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DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
OFFICE OF THE SECRETARY
Manila

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DEPARTMENT ORDER) SUBJECT: **INTERIM GUIDELINES FOR THE MAINTENANCE AND REHABILITATION OF UNREINFORCED CONCRETE ROADS**

No. 45

Series of 2006 09.08.06

In order for concrete roads to achieve the longest possible economic life, the attached Interim Guidelines for the Maintenance and Rehabilitation of Unreinforced Concrete Roads are hereby prescribed for the guidance and compliance of all concerned. This document purports to give guidance to DPWH engineers in the identification of the common modes of distress in unreinforced concrete pavements and the most appropriate maintenance and rehabilitation methods.

This Order takes effect immediately.

HERMOGENES E. EBDANE, JR.
Acting Secretary

WIN6U00106

INTERIM GUIDELINES
FOR THE
MAINTENANCE AND REHABILITATION
OF
UNREINFORCED CONCRETE ROADS IN THE PHILIPPINES

Prepared by: Bureau of Research and Standards
Department of Public Works and Highways
August 2006

FOREWORD

A correctly designed and properly constructed unreinforced concrete carriageway should provide many years of satisfactory service with limited maintenance. However, if such maintenance is neglected or the techniques are inappropriate, the potential life is unlikely to be realized. This document aims to provide guidance on maintenance and rehabilitation in order that unreinforced concrete roads in the Philippines can achieve the longest possible economic life.

The Philippines has a concrete road network of approximately 13,000kms. Much of the new concrete road construction is still carried out without the use of paving machines, particularly on small works, and this practice often results in a poor ride quality. Rehabilitation of the concrete road network is generally confined to simply overlaying roads with thin layers of Hot Mixed Asphalt (HMA). These overlays are used to either restore the uneven surface on relatively new pavements or to maintain more deteriorated pavements. In some cases these overlays have been successful, however it is often the case that the defects in the underlying damaged rigid pavement layer rapidly cause failures in the new HMA overlay.

Increased thicknesses of HMA overlay have been used with varying success. If the underlying concrete pavement is not stable, increasing the thickness to 100mm does not prevent reflection cracking for any substantial length of time. A previous IBRD assisted Pavement and Axle Load Study (Renardet, 1985) reported that HMA overlays on unreinforced concrete (URC) were rarely successful and that successive thin overlays on damaged concrete pavements were less successful than an equivalent thickness applied at one time.

This Guideline gives professional highway engineers in the Philippines guidance on the identification of the common modes of distress in unreinforced concrete pavements and the most appropriate maintenance and rehabilitation methods. The guidance is based on a combination of the research program presently being undertaken by the Bureau of Research and Standards (BRS) of the Department of Public Works and Highways (DPWH) and the experiences of other highway authorities elsewhere in the world. The guidance on the maintenance of unreinforced concrete roads is largely based on the experience gained by the Highways Agency in the UK and the authors gratefully acknowledge the permission to utilize sections of 'Concrete Pavement Maintenance Manual' (Highways Agency, 2001) in this Guideline.

The research at BRS is currently concerned with the maintenance and rehabilitation of unreinforced concrete using HMA and concrete overlays. The research includes four full-scale experiments. The authors acknowledge the support of all those involved in the design and construction of these trials.

This Guideline addresses the maintenance and rehabilitation of unreinforced concrete. For recommendations on the maintenance of reinforced concrete pavements and continuously reinforced concrete the reader is referred to other sources (e.g. Highways Agency, 2001).

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INTERIM GUIDELINES FOR THE MAINTENANCE AND REHABILITATION OF UNREINFORCED CONCRETE ROADS

These guidelines aim to provide appropriate maintenance and rehabilitation methods for the common modes of distress found in unreinforced concrete pavements.

1.0 MAINTENANCE AND REHABILITATION PROCESS

Figure 1.1 shows the evaluation and design process.

