VOLUME 7 PAVEMENT DESIGN AND MAINTENANCE

SECTION 4 PAVEMENT MAINTENANCE METHODS

PART 2

HD 32/16

MAINTENANCE OF CONCRETE ROADS

SUMMARY

The purpose of this document is to describe how to maintain exposed concrete road pavements including the repair of structural damage and refurbishment of worn running surfaces on the UK strategic road network.

INSTRUCTIONS FOR USE

1. This document supersedes HD 32/94 which is now withdrawn.
2. Remove existing contents page for Volume 7 and insert new contents page for Volume 7 dated February 2016.
3. Remove HD 32/94 and archive as appropriate.
4. Insert HD 32/16 in to Volume 7, Section 4, Part 2.
5. Archive this sheet as appropriate.

Note: A quarterly index with a full set of Volume Contents Pages is available separately from The Stationery Office Ltd.

HD 32/16
Volume 7, Section 4,
Part 2

HIGHWAYS ENGLAND

TRANSPORT SCOTLAND

WELSH GOVERNMENT
LLYWODRAETH CYMRU

THE DEPARTMENT FOR REGIONAL DEVELOPMENT
NORTHERN IRELAND

Maintenance of Concrete Roads

SUMMARY

The purpose of this document is to describe how to maintain exposed concrete road pavements including the repair of structural damage and refurbishment of worn running surfaces on the UK strategic road network.

Volume 7 home page

VOLUME 7 PAVEMENT DESIGN AND MAINTENANCE

SECTION 4 PAVEMENT MAINTENANCE METHODS

PART 2

HD 32/16

MAINTENANCE OF CONCRETE ROADS

Contents

1. INTRODUCTION

GENERAL

1.1 Proper maintenance of pavements is important if the structure is to have a reasonable expectancy of remaining in a satisfactory condition and achieving the designed service 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 of the DMRB gives recommendations for maintenance, repair and structural strengthening of layers of concrete and hydraulically bound mixtures in pavements based on current experience using products and technologies which are tried and proven. Allowance has also been made for innovation, with alternative products and technologies encouraged for consideration. The latest advice should be sought from the Overseeing Organisation if alternative products and technologies are to be considered.

1.3 Procedures for maintenance and repair are given in Annex 1 of this document and reference shall also be made to the Specification (MCHW). For more general information on the maintenance and repair of concrete roads reference can be made to the Manual for Maintenance and Repair of Concrete roads.

1.4 For the purpose of minor repairs, surface treatments, and major strengthening works; pavements with equal to or greater than 50 mm of bituminous "surfacing" over concrete and/or hydraulically bound mixtures should be treated in accordance with HD 30 (DMRB 7.3.3) and HD 31 (DMRB 7.4.1).

1.5 The requirements and guidance on this document are given on the basis that the maintenance of concrete roads will be carried out using the Specification for Highway Works (MCHW Vol.1). However, products conforming to equivalent standards and specifications of other member states of the European Union and tests undertaken in other member states may be acceptable in accordance with the terms of the 104 and 105 Series of Clauses of that Specification.

MUTUAL RECOGNITION

1.6 Any reference in this specification to a "British Standard", or to a "British Standard which is an adopted European Standard", is to be taken to include reference also to the following standards:

a) a standard or code of practice of a national standards body or equivalent body of any EEA state or Turkey;

b) any international standard recognised for use as a standard or code of practice by any EEA state or Turkey;

c) a technical specification recognised for use as a standard by a public authority of any EEA state or Turkey; and

d) a European Technical Approval (ETA) issued in accordance with the procedure set out in directive 89/106/EEC.

Where there is a requirement in this specification for compliance with any part of a British Standard or a British Standard which is an adopted European Standard, that requirement may be met by compliance with any of the standards given above, provided that the relevant standard imposes an equivalent level of performance and safety provided for by a British Standard or a British Standard which is an adopted European Standard.

"EEA State" means a state which is a contracting party to the EEA Agreement.

"EEA Agreement" means the agreement on a European Economic Area signed at Oporto on the 2nd of May 1992 as adjusted or amended.

IMPLEMENTATION

1.7 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 Organisation this would not result in significant additional expense or delay. Design organisations should confirm its application to particular schemes with the Overseeing Organisation.

2. DECIDING ON TREATMENT TYPE

SCOPE OF GUIDANCE

2.1 There are several different types of pavements incorporating concrete and/or hydraulically bound mixtures. The appropriate treatments will vary according to type of pavement and defect. Those types of pavement incorporating concrete and/or hydraulically bound mixtures most commonly encountered are:

- CRCP – Continuously reinforced concrete pavement
- CRCB – Continuously reinforced concrete base
- JRC – Jointed reinforced concrete pavement
- JUC – Jointed unreinforced concrete pavement
- Thinly overlaid concrete pavements and/or hydraulically bound materials with less than 50 mm thick flexible "surfacing"

2.2 For the purpose of minor repairs, surface treatments, and major strengthening works; maintenance of the pavements types detailed in Section 2.1 will be undertaken in accordance with this document HD32 (DMRB 7.4.2).

2.3 Structural deterioration mechanisms in flexible pavements are very different to those in rigid pavements and pavements with hydraulically bound base layers. Therefore, pavements with equal to or greater than 50 mm of bituminous "surfacing" are outside of the scope of HD32 (DMRB 7.4.2) and shall be treated in accordance with HD 30 (DMRB 7.3.3) and HD 31 (DMRB 7.4.1).

MAINTENANCE ASSESSMENT

2.4 The maintenance assessment procedure for the types of pavements described in Section 2.1, shall have been carried out in accordance with HD 30 (DMRB 7.3.3). The Network survey data sets need to be collected and reviewed following the route of assessment of treatment for rigid pavement and pavements with hydraulically bound base layers. The following section describes the major and minor defects.

MAJOR AND MINOR DEFECTS

2.5 Distress in the types of pavement described in Section 2.1 is evident by the following defects, identified using pavement conditions data sets:

Major Defects

Provision of skid resistance below investigatory level with related accident history as detailed in HD 28 (DMRB 7.3.1)

- Rocking slabs
- Stepping (transverse and longitudinal)
- Pumping
- Longitudinal Cracking

- Transverse Cracking
- Deep Spalling (equal to or greater than 10 mm depth)
- Structural rutting within bituminous surfacing
- Reflective cracking within bituminous surfacing
- Corner Cracking (also known as Corner Break)
- “Slab” sinking
- Extensive shallow spalling to a depth less than or equal to 10 mm

Minor Defects

- Joint seal damage/missing
- Surface scaling
- Localised shallow spalling to a depth less than or equal to 10 mm
- Skid resistance below investigatory level without related accidents as detailed in HD 28 (DMRB 7.3.1)
- Accident Data where the skid resistance is above the investigatory level as detailed in HD 28 (DMRB 7.3.1)
- Asphalt surfacing defects such as surface cracking, loss of aggregate due to hardening of the bitumen (fretting) and surface rutting

MAINTENANCE SCHEME AND WORKING WINDOWS

2.6 The general decision making process for treatment design is given in HD 30 (DMRB 7.3.3), including consideration of necessity of treatment and whole life cost. In addition to the pavement and defect type; the selection pavement treatment for each scheme will depend on the length of the available working window. Advice should be sought from the Overseeing Organisation as to the whole life cost of treatments and want can be achieved in available working windows. The following section gives specific detail for the types of pavement described in Section 2.1.

