaligned or badly corroded dowel bars, severe spalling, longitudinal cracks, a lack of bond between upper and lower layers of concrete (in two layer slab construction) and poorly compacted concrete. "Blow-ups" normally extend the whole width of at least one traffic lane and require immediate temporary repair to enable traffic to continue using the carriageway. Permanent repair is effected by means of bay replacement or transverse full depth repairs across the full carriageway width incorporating a 20mm filler board to enable a larger amount of expansion to take place subsequently.

CONTINUOUSLY REINFORCED CONCRETE

4.32 Continuously reinforced concrete pavements, and in particular those which have a concrete running surface, are generally more difficult and costly to repair than other types of rigid pavement because of the large quantity of heavy steel reinforcement in the slab and the high levels of stress that are generated in it. The most appropriate time of the year to carry out work requiring part of the slab to be demolished (eg full depth repairs), is during the Spring and Autumn months, which avoids working during particularly hot weather when compressive stresses are high and the slab may buckle, or during cold weather when the slab is in tension.

4.33 Preventive maintenance to prolong the structural life of the slab is highly desirable. Measures such as the sealing of medium to wide cracks, repair of spalled cracks, and grouting to stabilise vertical slab movement may all be necessary.

4.34 A defect peculiar to continuously reinforced slabs is that known as a "punchout" in which fragments of broken concrete may be "punched" by the action of traffic downwards into the underlying sub- base layer. This type of defect usually occurs at locations where severe differential settlement has taken place or failure of the sub- base is evident. "Punchouts" occur particularly where closely spaced transverse cracks have developed along with longitudinal cracks in a localised area. This subsequently results in the progressive disintegration of the slab under the action of traffic.

4.35 Construction defects, such as poorly compacted concrete or inadequate laps of the longitudinal reinforcing bars, can result in localised damage to continuously reinforced slabs. Extensive spalling of concrete above the reinforcement is rare in continuously reinforced slabs unless there is insufficient cover to the steel.

4.36 The appropriate remedy for both deep spalling and the "punchout" type of defect is a full depth repair (Procedure given in Annex 1). Where possible, the repaired area shall be not less than 0.5m from the nearest adjacent transverse crack that is to remain, nor closer than 3m to an end-of-day construction joint. Because of the relatively high level of stress that can develop in this type of pavement, full depth repairs shall be carried out one lane width at a time and succeeding repairs not made until the first has achieved sufficient strength to be trafficked. The continuity of the reinforcement shall be maintained where necessary by adequate laps.

TEMPORARY REPAIRS

4.37 On some occasions it may be necessary to undertake temporary or emergency repairs quickly, using materials which can be trafficked in a short time. However it is advisable to carry out permanent repairs as soon as practicable, otherwise further deterioration of the slab may occur. Temporary repairs may be required to perform satisfactorily for several years and therefore adequate preparation, such as removal of all loose and damaged concrete, should be carried out.

4.38 For full depth temporary repairs, either dense bituminous macadam or hot rolled asphalt may be used. Alternatively, suitably sized precast concrete slabs can be used, provided they are properly levelled and seated on the existing sub-base to prevent rocking. Any potential difference in finished road level may be made up by a layer of CBM3 or 4 between the precast slab and existing sub-base.

4.39 Partial depth repairs using either normal bituminous, special proprietary bituminous or thermoplastic material may be undertaken as a temporary remedy to shallow or deep spalling at joints or to surface scaling. If compacted by hand it may be necessary to lay the repair material slightly higher than the surface of the surrounding slab to allow for further compaction under traffic. It is recommended that the minimum thickness of this type of repair should be 20mm and if the repair is a deep one, it is advisable to apply the repair material in layers approximately 50-100 mm thick.

4.40 Materials that are applied across a joint should have elastic properties that will enable them to accommodate movement at the joint. If necessary, the surface of temporary repairs may be 'dusted' with cement or sand to prevent the repair materials being picked up by the tyres of vehicles which traffic it soon after the repair.