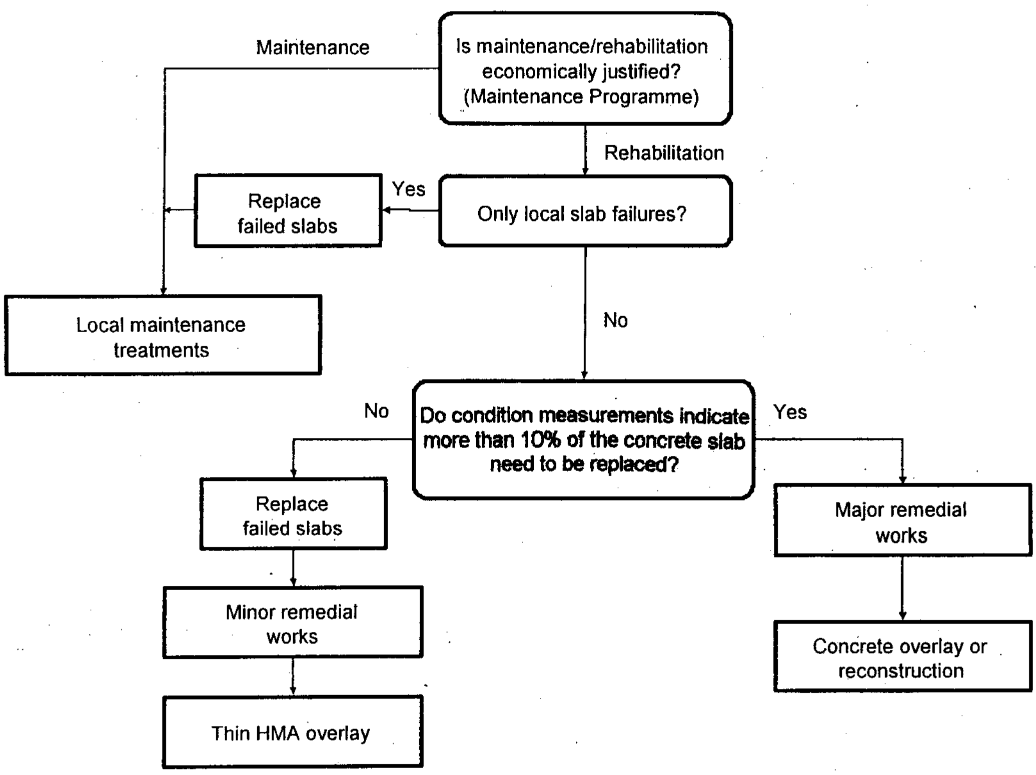


Figure 1.1 Maintenance and rehabilitation process

Where there are relatively few failures, it is appropriate to remove and replace those slabs and apply a thin Hot Mixed Asphalt (HMA) overlay. Where there are many slabs to remove, it will be more economic to crack and seat the existing unreinforced concrete road and apply a concrete overlay.

The criteria that has been developed to identify those slabs to be replaced is based on a visual assessment of the concrete slab and the Falling Weight Deflectometer (FWD) deflection measured at the middle of the slab. These criteria are described in Table 4.3 under subsection 4.2.

2.0 DEFECT DIAGNOSIS

Maintenance of concrete pavements that treat the symptoms of distress but do not address the underlying cause of the defect will not be successful. It is therefore important to find out why the defect has occurred before selecting the maintenance treatment. The following flow charts provide a means of selecting the most appropriate maintenance treatment. The maintenance treatments are referred to as Medium Term (MT) or Long Term (LT). Medium Term is considered to be a repair that is effective for 5-7 years and Long Term is a repair that is effective for greater than 7 years.

2.1 DEFECTIVE JOINT SEALS

Defective joint seals allow silt, grit, stones and water to enter between the slabs and infiltrate the lower levels of the pavement.

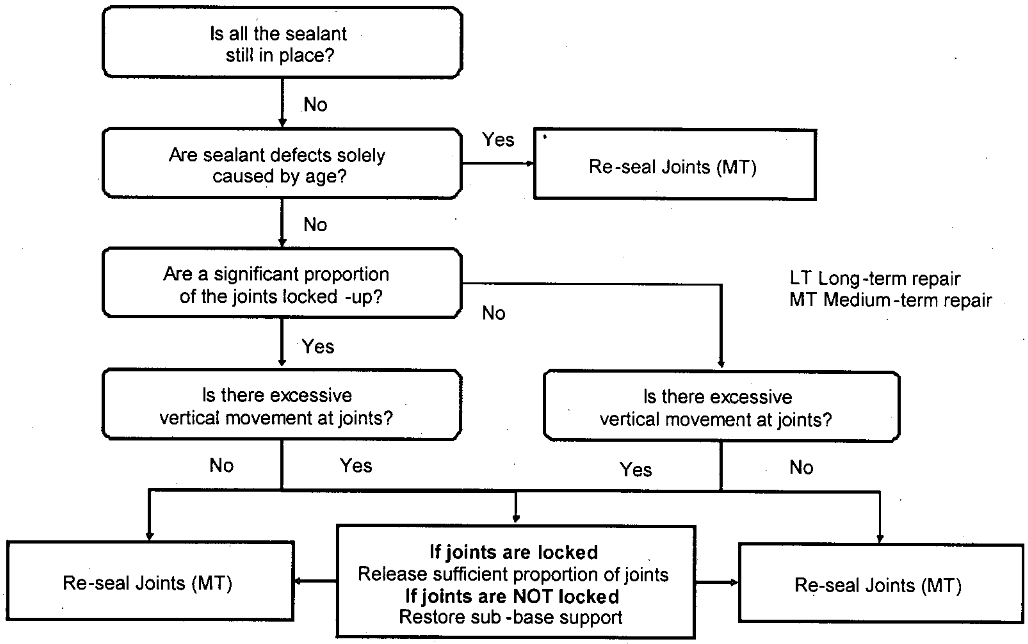


Chart 2.1 – Defective joint seals

2.2 SHALLOW SPALLING AT JOINTS

Shallow spalling at a joint is defined as cracking, breaking away or erosion of concrete alongside the joint and extending no deeper than the depth of the joint groove.

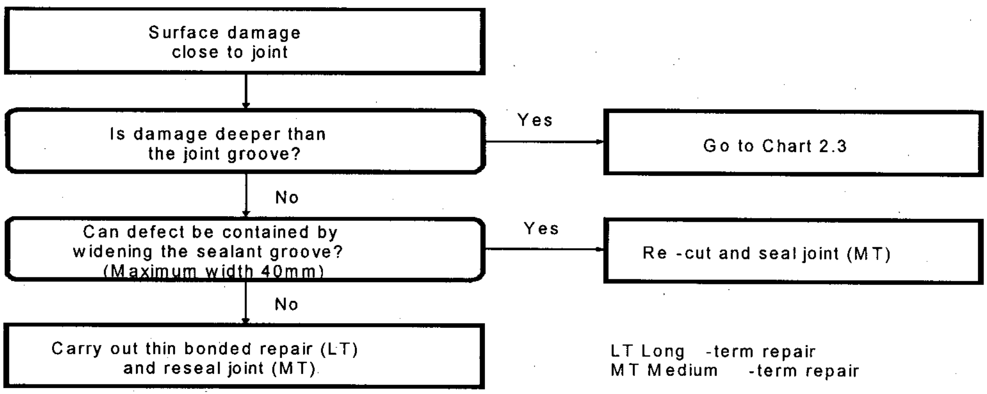


Chart 2.2 – Shallow spalling at joints

2.3 PARTIAL-DEPTH AND DEEP SPALLING AT JOINTS

Partial-depth spalls are those in which the depth of spalling exceeds the depth of the sealing groove but does not exceed one-third of the slab depth.