SELECTION OF MAINTENANCE TREATMENT

2.7 Selection of the appropriate maintenance treatment products and systems is dependent on the pavement type, defect and wider considerations such as safety, serviceability, financial, environmental and traffic disruption considerations. For the types of pavement described in Section 2.1, the treatment type associated with defect can broadly be split into:

- Surface defects (Section 3)
- Joint defects (Section 4)
- Structural defects that require strengthening (Section 5)
- Structural defects that require full depth structural repairs and reinstatement (Section 6)

2.8 Figure 2 gives an overview of maintenance treatment type for the Major and Minor Defects. Recurrence of defects, assessment management strategy and constraints on working windows need to be considered in the selection of appropriate treatments and further information on overlay treatments for jointed reinforced concrete pavements, jointed unreinforced concrete pavements and thinly overlaid concrete pavements and/or hydraulically bound mixture with less than 50 mm thick flexible "surfacing" can be found in TRL Report TRL 657 (2006).

2.9 Structural defects in continuously reinforced concrete pavements and continuously reinforced concrete base are detailed separately in Section 5.45 to 5.49.

Further general information on maintenance of concrete roads can be found in "The Concrete Pavement Maintenance Manual". Highways Agency 2001

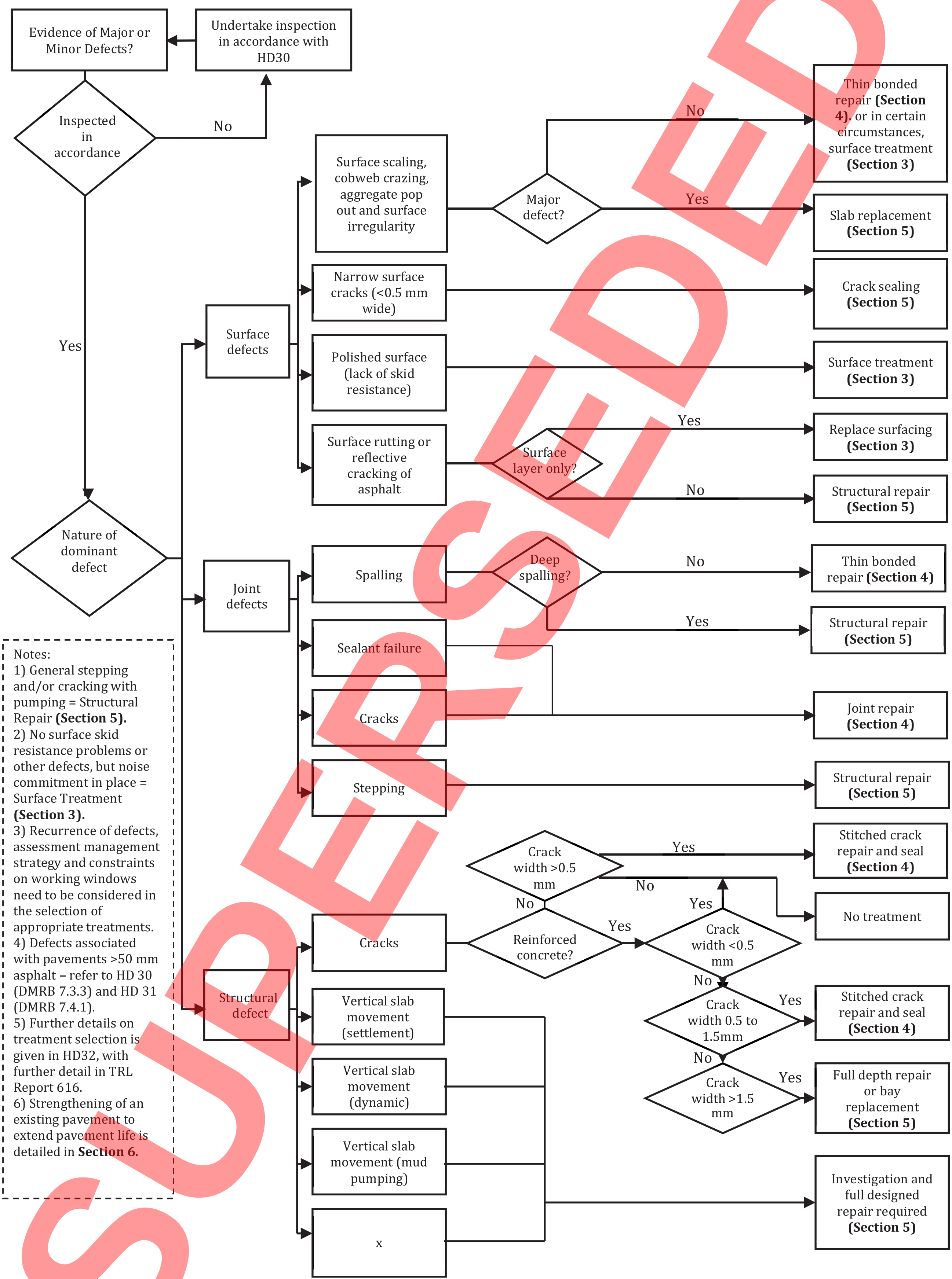

Figure 2 Overview of Defects and Maintenance Requirements

3. SURFACE TREATMENT PRODUCTS AND SYSTEMS

OVERVIEW OF SURFACE TREATMENT OPTIONS

3.1 Surface treatment options are primarily used to restore skid resistance. In-service concrete pavements lose surface texture due to both the attrition of the cement mortar matrix and polishing effects of traffic on the exposed aggregate component. Brush finished surfaces are particularly prone to this effect.

3.2 HD 28 (DMRB 7.3.1) discusses the assessment of skidding resistance using the sideway-force Coefficient Routine Investigation Machine (SCRIM), Pavement Friction Tester and Portable Pendulum Tester. SCRIM only measures skidding resistance at speeds within a road speed range 30 to 85 km/hr but has a skidding component of 17 to 20 km/hr. The Pavement Friction tester can measure the peak and sliding friction of a road surface at traffic speed.

3.3 There are several different methods of restoring skidding resistance to concrete roads, and selecting the most suitable depends on the type of road, speed of traffic, and the aggregate used in the concrete. Some methods will restore macrotexture, while others only improve microtexture, and some do both. The following categories of surface treatment products and systems techniques are covered in this section:

- Bituminous overlay
- Ultra thin and thin Concrete overlay
- Transverse grooving
- Retexturing
- Surface re-profiling
- Surface protection products and systems

A general summary of expected service life and other considerations (including tyre/road noise and skid resistance) given in Table 3.3.

BITUMINOUS OVERLAY

3.4 Bituminous overlays comprise a range of mixtures and techniques; including: slurry surfacing, surface dressing, cold applied ultra thin surfacing, ultra thin and thin surface course system. These applications range in durability and expected service life (see Table 3.3), with thin surfacing overlays being the standard on the Highway Agency network.