TRENCH REINSTATEMENTS

4.41 Advice on the excavation and reinstatement of openings in a rigid pavement are given in the Specification (MCHW1) Series 700. The use of foamed concrete as backfill material may be appropriate in some circumstances.

5. STRENGTHENING

5.1 Strengthening of an existing rigid or rigid composite pavement may be required to extend its life due to an increase in traffic because the structural condition of the existing pavement has deteriorated to the point where it is no longer able to carry the predicted future traffic. HD 29 (DMRB 7.3.2) and HD 30 (DMRB 7.3.3) describe methods of assessing the residual life of rigid pavements and the selection (and basic thickness design) of maintenance measures. This chapter concentrates on the practical considerations of carrying out such works.

OVERLAYS

5.2 If the existing slabs are relatively intact then it is usual to recommend their retention in any strengthening measures. However before overlaying, the pavement must be brought up to a relatively uniform standard, by replacing failed bays, grouting of voids, rectifying joint defects, etc.

5.3 Overlaying of concrete pavements (excluding continuously reinforced concrete) represents greater difficulties than overlaying bituminous pavements due to the discontinuities which occur at joints or wide cracks. Joints (and wide cracks) represent a source of concentrated movement in the pavement brought about by a combination of:-

a) Load induced movements;

b) Long term temperature induced movements (seasonal);

c) Short term temperature induced movements (diurnal);

d) Drying shrinkage movements.

5.4 An overlay placed over existing jointed concrete slabs will be subjected to a concentration of strain at locations of joints (and wide cracks) in the underlying pavement. Therefore the overlay must be designed to accommodate this movement.

5.5 For concrete overlays this can be carried out in two basic ways:-

a) By forming joints in the overlay at the same location as joints (and wide cracks) in the underlying pavement;

b) By separating the overlay from the underlying pavement using, say, as regulating layer of bituminous material.

5.6 It should be noted that a concrete overlay that is sufficient to strengthen the road may be of inadequate thickness to provide cover to reinforcing steel, and may therefore need increasing in depth.

5.7 To help delay/resist reflection cracking of bituminous overlays one or more of the following measures are required:-

a) Using thicker bituminous layers than required for the predicted traffic loading only;

b) Creating a "joint" in the bituminous surfacing by sawing and applying a suitable sealant;

c) Using modified binder to improve the elastic recovery and fatigue cracking properties of the bituminous materials;

d) Using stress-absorbing or "reinforcing" materials to distribute strains above joints (or wide cracks) by partial debonding or other mechanisms.

5.8 In method b) reflection cracks do not always follow the line of the formed joint and several parallel cracks can be created. To help overcome this, a band of surfacing material is sometimes removed, and replaced with a modified bituminous material.

5.9 Modified binders and some stress-absorbing or "reinforcing" materials are relatively new and there is insufficient evidence to date to prove their long term effectiveness and overall economy.

5.10 If the existing concrete slabs are in poor condition, with many cracks, underslab voiding, stepping at joints, etc. then it may be advantageous to break up the slabs further, followed by seating the resulting concrete "blocks", to give a more uniform supporting layer for either a concrete or bituminous overlay and to effectively eliminate the large strain concentrations at joints (and wide cracks). This is discussed further in 5.24 to 5.31.

Bonded Concrete

5.11 Bonded concrete overlays are only appropriate for existing concrete pavements in good condition and where structural and level considerations dictate that only a thin overlay (eg. 50-100mm) is required. A relatively small increase in slab thickness can greatly increase pavement life, but is not considered worthwhile to apply overlay thicknesses less than 50mm since the material cost is only a fraction of the overall strengthening cost. Any assessment of increased life should be based on the properties (eg. strength) of the existing slab, making allowance for fatigue damage to date due to past traffic.