Deep spalls are deeper than one-third of the slab depth.

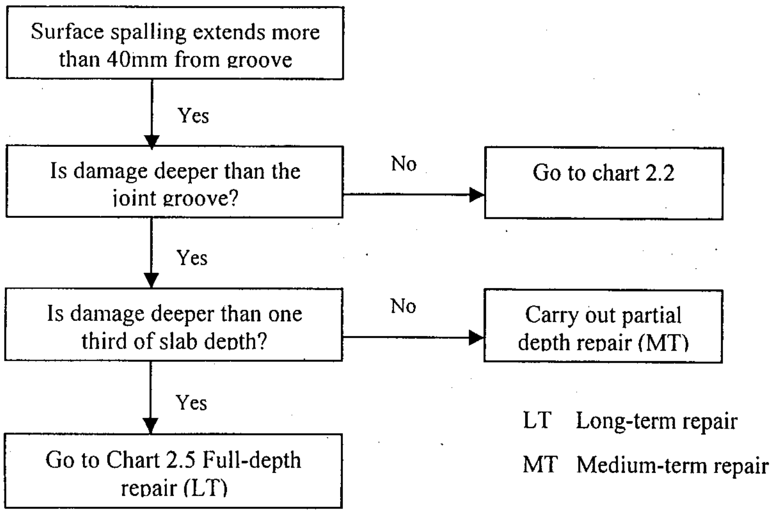


Chart 2.3 – Partial – depth and deep spalling at joints

2.4 FAULTING AT JOINTS

Faulting at joints is defined as an abrupt change in level in the running surface at a joint between two bays.

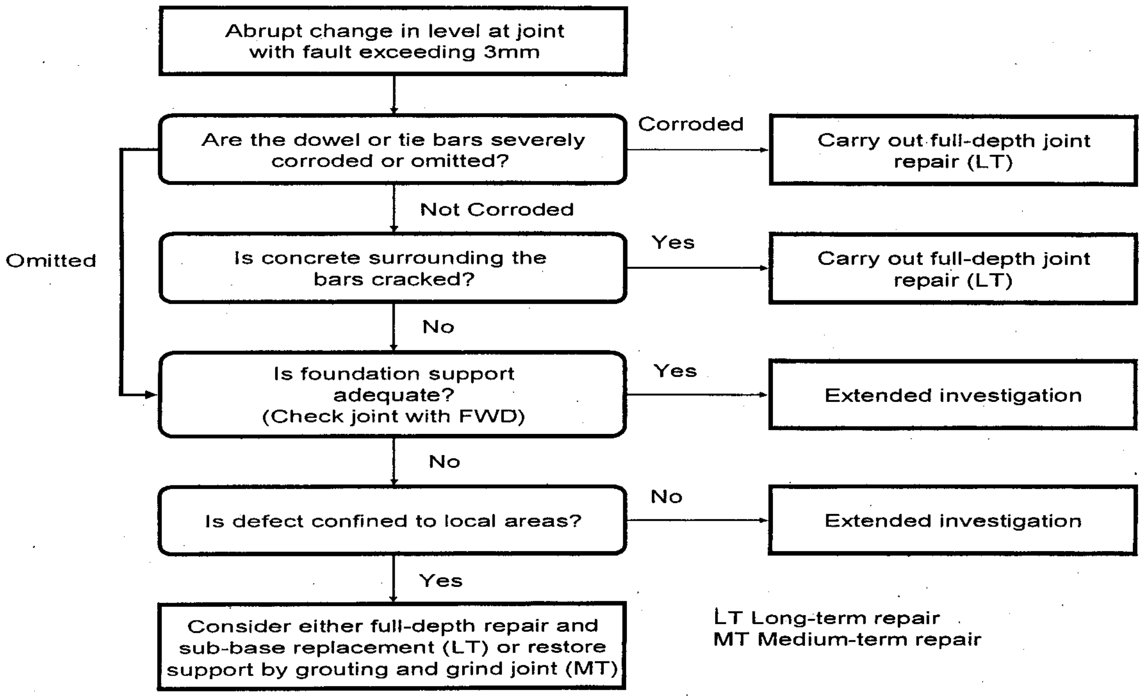


Chart 2.4 – Faulting at joints

2.5 CRACKS AT TRANSVERSE JOINTS

A crack at a transverse joint is a crack that may extend across the full width of a bay near a transverse contraction joint.