3.5 Overlay design and selection as a technique requires consideration of levels to retain sufficient headroom under over-bridges, to minimise the need to raise kerbs, safety barriers and/or ironwork. In addition, applying an overlay may result in the existing Vehicle Restraint System (VRS) becoming out of tolerance. If this is an issue, experience has shown that a thin surface overlay not exceeding a thickness of 25 mm, with a nominal aggregate size is equal to or lower than 10 mm often enables the pavement VRS height to remain within tolerance.

3.6 Bituminous overlays are detailed in Series 900 of the Specification (MCHW) and Table 3.1 gives an overview of each technique, with further detail in Sections 3.6 to 3.10.

Technique	Maintenance	Application	
Slurry surfacing in accordance with clause 918 of the Specification (MCHW)	Restoration of microtexture and macrotexture on suitable intact structures	Departure required from Overseeing Organisation	–
Surface dressing in accordance with clause 919 or 922 of the Specification (MCHW)		Not permitted on motorway or all-purpose trunk roads, but often used on lower trafficked networks	–
Cold Applied Ultra Thin Surfacing in accordance with clause 923 of the Specification (MCHW)		Type dependent on road	Potential to reduce tyre/road noise Consideration required of surface water drainage (shedding)
Thin surfacing overlay in accordance with clause 942 of the Specification (MCHW)		Type dependent on road	

Table 3.1 Overview of bituminous overlays

Slurry surfacing in accordance with clause 918 of the Specification (MCHW)

3.7 Slurry surfacings are cold-applied, thin bituminous surface courses incorporating bitumen emulsion and fine graded aggregate with fillers; with application typically limited to pedestrian areas, cycleways and to traffic levels.

3.8 Technique selection and design is based on site and traffic data; with the slurry surfacing system having been subject to a Type Approval Installation Trial (TAIT) in accordance with BS EN 12273 or as otherwise approved by the overseeing organisation. Clause 918 Slurry Surfacing is not permitted without authorisation from the overseeing organization.

3.9 Further general information on slurry surfacing can be found on the Road Surface Treatments Association (RSTA) website: http://www.rsta-uk.org/index.htm.

Surface dressing in accordance with clause 919 or 922 of the Specification (MCHW)

3.10 Further information on the design of bituminous surface dressings, including those on concrete roads can be found in Road Note 39 and Series 900 of the Specification (MCHW). Clause 922 Surface Dressing is not permitted without authorisation from the overseeing organization.

3.11 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.

3.12 Further general information surface dressing can be found on the Road Surface Treatments Association (RSTA) website: http://www.rsta-uk.org/index.htm.

Volume 7 home page

High Friction Surfacing in accordance with clause 924 of the Specification (MCHW)

3.13 A high level of low speed skidding resistance can be achieved by the application of a surface treatment consisting of various resin based binders and highly abrasion resistant calcined bauxite chippings. 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.

Cold Applied Ultra Thin Surfacing in accordance with clause 923 of the Specification (MCHW)

3.14 Cold applied ultra thin surfacing (CAUTS) are bitumen and aggregate mixtures mixed and produced at temperatures below 100˚C, with selected performance criteria as for hot asphalt applied thin surfacing (Section 3.16).

3.15 Limitations for CAUTS for use on concrete surfacing, are similar to those for surface dressing (Section 3.11) and particular care should be taken as experience with their use is limited.

Ultra Thin and thin surfacing overlay in accordance with clause 942 of the Specification (MCHW)

3.16 Ultra thin and thin surface course systems are hot asphalt mixtures, mixed and produced at temperatures above 120˚C. Performance level requirements are detailed in clause 942 of the Specification (MCHW).

3.17 Thin surface course systems have a long track record of use, in particular for high speed skid resistance for use on the high speed trunk road network. In addition, where noise levels are high due to the intensity of high-speed traffic, thin surface course systems can significantly reduce tyre/road generated noise emission compared to other surfacings.

ULTRA THIN AND THIN CONCRETE OVERLAY

3.18 Concrete overlays are where a new concrete layer is placed on top of an existing pavement, with specific measures taken to ensure a bond between the new concrete and existing pavement surface. Overlay thickness is typically between 100 mm to 200 mm, and any increase in pavement levels requires consideration (as per bituminous overlays, see section 3.5).

3.19 This technique is well established in North America where it is used to overlay flexible pavements but lacks track record in the United Kingdom. Further information about this technique can be obtained from NCHRP Synthesis 338, 2004. A departure should be sought from the overseeing organisation for its application.

3.20 Surface finishing of the concrete overlay to provide adequate skid resistance, and the bond between the pre-existing pavement and the overlay are particular areas for attention.

TRANSVERSE GROOVING

3.21 Transverse grooving in accordance with clause 1029 of the Specification (MCHW) involves creating a macrotexture on concrete surfaces by sawing grooves typically between 2 and 5 mm wide, using diamond or abrasive cutting discs.

3.22 The sawed grooves are cut at right angles to the direction of traffic; restoring macrotexture, providing improved high speed skid resistance and improving drainage pathways for surface water. This technique also has the potential to increase tyre/road noise.

3.23 Transverse grooving is not required to be a continuous process and areas where other defects may be created should be avoided. An example of this is stopping short (typically 300 mm) of white lines demarking lanes and also joints. The risk of continuing grooving up to joints is that the angles may slightly differ, resulting in the creation of tapering "wedges" which could be susceptible to deterioration under trafficking.

RETEXTURING

3.24 The wet skidding resistance of a road is dependent on the tyre interacting with the microtexture of the road surfacing. On a concrete road, microtexture comes primarily from the sand and fine aggregate in the concrete surface layer. Microtexture is gradually polished by traffic until an equilibrium level of skidding resistance is reached. On a concrete road, the laitance containing the fine aggregate may be worn away to expose the coarse aggregate which may be unable to maintain adequate microtexture. HD 28 (DMRB 7.3.1) provides advice on standards for the skidding resistance of in-service roads. Microtexture is essential to maintain an adequate skid resistance level at all speeds. The ability of a surface to maintain adequate skidding resistance at high speeds is also governed by the macrotexture of the surfacing. As a surfacing ages, the level of macrotexture may fall as the ridges created by brushing, are worn away.

3.25 Retexturing is the mechanical reworking of a sound road surface to restore either skidding resistance, texture depth or both. The surface levels of an area which has been retextured should remain the same as the surrounding surface. The suitability and effectiveness of a retexturing treatment depends on the condition of the road prior to treatment. The most appropriate technique to be employed in any given situation depends upon the nature of the existing surface and the fault or faults to be remedied. It should be noted that all retexturing treatments are different and that technique selection should always be made on a site specific basis. Most processes can be carried out at any time of year in all but the most severe weather conditions. Retexturing can be used as a short to medium term measure to treat, high-risk sites and most processes are repeatable. Retexturing is most effective on a concrete road surface that is generally sound but caution is needed with some treatments where there are joints within the concrete surface. In some circumstances reinstatement of the joints may also be required. Further advice should be sought from the contractor as to limitations concerning a particular process.

3.26 Improved skidding resistance can be achieved by roughening the worn surface by the use of various retexturing techniques summarised in Table 3.2. The durability of an increase in skid resistance level and texture depth will depend on the type and geometry of road, the quantity and behaviour of the traffic and the raw materials which make up the surface, in particular the aggregate. The durability of macrotexture and microtexture improvements may also differ.