5.12 It is essential that a good bond is achieved between the overlay and the existing concrete, since bond failure could lead to major distress, with cracking and spalling of the concrete across the carriageway width. Special surface treatment is therefore required, the extent depending on the existing surface condition, aggregate type, etc.

5.13 This may consist of two passes of a grit or shot blaster, the second one just prior to overlaying. A cement grout may be used to assist in creating the bond, but, if used, this must be applied immediately before the overlay concrete is placed, otherwise premature setting of the grout may create a slip layer. The existing joints shall also be cleaned and resealed and any spalling at joints repaired prior to overlaying.

5.14 Joints and wide cracks in the underlying pavement should be reproduced in the bonded concrete overlay, ensuringthat the appropriate joint type (eg. contraction or expansion) is used. There are problems in achieving this in practice which means that the work is labour intensive and requires close supervision.

5.15 Consideration should be given to using a limestone aggregate in the overlay since this has a lower coefficient of thermal expansion than, say, flint gravel or granite aggregates and will therefore shrink less during curing. Use of fabric reinforcing mesh in the overlay may be required to help control shrinkage induced cracking.

5.16 Since there is no reduction in the total number of joints, this method of overlaying can lead to continuing maintenance expenditure, and associated traffic delays, in the future.

Unbonded Concrete Overlays

5.17 When structural and level consideration dictate that a thicker overlay is required, then an unbonded overlay may be used. Such concrete overlays may be either unreinforced, jointed reinforced or continuously reinforced slabs. Reinforced concrete overlays are suitable for strengthening of existing pavements that have deteriorated to a considerable degree as well as those that are still in good structural condition.

5.18 Prior to the construction of the overlay it is necessary to stabilise any vertical movement that might be occurring at joints or cracks in the existing slab by grouting or full depth reconstruction. Any spalling at joints shall also be rectified with bituminous or cementitious materials and the surface levels regulated if necessary. A partially unbonded overlay must not be attempted since this cannot be specified nor produced in a uniform manner in practice.

5.19 Use of an unbonded overlay does not constrain the designer to the same slab shape and size as the underlying pavement. Therefore continuously reinforced concrete may be used.

5.20 For an unbonded overlay in jointed reinforced concrete, joints need not be reproduced in the same locations as the existing slab. However, the pavement design must ensure that debonding occurs by some positive means (eg. by use of a bituminous regulating layer of nominal thickness 40-50mm).

5.21 The minimum practical thickness recommended to achieve cover to reinforcement, to enable proper compaction and to help prevent reinforcement ripple (for continuously reinforced concrete overlays) is 200mm.

Bituminous Overlays

5.22 The thickness of bituminous overlays is determined not only by structural requirements but also by the need to minimise or avoid reflection cracking which may result from movement in joints or cracks int he underlying slab. Recommended thicknesses are given in HD 30 (DMRB 7.3.3).

5.23 Considerable care must be taken before the overlay is applied. Joints will require checking and remedial works carried out if necessary. Depressions and potholes should be filled and all cracks sealed. In particular, measures must be taken to limit the amount of horizontal and vertical movements at joints and wide cracks.

Cracking and Seating

5.24 If the existing pavement is too distressed and variable to repair to a relatively uniform condition, then cracking and seating in situ may be appropriate prior to overlaying. This method has also been proposed as a means of delaying or controlling reflection cracking in a bituminous overlay to a rigid pavement. The aim is to reduce the size of each concrete element so that movements are no longer concentrated at joints.

5.25 The process also helps to seat the concrete, eliminating any voiding which may have developed below the slab during its life. However the resulting load spreading ability of the concrete is considerably reduced. Consequently there is a contradictory requirement between the need to increase the number of cracks to help control reflection cracking, and the need to retain some integrity to help load spreading and overstressing of the subgrade.

5.26 An optimum crack spacing for each site has to take into account the following:-

a) Existing Thickness and Type of Concrete Pavement;

b) Existing type and quality of Subgrade;

c) Proposed Overlay Thickness and Material Type;

d) Climatic Factors;

e) Trafficking Factors.