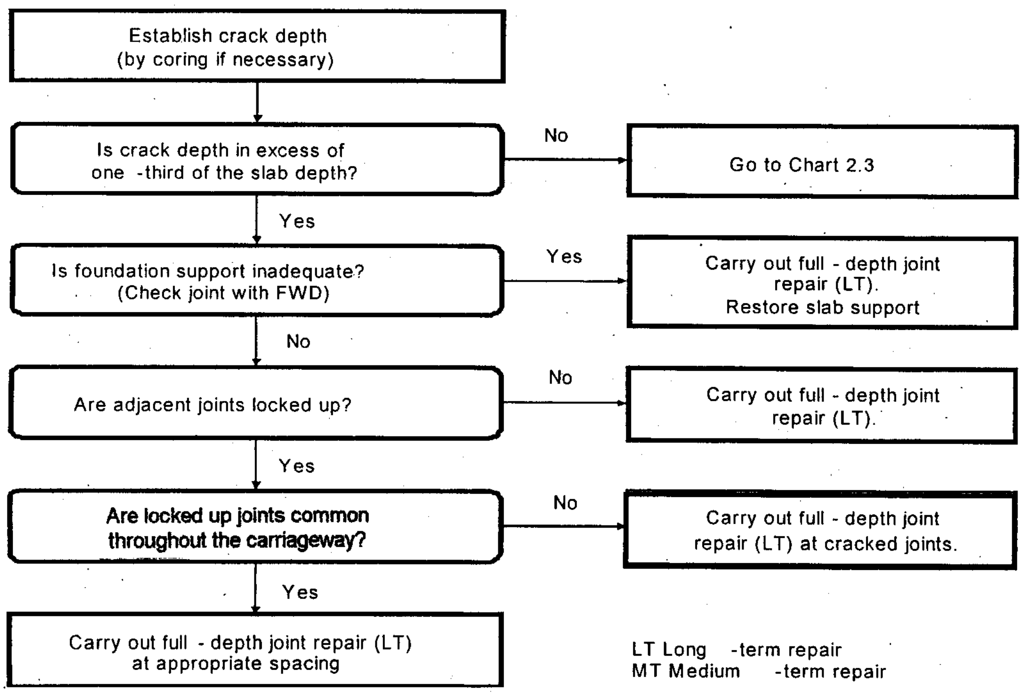


Chart 2.5 – Deep cracking at joints

2.6 LONGITUDINAL CRACKS

A longitudinal crack is a crack running longitudinally along the pavement. It can occur singly or as a series of nearly parallel cracks.

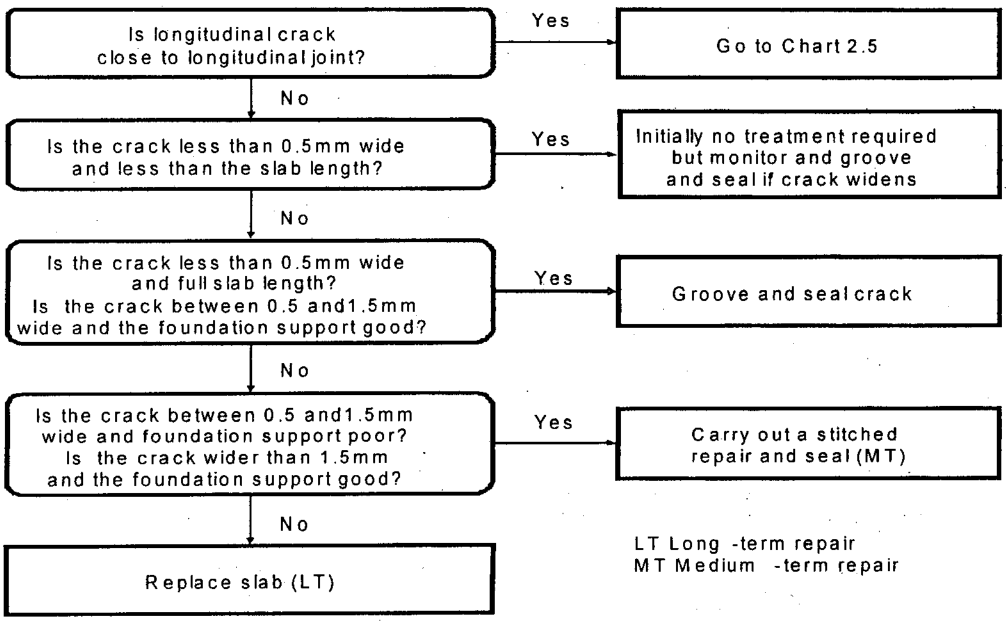


Chart 2.6 – Longitudinal cracks

2.7 TRANSVERSE CRACKS (MID SLAB)

Trasverse crack (mid slab) is a crack remote from the joints.

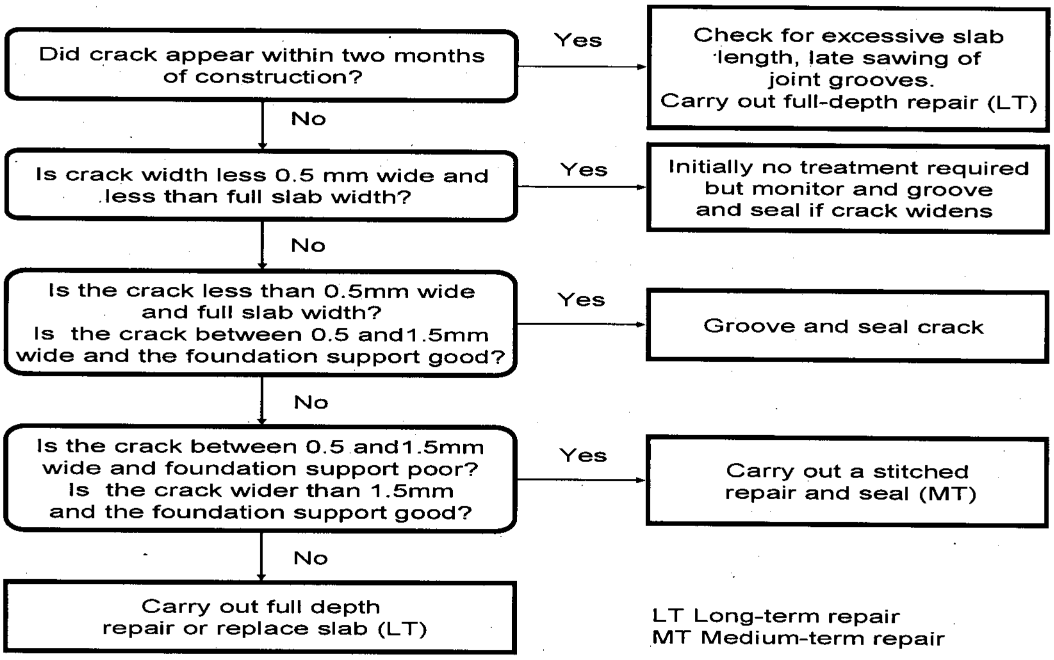


Chart 2.7 – Transverse cracks (midslab)

2.8 DIAGONAL CRACKS AND CORNER CRACKS

The term diagonal cracks is intended to include all multi-directional full-depth cracks that are neither generally transverse, longitudinal, nor across bay corners. Corner cracks include single full-depth cracks about 0.3-2m long across the bay corners.