3.27 Some retexturing treatments can be accompanied by an increase in the volume or a change in the characteristic of traffic/tyre noise, the nature of which will depend on the type of treatment that is adopted.

<table>
<tr><th>Technique</th><th>Maintenance</th><th colspan="2">Application</th></tr>
<tr><td>Flailing transverse</td><td rowspan="6">Restoration of macro texture (for high speed skid resistance) on suitable intact structures, with suitability dependent on characteristics of coarse aggregate and concrete</td><td rowspan="6">Suitability assessed on site specific basis</td><td rowspan="5">Improves microtexture and macrotexture, but there is potential for a change in traffic tyre noise</td></tr>
<tr><td>Fine milling (shallow)</td></tr>
<tr><td>Bush hammering</td></tr>
<tr><td>Shot blasting</td></tr>
<tr><td>Grinding with longitudinal grooving (following surface profile)</td></tr>
<tr><td>Water jetting</td><td>Removes aggregate surface polish and contaminants to expose existing microtexture</td></tr>
</table>

Table 3.2 Overview of retexturing techniques

Flailing transverse

3.28 Flailing-transverse improves macrotexture and removes polish from aggregates by mechanical impact on the concrete road surface. The technique involves hardened tips set into the edges of steel washers loosely mounted side-by-side and drawn across the road surface while being hydraulically loaded. Surface texture depth can be reduced as the material from tops of the particles is removed.

Bush hammering

3.29 During bush hammering the concrete surface is struck by a number of impact heads with chisel-ended hammers with hardened tips. This technique improves macrotexture and microtexture of the road surface.

Shot blasting

3.30 Steel shot blasting is an abrasive system that impacts the surface of the pavement with high velocity steel particles.

3.31 This technique improves macrotexture and microtexture of the road surface and equipment is available which is suitable for treating both large and small areas.

Grinding with Longitudinal Grooving (following surface profile)

3.32 Grinding with longitudinal grooving (following surface profile) involves the creation of longitudinal grooves using diamond tipped saw blades. The closely spaced saw blades cut longitudinal grooves at a predetermined width and depth and this process follows the profile of the surface. The surface levels of the treatment area remain the same as the surrounding surface and the treatment is repeatable. This technique improves microtexture and macrotexture, thereby improving skid resistance and increasing texture depth, and has the potential to reduce tyre/road noise. The treatment causes no damage to joints and road markings, road studs and ironwork do not have to be removed prior to treatment.

Water jetting

3.33 This process involves the controlled jetting of water through a series of nozzles at high or ultra high pressure onto the road surface. This treatment does not involve a mechanical reworking of the surface to expose new aggregate surfaces and, as a result, does not restore skidding resistance lost through the polishing action

Volume 7 home page

of the traffic. This technique thoroughly cleans the surface and removes surface contaminants and rubber deposits to expose the existing microtexture.

Fine milling (shallow)

3.34 Fine milling can be used to provide an enhanced texture depth only if the planer is set to scarify the surface to a nominal depth of 1mm. This can also be used to provide a key for an overlay treatment.

SURFACE REPROFILING

3.35 Restoration of macrotexture and potential to reduce tyre/road noise can be achieved by surface reprofiling of concrete surfaces. Where these techniques are used the thickness of the concrete surface layer will be reduced. Therefore, surface reprofiling is only suitable for concrete pavements which exhibit a generally good structural condition.

3.36 Structural assessment required prior to maintenance design to check both cover to reinforcement and structural capacity. Structural design checks on the pavement capacity shall be undertaken in accordance with HD 26 (DMRB 7.1.3).

3.37 With surface reprofiling, it is important that concrete bays remain largely intact, that joint performance is good and that support from the foundation is suitable to prevent significant differential movement under or between slabs.

3.38 The mechanical hardness of the aggregate used in the concrete mix will affect the speed at which the reprofiling process can progress; for example a flint gravel has a greater resistance to diamond cutting than limestone, and may require slower movement with a greater load applied to the cutting drum. Fine milling (deep) and grinding with longitudinal grooving are two techniques for surface re-profiling. Significant reduction in concrete thickness from deeper or multiple treatments could give rise to a structural failure. Consult HD26 to calculate the reduced bearing capacity of the road after treatment.

Fine milling (deep)

3.39 Fine milling can also be used to provide an improved ride quality by increasing the depth of scarification above 1mm.

3.40 Texture measurements undertaken following fine milling are typical of that required for a trafficked asphalt pavement surface. The mechanical hardness of the aggregate used in the concrete mix will affect the speed at which the fine milling process can progress; a harder stone having a greater resistance may require slower movement with a greater load applied to the milling drum.

3.41 Fine milling of concrete surfaces produces a milled surface which provides an improved level as surface irregularities are generally removed by the process hence resulting in an improvement of ride quality but it has been found to increase road/tyre noise. The process results in a significantly roughened surface.

Grinding with longitudinal grooving

3.42 Grinding with longitudinal grooving involves the removal of a thin layer of concrete using diamond tipped saw blades. A level surface is achieved by running an assembly of closely spaced blades across the pavement surface. This produces saw cut grooves which provide a relatively constant level as any stepped joints or surface irregularities are removed by the process hence resulting in a significant improvement of ride quality and tyre/road noise reduction. The cutting process exposes a clean, un-polished aggregate face which helps to restore texture and enhance skid-resistance characteristics.

3.43 Grinding with longitudinal grooving can be used also following removal of thin overlay, subject to analysis of geometry tolerances.

3.44 The long term performance of diamond ground concrete surfaces is further detailed in TRL report PPR 607 (2012).

SURFACE PROTECTION PRODUCTS AND SYSTEMS

3.45 Surface protection systems work via impregnation or coating. They are designed to provide protection (such as preventing water penetration) to the concrete surface. Therefore, do not necessarily improve macro or micro texture. Proprietary systems combining resins and aggregates have track record of use on airfield applications, effectively acting as an overlay.

EXPECTED SERVICE LIFE AND OTHER CONSIDERATIONS

3.46 The selection of surface treatment products and systems is dependent on the defect being treated, asset management policy, practical considerations (working window, weather and so on) and each has a different range of effective service life. Table 3.3 summarises the range of expected service life, some of the aspects about the process, other factors (benefits and issues) and whether a Departure is required from the overseeing organization to use the technique.

3.47 In England, no surface treatment should be considered without taking into account the Highways Agency's requirements for low-noise surfacing. In Wales, no surface treatment should be considered without consulting the current Welsh Government list of noise action planning priority areas.

3.48 The expected service life in table 3.3 is defined as the period over which the intended performance for the treatment is likely to be achieved. The expected service lives quoted in table 3.3 are for over 50 msa designs. Where the msa is lower, then the service life for each surface treatment is likely to be higher than the quoted upper limit. For most retexturing treatments the service life refers to the period of elevated skid resistance as measured by SCRIM and/or the pavement friction tester.