5.27 The first site using cracking and seating in the UK was in 1978 and several other sites have subsequently been treated. However, there appears to be insufficient experience to choose an optimum crack spacing, as evidenced by USA practice where recommendations for the size of the broken concrete elements range from 450mm x 600mm to 2m x 2m. Where the pavement is lightly trafficked and only a thin bituminous overlay is envisaged, cracking the slabs to little more than a granular sub-base may be appropriate.

5.28 Cracking should be carried out using equipment designed for the process to produce concrete `blocks' of relatively uniform shape. Equipment currently available includes:-

a) Guillotine type drop hammer;
b) Pneumatic or hydraulic hammer;
c) Whip hammer;
d) Demolition ball.

5.29 For 1m to 2m size blocks a guillotine hammer, demolition ball or heavy impact hammer would be suitable. With the smaller whip hammers and hydraulic type hammers the impact spacing is less, but the overall effect is to produce cracks at up to 1m spacing. These are suited to more lightly trafficked roads, or in urban areas, where heavy percussion equipment would be undesirable for environmental reasons.

5.30 Trials should be carried out at each site to determine the optimum energy for each "drop" and spacing of "drop" to achieve the desired objective. It is essential that the cracked slabs are properly seated by appropriate use of both deadweight and vibratory rollers, to ensure that all voids are filled and that no future "rocking" of concrete elements will occur.

5.31 Prior to overlaying a regulating layer is required and this can be provided by either a bituminous or cement bound material. The overlay itself may consist of a flexible or rigid pavement, but continuously reinforced concrete in particular offers good load spreading properties which enable it to accommodate some localised variation in support from the underlying materials.

Reconstruction

5.32 Strengthening can also be achieved by the demolition and reconstruction of the existing pavement. This will be necessary when the existing slab has deteriorated structurally to the extent that it is considered unsuitable for use as the sub-base or roadbase beneath a new overlay or in those cases where an increase in the level of the running surface of the road cannot be accommodated.

5.33 Slabs may be demolished in a variety of ways with either pneumatic, mechanical or resonant breakers, the latter being claimed to be particularly appropriate for the demolition of reinforced slabs.

5.34 Consideration should be given to recycling the excavated slabs by crushing and using as aggregate for capping, sub-base, cement-bound materials or concrete.

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MAINTENANCE AND REPAIR PROCEDURES

Stitched Crack Repair - Type 1

1.1 Procedure (see Chapter 3, Fig 3.5)

a) Chase out slots 25-30mm wide by 470mm long at 600mm centres and at right angles to the line of the crack. The depth of the slots shall be such as to ensure that, when bedded, the tie bars lie between 1/3 and 1/2 the depth of the slab below the surface.

b) Drill holes 25-30mm in diameter by 50mm deep at each end of the slots.

c) Clean out the slots using oil-free compressed air.

d) When in a dry state, prime the slots, place the staple tie bars into beds of epoxy resin mortar and cover to a minimum depth of 30mm with the same material.

e) Prepare the sides and complete the filling of the slots with thoroughly compacted resin or cementitious mortar.

f) Cure and open to traffic.

g) Saw a groove along the line of the crack and seal.

Stitched Crack Repair - Type 2

1.2 Procedure (see Chapter 3, Fig 3.5)

a) Ascertain the depth of the slab.

b) Mark out drilling points at a distance from the crack equivalent to the depth of the slab, at 600mm intervals along the crack with alternate points on opposite sides of the crack.

c) Drill holes (min. 16mm diameter) at approximately 26º to the surface of the slab to a depth which allows 50mm cover at the bottom of the slab.

d) Place in cartridges of epoxy resin type adhesive.

e) Insert 12mm diameter deformed tie bars through the cartridges.

f) Rotate the bars for about 1 minute to ensure adhesive is well mixed.

g) Cut the bars so that the end is approximately 50mm below the surface.

h) Alternatively, the length of the tie bars may be pre-determined by measuring down the hole and notching the bars at a point 50mm below the surface. After the bars have been driven in, rotated and the mortar set, the surplus can be broken off by twisting. Any bars which continue to twist after the mortar should have set shall be deemed to be unbonded. They shall be withdrawn and the hole redrilled.

i) Plug the remainder of the hole with an epoxy resin mortar.

j) The road may be opened to traffic as soon as the mortar in the holes has set.