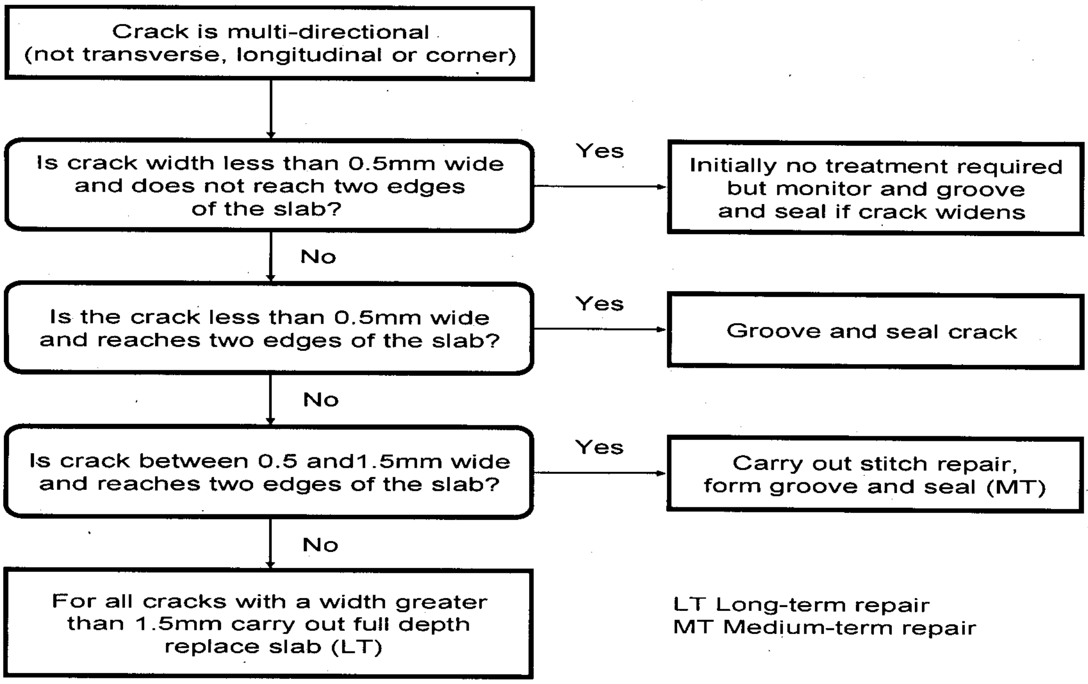


Chart 2.8 – Diagonal cracks

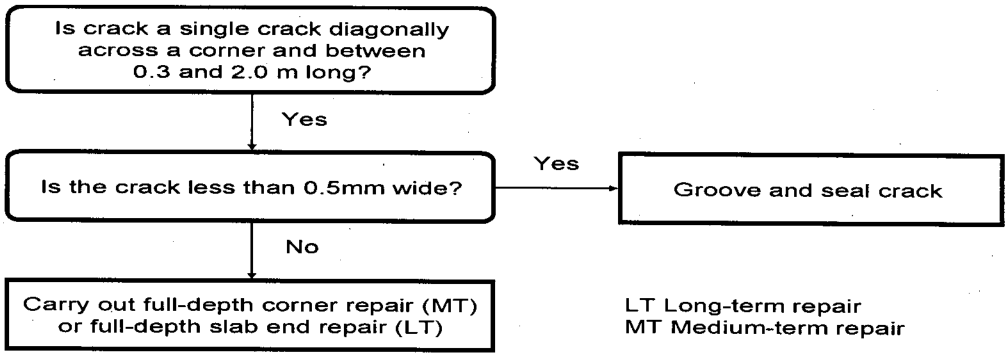


Chart 2.9 – Corner cracks

2.9 PLASTIC CRACKING

Plastic cracking are surface cracks that form before the concrete hardens in a pattern of short cracks usually approximately parallel to each other, oriented diagonally to the bay sides and not extending to the edges of the slab. Plastic cracks are caused by the concrete mix being too wet and they appear as the concrete cures. Although these cracks appear as minor defects at construction they will propagate downwards through the concrete over time and affect the life of the pavement. If noticed soon after construction the slab should be replaced.