3.49 Limited research has been carried out to compare the change in noise levels contributed by the road surface when various treatments have been applied to concrete roads. The method of measurement used is the statistical pass by method which generates a road surface influence (RSI) measure. Thin surfacing course systems (TSCS) have a declared noise level determined by their RSI measure as described in clause 942 of MCHW and are compared to Hot Rolled Asphalt (HRA) surfacing materials. TSCS are in the range 0.5 to 3.5 dB(A) quieter than HRA. A worn brushed concrete road surface can be 2.7dB(A) more noisy than HRA. Most retexturing processes do not change the absolute noise level of the concrete road surface significantly but some can cause a change in the tonal quality of the sound of traffic due to the introduction of a more regular macrotexture pattern. The reprofiling treatment grinding with longitudinal grooving results in a significantly quieter concrete road surface with a reduction of 4.0dB(a) compared to HRA. More information is contained in TRL report PPR677 (2014).

Surface treatment		Range of expected service life	Installation Issues	Road Surface Benefits & Issues	Departure required for treatment
Bituminous overlay	Slurry surfacing in accordance with clause 918 of the Specification (MCHW)	8-12 years	Should not be used in very cold weather	Can plate off and can regulate surface profile	Yes
	Surface dressing in accordance with clause 919 or 922 of the Specification (MCHW)	10-15 years	Limited season and weather conditions for application	Can produce a very noisy surface. Aggregate eventually wears off to leave bituminous film on road surface	Yes
	Cold Applied Ultra Thin Surfacing in accordance with clause 923 of the Specification (MCHW)	Insufficient experience in UK	Limited season and weather conditions for application	A lower noise surface produced	Yes
	Thin surfacing overlay in accordance with clause 942 of the Specification (MCHW)	8-12 years	Usually requires raising of VRS.	A low noise surface produced. Tendency for fretting to occur at joints which quickly reflect through	No
Ultra thin and thin Concrete overlay		Insufficient experience in UK			Yes
Transverse grooving in accordance with clause 1029 of the Specification (MCHW)		20-40 years	Very slow process to install	Produces a very noisy surface	No
Retexturing	Flailing	2-3 years	These processes can be noisy during installation requiring vacuum sweepers. Considerations required to mitigate exposure to local residents	The resultant surface is likely to be slightly more noisy than before treatment	Yes
	Bush hammering	2-3 years		Little change in surface noise from pre-treatment levels.	Yes
	Fine milling (shallow)	2-5 years		Little change in surface noise from pre-treatment levels	Yes
	Shot blasting	2-3 years	Dust production can be significant and should therefore be controlled.	Little change in surface noise from pre-treatment levels.	Yes
	Water jetting	< 3 months	Possible contaminants in run off from process	Achieves little more than removal of surface contaminants	No
Surface Re-profiling	Fine milling (deep)	Insufficient experience in UK	The process is noisy. Considerations required to mitigate exposure to local residents	The resultant surface may be noisier than before and can exhibit a noticeable change in noise tone.	Yes
	Grinding with longitudinal grooving	3-5 years	The process is noisy. Considerations required to mitigate exposure to local residents. Arisings must be disposed of in the proper manner or recycled.	A very low noise surface is produced which has a smooth ride quality, eliminating stepping at joints and slab distortions.	Yes
Surface protection systems		Insufficient experience in UK			Yes

Table 3.3 Surface Treatment Options

4. JOINT REPAIRS

4.1 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.

4.2 The maintenance of joints and their repair of minor defects are a frequent requirement compared to the life of a concrete pavement, and as such are generally considered regular maintenance. Appropriate maintenance of joints is critical to avoiding major defects, such as deep spalling. The main defects categories requiring joint repair are:

- Defective joint seals
- Shallow spalling
- Deep spalling (see Section 5)
- Other cracks at joints

DEFECTIVE JOINT SEALS

Consequences

4.2 Appropriate maintenance should focus on keeping joints sealed, as 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 pavement foundation, and corrosion of steel dowels and tie-bars, especially in the presence of de- icing salt. In short, defective joint sets will reduce the service life of concrete pavements.

Types

4.3 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 need to be replaced regularly (typically every 5 to 10 years). A guide to the main types, and usage is given in Table 4.1.

Classification	Chemical	Physical Type	Type of Joint
Hot Applied	PVC/pitch polymer	Elastomeric	All
	Polymer/Bitumen	Elastomeric	All
Cold Applied	Polysulphide	Elastomeric	All
	Polyurethane	Elastomeric	All
	Silicone	Elastomeric	Warping
Compression	Polychloropene	Elastomeric	All

Table 4.1 Main Types of Joint Sealing Material

4.4 New joint seals shall consist of hot or cold applied sealant or compression seals or self expanding cork seals, complying with Clause 1017 of the Specification (MCHW). On some older roads a bituminous sealant was used, with which the present specified hot applied sealants are incompatible. 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 product chosen must be installed according to the manufacturers' instructions.

4.5 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 locations vulnerable to contamination by fuel or oil, e.g. bus lay-bys or parking areas, a fuel resistant sealing material must be used. At joints between concrete and bituminous pavements hot applied polymer modified bituminous sealants or preformed polymer modified bituminous strips are most suitable.

4.6 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.

4.7 Overbanding materials are not suitable for use 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 arises.

4.8 For fast-track slab replacement, 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 (MCHW) Series 1000 and to HD27 (DMRB 7.2.4.3).

4.9 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 4.2, and the correct amount of sealant to apply is shown in Figure 4.1.

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	
Extrusion	Overfilled sealing groove Lack of compressible caulking strip in bottom of sealing groove Incorrect sealing groove dimensions	

Table 4.2 Joint Seal Defects: Causes and Remedies

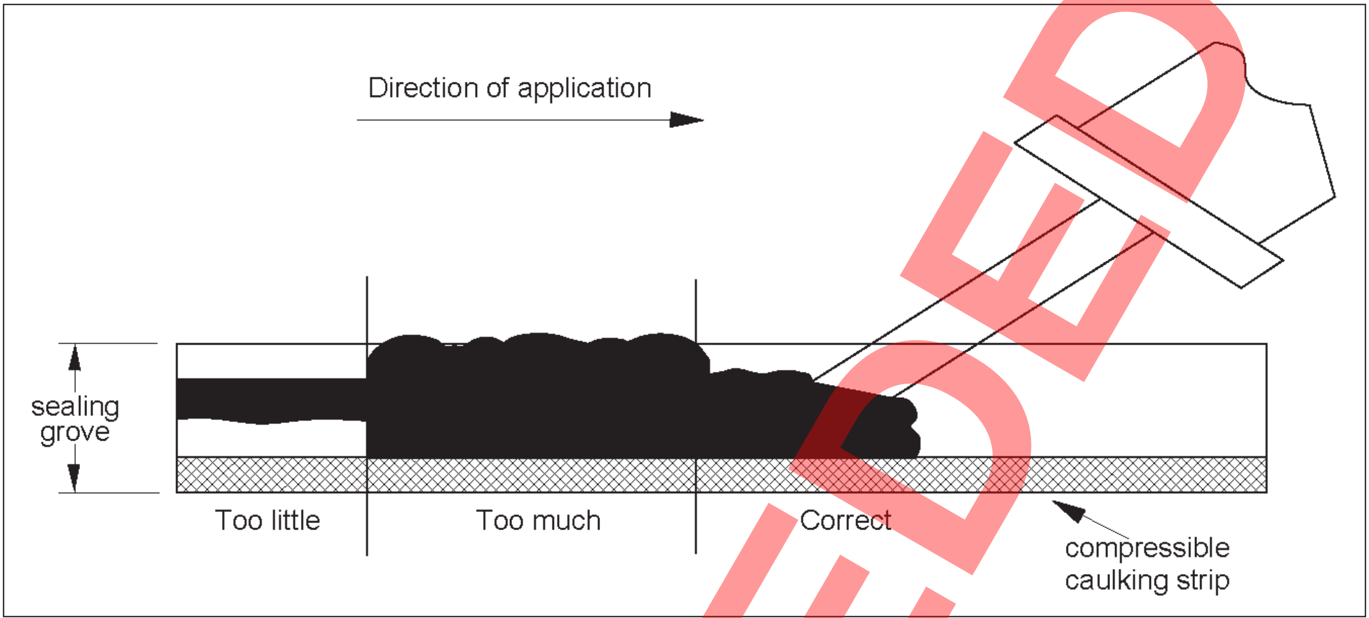

Figure 4.1 Application of Gun Grade Cold Applied Sealant

4.10 Preparation and sealing of joint grooves must be in accordance with the relevant standard for hot or cold applied sealants and with the clause 1016 of the Specification (MCHW volume 1) and manufacturer's recommendations for compression seals.