Bay Replacement

1.3 Procedure

a) **Make a vertical saw cut around the perimeter of the repair through the full depth of the slab taking care to ensure that saw cuts do not extend into the adjacent bays. Further saw cuts may be made to enable the concrete to be removed in convenient pieces.**

b) **Carefully break out and remove the existing concrete from within the repair area without damaging the remaining slab and with the minimum amount of damage to the sub-base.**

c) **Reinstate or regulate the sub-base as necessary.**

d) **Drill for and fix new dowel and tie bars at transverse and longitudinal joints.**

e) **Provide new separation layer.**

f) **Position reinforcement if required.**

g) **Stick groove forming strips along the top edges of the existing slab.**

h) **Place, spread, compact and finish pavement quality concrete in accordance with the requirements of the Specification (MCHW1) Series 1000, flush with the surface of the adjacent slab and to within a tolerance of 3mm and with a difference of not more than 4mm between the surface of the repair and a 3m straight edge.**

i) **Apply a wire brushed surface texture and cure immediately by the application of a sprayed resin based, aluminized curing compound.**

j) **Seal joints as specified.**

Slab Lifting using Space Frames.

1.4 Procedure

a) **Make a full depth saw cut along the longitudinal joint or joints to separate the bays that are to be raised from the adjacent slab.**

b) **Drill 50mm diameter lifting holes into the bay at positions to suit the lifting frame, and to straddle joints or cracks.**

c) **Drill 32mm to 36mm diameter holes through the slab and bound sub-base on a 1m x 1m grid for grout injection.**

d) **Position hydraulically operated lifting frames transversely astride the bay with lifting bolts over the lifting holes.**

e) **Fix threaded female sleeves into the lifting holes with resin grout or mortar. Ensure the sockets remain vertical during setting of the mortar.**

f) **Screw the lifting bolts into threaded sleeves at the lifting points.**

g) **Establish a level reference datum across the bay that is to be raised.**

h) **Slowly raise the bay by controlled operation of the hydraulic jack at each corner of the lifting frames in sequence for a few millimetres.**

i) **Strat grout injection, using a Portland Cement/PFA dry mix in the ratio of 1 to 1, using the pressure grouting system for larger voids, or the vacuum grouting system for small voids (see procedure for pressure or vacuum grouting).**

j) **Lift and grout in stages until the correct level is reached or for a maximum lift of 50mm. If more than a 50mm lift is needed, raise adjacent areas along the carriageway, before returning to complete the process to the required level.**

k) **Repeat the process for adjacent lanes.**

l) **Clean out the injection and lifting holes and plug them with a cementitious mortar. Remove any excess grout or dry material.**

m) **For long lengths of more than 15m where the longitudinal joint tie-bars have been cut, use either of the crack stitching methods to tie the joint, with a minimum of 4 bars at 600mm centres placed in the centre of each unreinforced slab. The spacing of bars in reinforced slabs should be agreed for each site.**