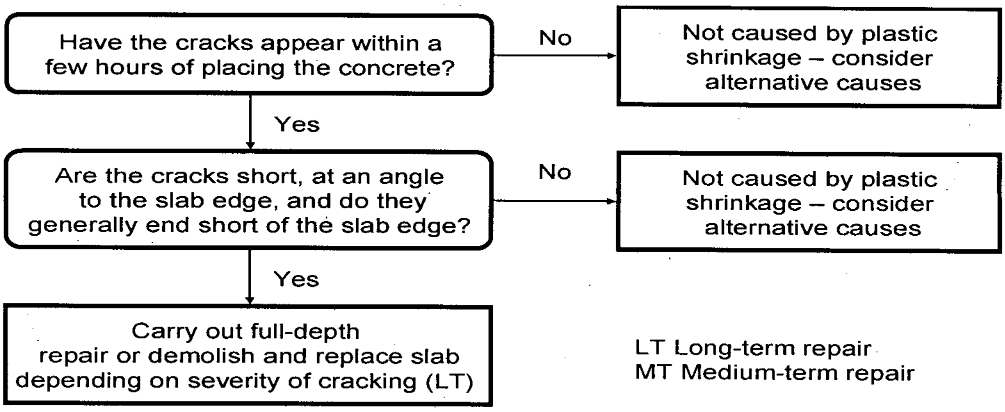


Chart 2.10 – Plastic cracking

3.0 MAINTENANCE TECHNIQUES AND METHODOLOGY

3.1 TECHNIQUES AT JOINTS

In selecting appropriate remedial treatments for defects at joints, the various functions they are required to perform in a concrete pavement must be considered.

3.1.1 Failed joint seal

Most joint seals do not last as long as the concrete pavement because they tend to harden and become brittle. Seals must therefore be replaced regularly, and Table 3.1 gives a guide to the main types, their relative life and usage. The sealants would generally be expected to last 7-10 years.

Table 3.1 Main types of joint-sealing materials

Classification	Chemical	Approximate Life
Hot –applied	PVC/pitch polymer	Medium
	Polymer/bitumen	Medium
Cold-applied	Polysulfide	Medium
	Polyurethane	Medium
	Silicone	Medium
Compression	Polychloroprene	Longest

Either hot or cold-applied elastomeric materials or compression seals are suitable for general re-sealing but gun-grade cold-applied materials are probably the most appropriate for small quantities of material. At joints between concrete and bituminous pavements, only hot-applied polymer modified bituminous sealants, or preformed polymer-modified bituminous strips are suitable.

For the seal to function properly, it must adhere to the sides of the sealing groove. This calls for an appropriate primer, with the sides of the sealing groove scoured by abrasive blasting, clean, dry and not too cold at the time of application. Caution is required with spray-applied primers at high ambient temperatures as they can vaporise before adhering to the concrete. Inadequate primer adhesion to the joint faces is a significant cause of premature failure of joint seals. As some sealants are mutually incompatible, all the old sealant should be removed before new is applied.

3.1.2 Shallow spalling

Removing the old joint seal will reveal the extent of shallow spalling. The quality of the concrete can be confirmed by tapping with a steel rod - a hollow sound indicating cracked material and a ringing tone indicating intact concrete. Where possible, such repairs should be carried out using either cement mortar or fine concrete depending upon the depth; the practicable minimum is about 10 mm. Cement mortar should be used for repairs up to 20 mm deep and fine concrete for deeper repairs. Thin bonded repairs at joints must not be used for depths greater than the joint groove.

Using epoxy concrete, or other 'concretes' with thermal properties and strengths different from the existing concrete, is not recommended, since further debonding or cracking of the existing concrete often follows. However, they can be used with care on small repairs less than 1 m long and less than 30 mm deep when there is insufficient time for cement mortar or fine concrete to cure.

Thin-bonded repairs to slab surfaces and joint grooves should be carried out in accordance with the procedure in Figure 3.1. The success of thin-bonded joint repairs depends entirely upon a good bond. This is best achieved by compacting the repair material against a freshly scabbled (roughened), clean surface and finishing it flush with the existing slab surface.