Preparation of the sealing groove

4.11 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.

4.12 Hot applied sealants must 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

4.13 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.

4.14 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.

4.15 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 need initially be not less than 5mm below the surface of the slab, except in the case of cork seals.

SHALLOW SPALLING AT JOINTS

4.16 Spalling of joints (or the edge of slabs) are likely to impair the effectiveness of the joint seal. Possible causes are given in Table 4.3.

Type of defect	Causes	Remedies
Shallow spalling of transverse and longitudinal joints 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 40 mm wide at transverse joints and 30 mm wide at longitudinal joints necessary in conjunction with flat grinding as with in this way should be rectified repair Spalling which cannot be dealt with in this way should be rectified by means of a thin bonded arris repair

Table 4.3 Shallow Spalling: Causes and Remedies

4.17 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.

4.18 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 20 mm deep.

4.19 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

4.20 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.

4.21 The method for carrying out thin bonded repairs is contained in clause 1032 of the Specification (MCHW).

4.22 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 10 mm. Cement mortar should be used for repairs up to 20 mm deep and fine concrete for thicknesses greater than this.

4.23 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.

4.24 Thorough preparation, attention to detail and good workmanship are essential for the service life of thin bonded repairs to be achieved.

4.25 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 4.2). 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.

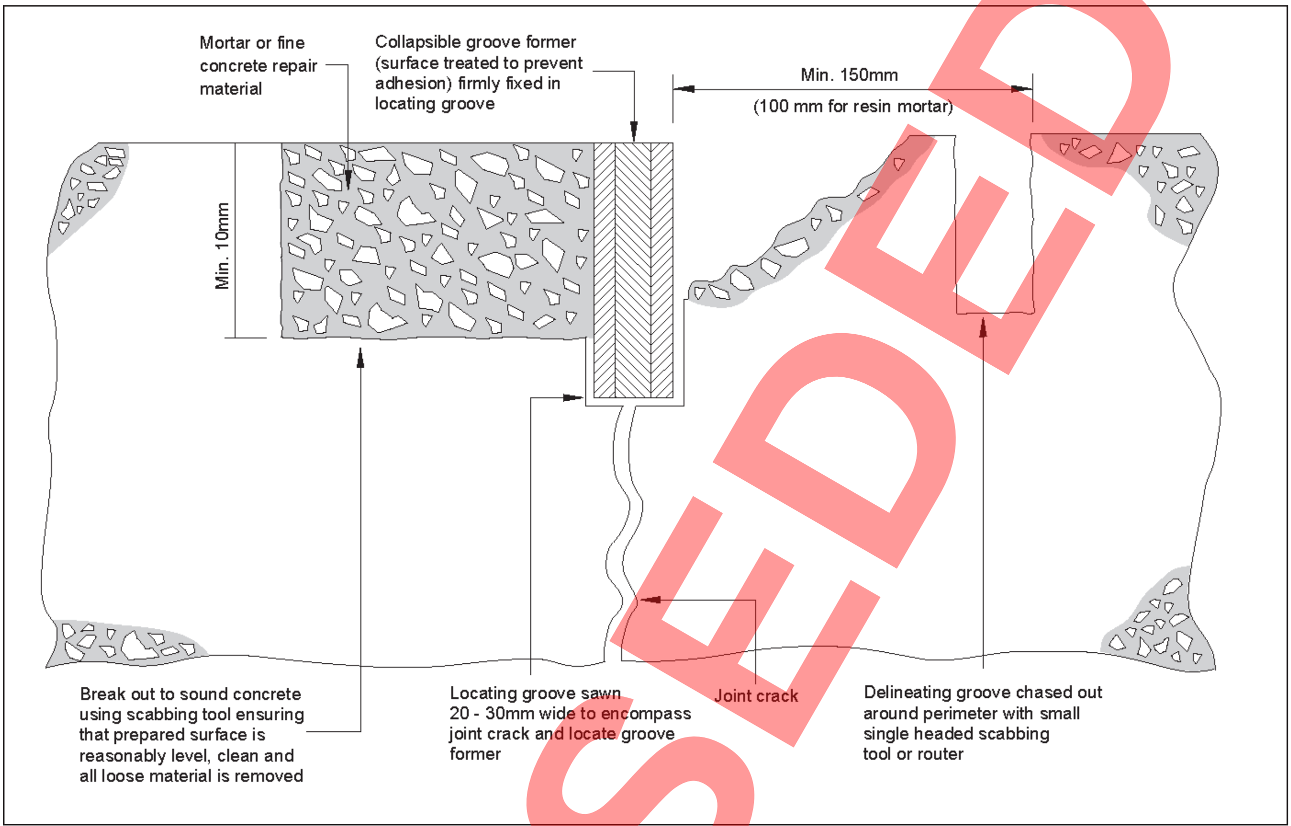

Figure 4.2 A Thin Bonded Arris Repair

4.26 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.

OTHER CRACKS AT JOINTS

4.27 The main types of these cracks, their likely causes and appropriate remedies are summarised in Table 4.4. The two types of stitched crack repair are shown in Figure 4.5, and procedures described in MCHW. In addition, fill and overband can be permitted via a Departure. The main advantage of this technique is speed, low cost, prevention of further deterioration (including prevent water ingress); but its service life is likely to be relatively short and as such needs to be considered as part of the maintenance strategy.

Type of defect	Causes	Remedies
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 4.4 Other Cracks at Joints: Causes and Remedies

4.28 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.

4.29 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.