Pressure Grouting

1.5 **Procedure (see Figure 1.1)**

a) **Avoiding services, drill 32mm to 36mm diameter grout injection holes through the slab and any bound sub-base on a 1m x 1m grid extending over the whole area of the void under the slab.**

b) **Remove any water from the void by blowing with compressed air at each end of the grout holes in sequence, working progressively across and along the bay, down crossfalls and longitudinal gradients.**

c) **Inject fluid grout or dry mix mortar under pressure at each of the grout holes in sequence, working progressively across and along each bay. Grouting shall continue at each hole until refusal. Temporarily plug adjacent holes when excess grout or plumes of dry mortar emanate from them.**

d) **Upon completion of the pressure grouting process any surplus grout shall be removed from the surface of the slab and the holes cleaned out and made good with resin or cementitious mortar . Any resin grout which cannot be removed from the surface of the slab may be blinded with calcined bauxite if this can be done before the grout has gelled.**

e) **Open to traffic after the appropriate minimum curing period has elapsed.**

Vacuum Grouting.

1.6 **Procedure (see Figure 1.1)**

a) **Avoiding services, drill 32mm to 36mm diameter grout injection holes through the slab and any bound sub-base on a 1m x 1m grid extending over the whole area of the void under the slab.**

b) **Temporarily plug the holes and sweep the surface clear of all debris.**

c) Remove the temporary plugs and place vacuum channels in position.

d) Place clear, flexible plastic sheeting over the area to be grouted and on top of the vacuum channels.

e) Effectively seal around the vacuum and injection holes and around manholes to gully openings to prevent ingress of air into the voids or grout into the services.

f) Apply a vacuum to holes at edge of treatment area and draw off any water from the void beneath the slab.

g) With the vacuum applied, puncture the plastic sheeting at the injection holes, pour grout into them in the required sequence and continue the process until the grout ceases to be drawn into the void. If grout begins to be drawn up through any of the vacuum points, that hole should be plugged to avoid grout flowing on to the surface of the slab.

h) Upon completion of the vacuum process any surplus grout shall be removed from the surface of the slab and the holes cleaned out and made good with resin or cementitious mortar. Any resin grout which cannot be removed from the surface of the slab may be blinded with calcined bauxite if this can be done before the grout has gelled.

i) Open to traffic after the appropriate minimum curing period has elapsed.