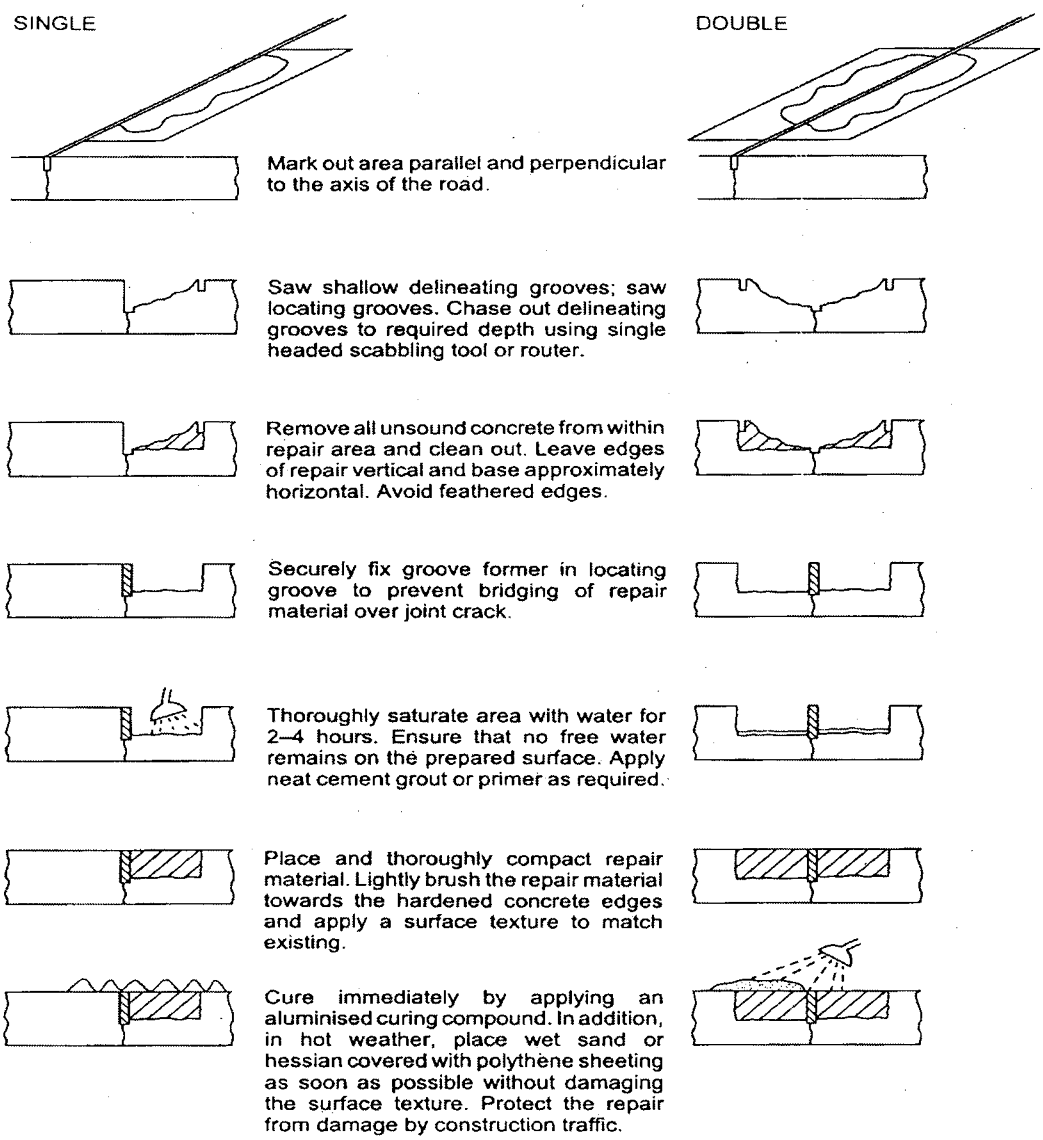


Figure 3.1 Procedure for thin bonded repair at joint

3.1.3 Deep spalling

Deep spalling usually extends to at least half slab depth and possible causes are given in Table 3.2. One cause, dowel bar restraint, may be due to misalignment and, or excessive bond along the bar (which must be free to move in one of the slabs). The only satisfactory remedy likely to achieve a long life is a full-depth bay-end replacement (See 3.2.3).

Table 3.2 Deep spalling - causes and remedies.

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 bay corners	Dowel restraint Ingress of solids into the joint crack	Transverse full-depth repair

3.1.4 Other structural cracks at joints

The main types of crack, their likely causes and appropriate remedies are summarised in Table 3.3.

Table 3.3 Structural cracks at joints: causes and remedies

Type of defect	Cause	Remedy
Transverse or diagonal cracks at transverse joint	Dowel restraint, gross mis-alignment Late sawing of joint groove Mis-aligned top and bottom crack inducers	Transverse full depth repair
Longitudinal crack at transverse joint	Compression failure Ingress of incompressible material into joint crack Edge restraint	Transverse or longitudinal full depth repair
Longitudinal cracks at longitudinal joints	Mis-aligned top and bottom crack inducers Omission of bottom crack inducer	Longitudinal full depth repair

3.2 LONGITUDINAL AND TRANSVERSE CRACKS

The most likely cause and appropriate treatment for structurally significant longitudinal and transverse cracks is shown in Table 3.4.

Table 3.4 Longitudinal and transverse cracks: causes and remedies

Type of Defect	Cause	Remedy
Transverse Crack	Excessive bay length Late sawing of joint grooves Dowel bar restraint at joints Inadequate reinforcement overlap Sub-base restraint	Full slab width narrow cracks and medium cracks with good support – groove and seal Full slab medium width with poor support and wide cracks with good support – stitch repair. Full slab width wide cracks with poor support – Full depth repair or slab replacement
Longitudinal Crack	Excessively wide bays Omission or displacement of bottom crack inducer at longitudinal crack Settlement	Full slab width narrow cracks and medium cracks with good support – groove and seal Full slab medium width with poor support and wide cracks with good support – stitch repair. Full slab width wide cracks with poor support – Full depth repair or slab replacement

3.2.1 Stitched crack repairs

It is possible to repair cracks using a stitched crack repair. The two types - Type 1, a staple tie bar repair and Type 2, a diagonal tie bar repair are shown in Figure 3.2. Such repairs are undertaken to convert the crack into a tied warping joint that will allow the slab to `hinge' at that point, maintaining aggregate interlock and preventing it from widening.

For Type 1, slots 25-30 mm wide by 470 mm long at 600 mm centres and at right angles to the line of the crack are chased out to a depth such that the tie bars lie between one-third and one-half of the slab depth below the surface when bedded. Holes of 25-30 mm diameter and 50 mm deep are drilled at each end of the slot and the slots then cleaned with oil-free compressed air.

Once dry, the slots are primed and the staple tie bars placed onto beds of epoxy resin mortar and covered with the same material to a minimum depth of 30 mm. The sides of the slots are then cleaned of loose material and filled with thoroughly compacted resin or cementitious mortar. After the repair material has cured, a groove is sawn or routed along the line of the crack and sealed in the same manner as a transverse joint.

With Type 2 crack repairs, cross-stitching is employed as shown in the lower diagram of Figure 3.2 and about 26 degrees to the slab surface. These holes are spaced every 600 mm along the crack with alternate entry points on opposite sides. The entry points should be at a distance from the crack equal to the slab depth.

The length of bar depends on the slab depth and should be enough to allow 50 mm cover at the bottom of the slab. Deformed 12 mm grade 460 steel tie bars are used and notched at a point that will be 50 mm below the slab surface when the bars are fully inserted.

Each hole is filled with epoxy resin mortar so that, with the tie bar inserted, the mortar level reaches to 25 mm below the notch. Epoxy resin mortar is recommended for stitch repairs because the material must harden before crack movement can disrupt the repair. Once the mortar has set, the length of tie bar above the notch is broken off by twisting. Any bars that rotate after the mortar should have hardened must be withdrawn and the hole re-drilled.