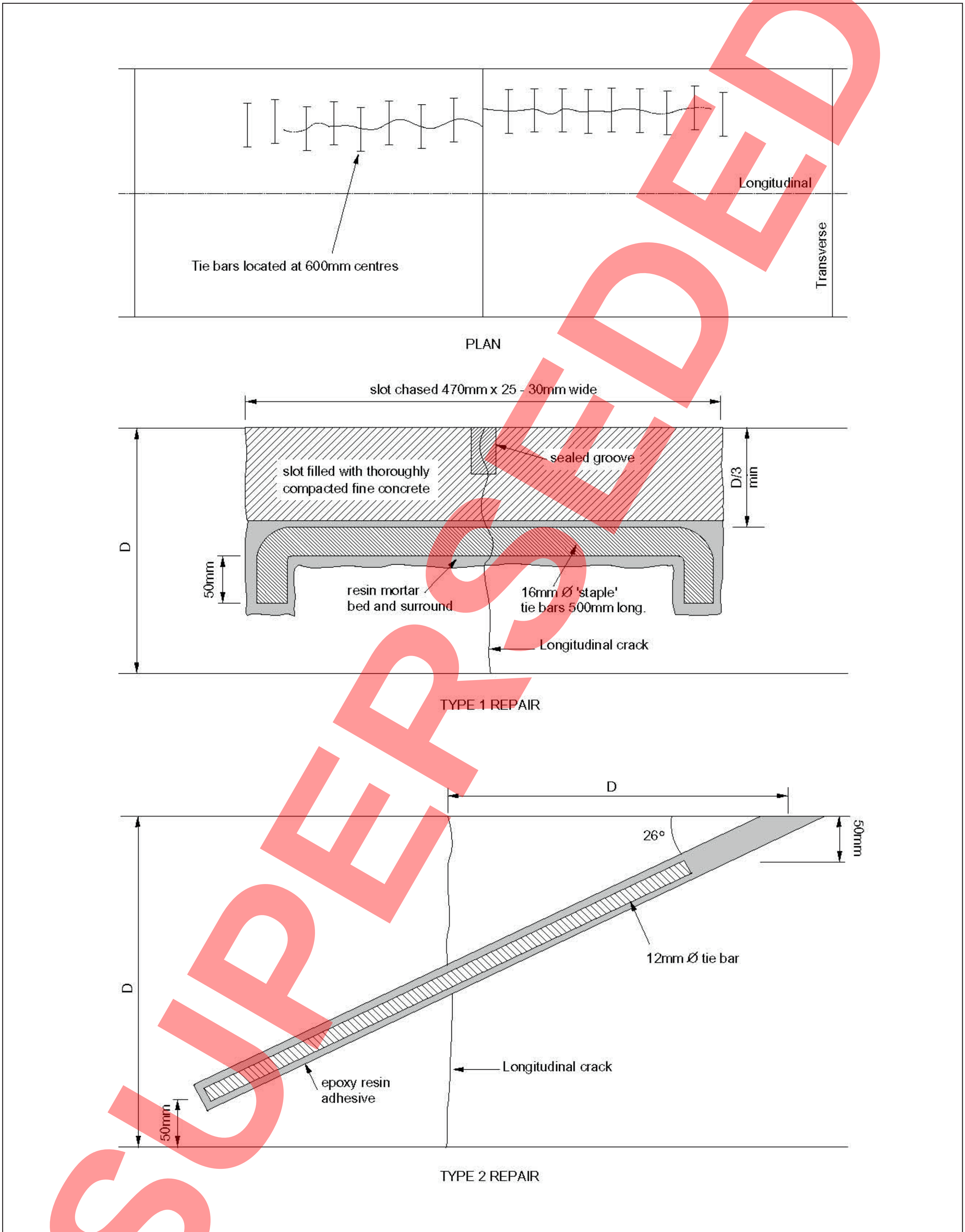

Figure 4.5 Stitched Crack Repairs

5. FULL DEPTH STRUCTURAL REPAIRS AND REINSTATEMENTS

5.1 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.

5.2 Due to the unique features of continuously reinforced slabs and bases they are dealt with separately in paragraphs 5.45 to 5.49.

5.3 The main defects categories requiring full depth structural repairs and reinstatements are:

- Deep spalling
- Cracking (dependent on nature and width)
- Settlement
- Movement
- Defects in an asphalt surface layer such as reflective cracking, resultant from underlying defects

DEEP SPALLING

5.4 Deep spalling usually extends to at least half slab depth and possible causes are given in Table 5.1. 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.

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		Full depth corner repair

Table 5.1 Deep Spalling: Causes and Remedies

Full Depth Repair

5.5 Concrete Slabs can be replaced with bituminous mixtures as a temporary measure. Temporary repairs must be replaced during the next planned maintenance period, or as a consequence of a defect (whichever occurs soonest). A permanent full depth repair must be in concrete. A repair incorporating bituminous mixtures is unlikely to have a comparable service life to the adjacent rigid pavement, and take into account existing sub-surface drainage.

5.6 Rapid cure concrete is a pragmatic potentially beneficial option for full depth repairs using concrete. Modifying concrete using water reducer, accelerator and additives can be carried out to achieve the required strengths in a very short amount of time and within a single night's possession. It is strongly recommended

Volume 7 home page

that any mix should be subject to off-site trials to ensure a sufficient speed of strength gain is achievable in the time available, and that maturity curves for strength gain against temperature and time, are utilised during the concrete mixture design. An example of a design which has proved satisfactory is provided in table 5.2. Further details can be obtained from the Overseeing Organisation.

Constituent	Quantity
Cement	500kg/m^3 (minimum)
Coarse Aggregate 4-20mm	912kg/m^3
Fine Aggregate 0-4mm	876kg/m^3
Super Plasticiser	0.77ltrs
Accelerator	4.0% BWC
Free Water	140ltrs
Water/cement ratio	0.28

Table 5.2 An example Design for Rapid Cure Concrete

An alternative to rapid cure concrete is roller compacted concrete produced and installed in accordance with series 800 of the Specification (MCHW). A Departure from the overseeing organization is required for the use of roller compacted concrete.

5.7 To make available as much time as possible for curing and to enhance the curing process, operational practices such as pre saw cutting and mechanical slab lifting (as opposed to breaking and excavating), use of volumetric mixers, heat blankets and space heaters, should be considered.

5.8 Full depth repairs shall be carried out in accordance with the Specification (MCHW volume 1) Series 1000. Existing materials must be cut back to sound concrete. Irrespective of whether the main slab is reinforced or not, it is advisable to reinforce the repair and should be done when the ratio of the longest to the shortest dimension is greater than 2. 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. All full depth repairs should be tied to the surrounding concrete system using dowel and tie bars.

5.9 Full depth repairs of continuously reinforced concrete pavements and continuously reinforced concrete base are detailed in Section 5.45 to 5.49.

5.10 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 2 m 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.

5.11 Where required it is essential that the any remaining corners of the repair are broken out either to a sharp right angle, or a 45^o 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 should not occur in the wheel paths. In transverse full depth repairs the expansion material will need to be extended around the corners to ensure complete separation at these locations.

5.12 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

5.13 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.

5.14 To reduce this risk:

a) Saw full depth cuts at cooler periods of the day (i.e. 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.

5.15 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.

5.16 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.

TRANSVERSE AND LONGITUDINAL CRACKS

Requirement for structural repair

5.17 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 5.3).

5.18 Narrow transverse cracks are a normal feature of all reinforced slabs and bases. 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.

5.19 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.

5.20 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.

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 5.3 Crack Classification

5.21 The most likely cause and appropriate remedies for structurally significant cracks are given in Table 5.4.

Type of defect	Cause	Remedies
Transverse cracks	Excessive bay length Dowel bar restraint at joints Late sawing of joint grooves Inadequate reinforcement lap repair 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
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 5.4 Transverse and Longitudinal Cracks: Causes and Remedies

Bay Replacement

5.22 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 must 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 needs to be broken out carefully to avoid undercutting the remaining slab.