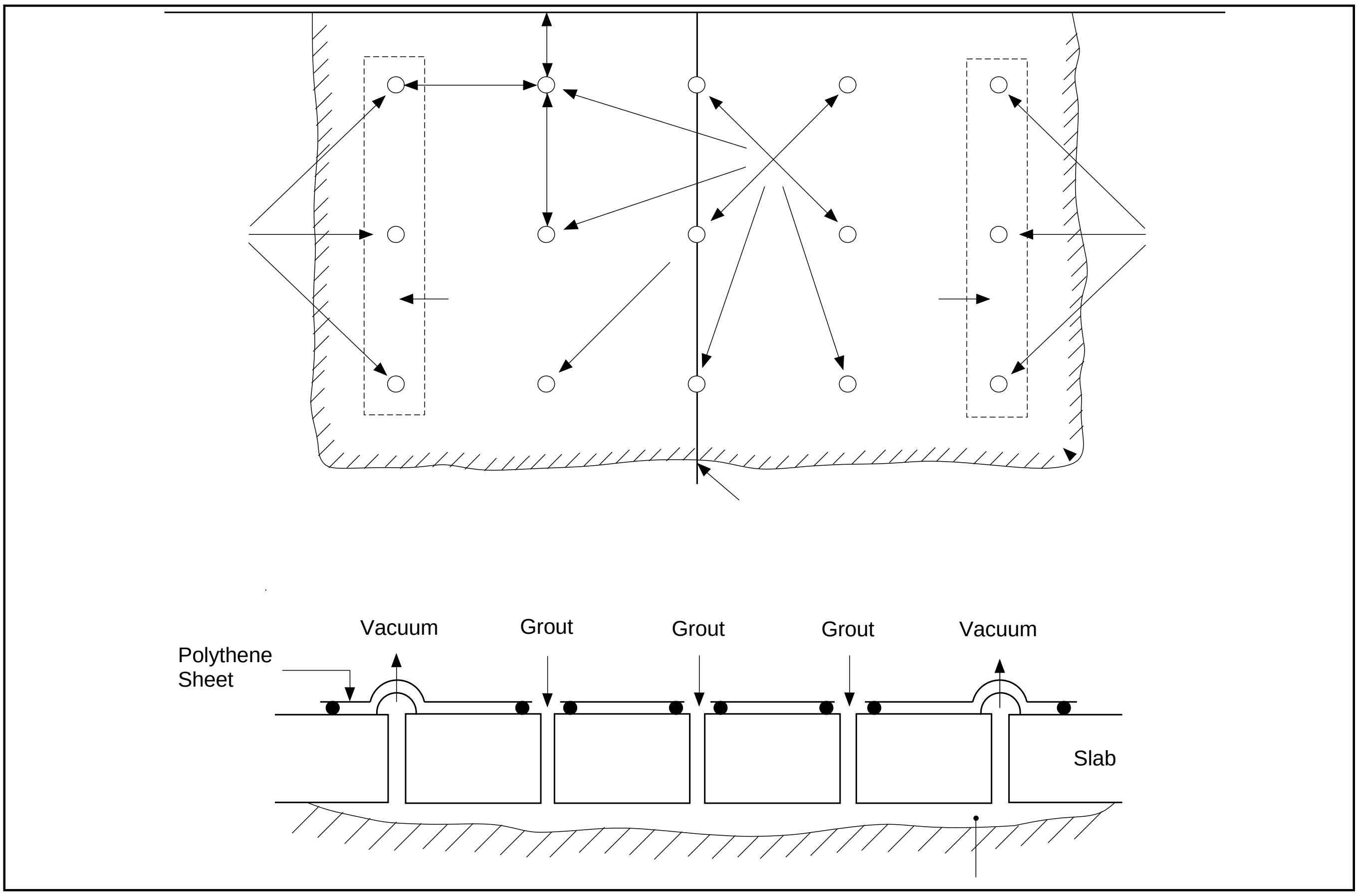

FIGURE 1.1 Vacuum Grouting Diagram

Continuously Reinforced Slabs and Roadbases - Full Depth Repair

1.7 Procedure

a) **Mark out a square or rectangular area encompassing the defect. The edges of the repair shall be at least 1.5m from the nearest transverse crack and 3m from any transverse construction joint. The minimum length of repair shall be 1.0m.**

b) **Saw a groove around the perimeter of the repair not more than 40mm deep and to a depth less than that of the reinforcement. (Particular care shall be taken to ensure that the reinforcement is not cut at the edge of the repair).**

c) **Carefully break out the defective concrete in order to form a sound vertical edge to the repair, care being taken to limit damage to and bending of the reinforcement to a minimum. Should it become necessary to cut the reinforcement in order to remove the concrete, the cut must be made at least one lap away from the edge. Bars made of high yield steel shall not be bent and subsequently straightened.**

d) **Reinstate the sub-base as necessary.**

e) **Lap and tie or weld in any new or additional reinforcement that may be required to replace that which has been damaged or removed. The length of tied laps shall be at least 35 bar diameters or 450mm, whichever is the greater for longitudinal bars and 300mm for transverse bars. The minimum length of any welded lap shall be 150mm.**

f) **Erect side forms where necessary.**

g) **Stick groove forming strips or cork seals along the top edges of the surrounding slab.**

h) **Clean out the area with compressed air and thoroughly dampen the sub-base and edges of the repair.**

i) **Place and evenly spread high early strength pavement quality concrete to the appropriate surcharge, compact using internal and surface vibration and finish flush with the surface of the adjacent slab and to within a tolerance ± 3mm and with a difference of not more than 4mm between the surface of the repair and a 3m straight edge. Particular care shall be taken to ensure thorough compaction around the reinforcement and the edges of the repair.**

j) **Apply a wire brushed surface texture and cure immediately by the application of resin based, aluminized curing compound.**

k) **Seal joints as specified.**