5.23 Any reinstatement of the sub-base that is necessary should 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 can be used to compact either unbound or hydraulically bound sub base mixture.

5.24 An existing hydraulically bound sub base may be reinstated and regulated as necessary using sand/cement mortar, fine concrete or 6 mm cold asphalt.

5.25 If an existing granular sub-base is to be replaced with a hydraulically bound mixture, any potential deleterious effect, due to creating a discontinuity in the under slab drainage, should be considered and appropriate action taken.

5.26 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.

5.27 The procedure for bay replacement is given in MCHW 1000 series. Note must be made of paragraphs 5.5 and 5.6 of this section, regarding removal of slabs in summer and about the potential use of bituminous materials and rapid cure concrete.

DIAGONAL AND CORNER CRACKS

5.28 The term diagonal cracks includes 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 0.3m to 2m 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 5.5.

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 5.5 Diagonal and Corner Cracks: Causes and Remedies

5.29 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.

5.30 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

Treatment options

Design detail to mitigate the risk of future cracking

5.31 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 200mm to the underside of the sub-base.

5.32 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

5.33 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.

5.34 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.

5.35 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, modified Deflectograph (with twin beams) 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.

5.36 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.

5.37 '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.

5.38 These defects, their likely causes and appropriate remedies are described in Table 5.6. However, it should be noted that the remedy for the immediate problem may not remove the original cause, for example ground softening due to water ingress. It is essential that the cause is understood before ordering repairs.

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
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 5.6 Vertical Slab Movement, Mud Pumping and Settlement: Causes and Remedies

Slab Lifting

5.39 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.

5.40 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

5.41 Pressure grouting is used either to fill small voids stabilising 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. 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

5.42 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 a nominal 1m x 1m grid to provide the vacuum suction and grout injection points.

5.43 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.

5.44 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.

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

COMPRESSION FAILURES

5.46 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.

5.47 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

5.48 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 (i.e. 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.

5.49 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.

5.50 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.

5.51 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.

5.52 The appropriate remedy for both deep spalling and the "punchout" type of defect is a full depth repair. The continuity of the reinforcement will need to be maintained where necessary by adequate laps.

TEMPORARY REPAIRS

5.53 On some occasions it may be necessary to undertake temporary or emergency repairs quickly, using materials which can be trafficked in a short time. Details of temporary repairs with bituminous materials are given in Sections 5.5 and 5.6. Adequate preparation, such as removal of all loose and damaged concrete, should be carried out to ensure service life is achieved.

5.54 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 hydraulically bound mixture HBM Category C in HD26 (DMRB 7.2.3) between the precast slab and existing sub-base.

5.55 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 between 50-and 100mm thick.

5.56 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

5.57 Advice on the excavation and reinstatement of openings in a rigid pavement are given in the Specification (MCHW volume 1) Series 700. The use of foamed concrete as backfill material may be appropriate in some circumstances.

6. STRENGTHENING

6.1 Strengthening of an existing 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 pavements and the selection (and basic thickness design) of maintenance measures. This chapter concentrates on the practical considerations of carrying out such works.

6.2 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 and so on.

OVERLAY OPTIONS

6.3 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.

6.4 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.

6.5 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.

6.6 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 increase in depth. Thin concrete overlays provide an alternative option, as well as bituminous overlays (Section 3).

6.7 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.

6.8 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.

6.9 Modified bitumen binders with polymer used within asphalt layers (including surfacing) have been show to have improved resistance to deformation and fatigue of the asphalt and to provide better adhesion between bitumen and aggregate compared to conventional bitumen. The effectiveness of the modified bitumen in the asphalt is dependent on the base bitumen, level and type of modification and design of the asphalt mixture. Stress-absorbing or "reinforcing" materials can be used in lower layers and are relatively new with insufficient evidence to date to prove their long term effectiveness and overall economy.

6.10 If the existing concrete slabs are in poor condition, with many cracks, under slab 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 Section 5.

Bonded Concrete

6.11 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 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 (for example strength) of the existing slab, making allowance for fatigue damage to date due to past traffic.

6.12 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 and so on.

6.13 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.

6.14 Joints and wide cracks in the underlying pavement should be reproduced in the bonded concrete overlay, ensuring that the appropriate joint type (for example 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.

6.15 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.

6.16 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

6.17 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.

6.18 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.

6.19 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.

6.20 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 (for example by use of a bituminous regulating layer of nominal thickness 40-50mm).

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

Bituminous Overlays

6.22 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 in he underlying slab. Recommended thicknesses are given in HD 30 (DMRB 7.3.3).

6.23 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

6.24 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.

6.25 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.

6.26 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.

6.27 The first site using cracking and seating in the UK was in 1978 and 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.

6.28 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.

6.29 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.

6.30 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.

6.31 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

6.32 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.

6.33 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.

6.34 Consideration should be given to recycling the excavated slabs by crushing and recycling the aggregate.

7. REFERENCES

NORMATIVE

BS EN 12273 Slurry surfacing. Requirements BSI

HD 26 (DMRB 7.2.3) Pavement Design

HD 27 (DMRB 7.2.4) Pavement Construction Methods

HD 28 (DMRB 7.3.1) Skidding Resistance

HD 29 (DMRB 7.3.2) Structural Assessment Methods

HD 30 (DMRB 7.3.3) Structural Assessment Procedure

HD 31 (DMRB 7.4.1) Maintenance of Bituminous Roads

Specification for Highway Works (MCHW1) 1000 Series

Specification for Highway Works (MCHW1) 900 Series

INFORMATIVE

Coley C and Carswell I 2006, TRL 657 Improved design of overlay treatments to concrete pavements

Mildenhall H S and Northcott G D S, "A Manual for the Maintenance and Repair of Concrete Roads", Department of Transport and Concrete Society

NCHRP Synthesis 338. Thin and Ultra-thin Whitetopping, Transportation Research Board (TRB). ISBN 0-309-07019-8

Road Note 39; "Recommendations for Road Surface Dressings", TRL and Department of Transport

Sanders P D, Brittain S and Sanders P J. 2013. PPR 677 Cost effective surface treatment of concrete roads. Wokingham: TRL

Sanders P D, Wayman M, Dunford A, Viner H E 2013. PPR607 Long term friction performance of longitudinally diamond ground Concrete, Wokingham: TRL

The Concrete Pavement Maintenance Manual. Highways Agency 2001

Specification for Highway Works (MCHW1) 700 Series

8. ENQUIRIES

Approval of this document for publication is given by:

Highways England Temple Quay House The Square Temple Quay Bristol BS1 6HA	M WILSON Chief Highways Engineer
Transport Scotland 8th Floor, Buchanan House 58 Port Dundas Road Glasgow G4 0HF	R BRANNEN Director, Trunk Road and Bus Operations
Welsh Government Transport Cardiff CF10 3NQ	S HAGUE Deputy Director Network Management Division
Department for Regional Development TransportNI Clarence Court 10-18 Adelaide Street Belfast BT2 8GB	P B DOHERTY Director of Engineering

All technical enquiries or comments on this Standard should be sent to standards_enquiries@highwaysengland.co.uk

This document was notified in draft to the European Commission in accordance with Directive 98/34/EC, as amended by Directive 98/4

Volume 7 home page