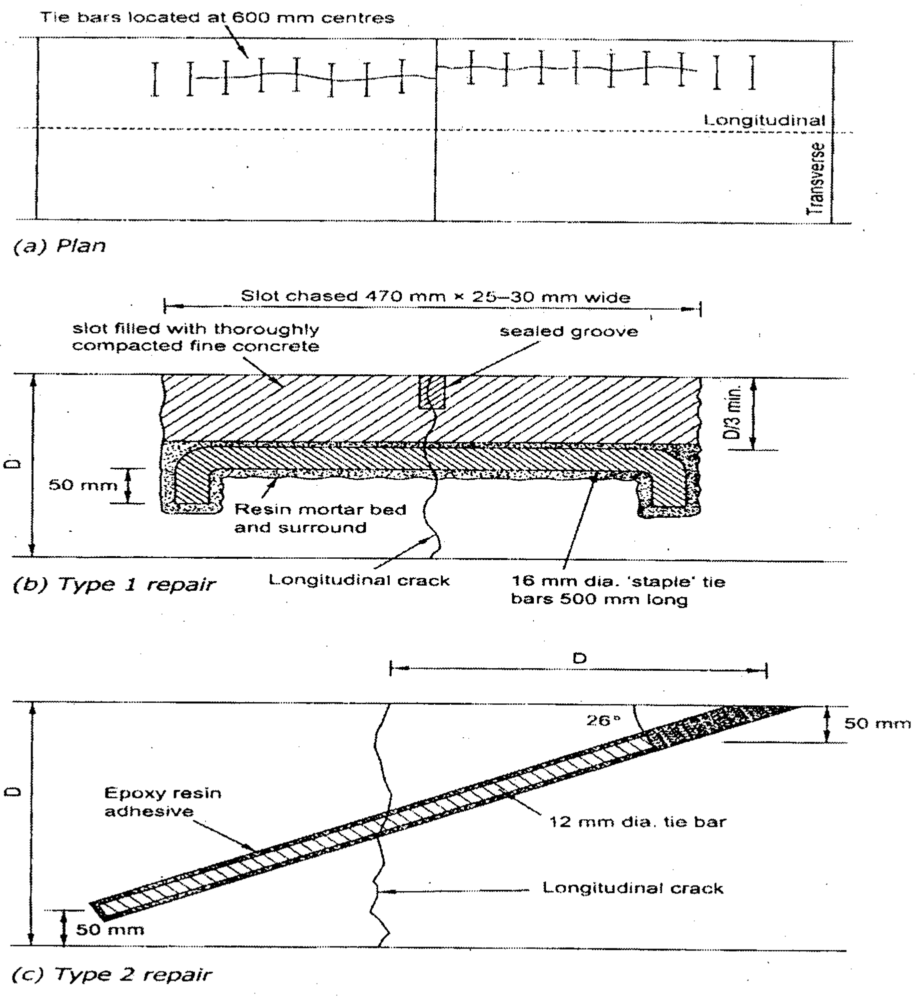


Figure 3.2 Stitched crack repair

3.2.2 *Slab replacement*

Before an affected slab is broken out, a full-depth saw-cut should be made around the perimeter of the repair to minimise damage to the surrounding slab. This should include the existing transverse and longitudinal joints: saw cuts must not extend into adjacent bays. The concrete may then be sawn into smaller pieces before being broken up and removed.

Any necessary reinstatement of the sub-base should be done before new dowel and tie bars are fixed at the transverse and longitudinal joints. Any new sub-base material must be fully compacted, especially at corners; a heavy plate vibrator is required to compact granular or cement-bound sub-base material.

3.2.3 *Full-depth repairs*

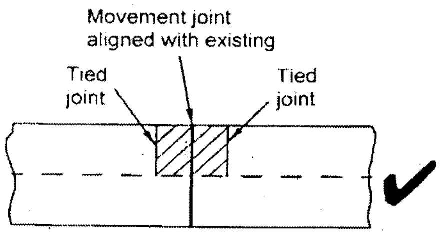
Where there is an unbound sub-base, the length of a full-depth repair should be at least 2m so that sub-base compaction can be effective and the traffic load spread over a greater length, eliminating the punching effect on a shorter repair. Therefore longitudinal or mid-slab transverse cracks necessitate a slab replacement.

Where undertaken, full-width repairs constitute small slabs and so should be at least equivalent to the main slab in all respects (see Figures 3.3 and 3.4). It is advisable to reinforce such repairs and this must be done when, as is often the case, the ratio of the longest to the shortest dimension is greater than two. Either a square or long mesh reinforcement of appropriate weight is suitable. For the latter, the main bars must be parallel to the longest dimension. The quantity of reinforcement should be 500-800 mm^2 per metre width of concrete, depending on traffic (see Figure 3.4).

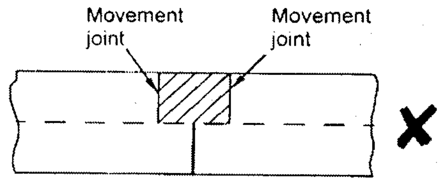
The function of any joints between new and existing concrete that may be introduced as a consequence of a full-depth repair must be considered. Failure to do so has frequently resulted in sympathetic cracking in the repair concrete or in the retained adjacent original concrete. Joint arrangements that have proved satisfactory are shown in Figure 3.3. Movement joints in this context are either transverse contraction joints or transverse expansion joints. New joints will usually be contraction joints unless the retained pavement adjoining the repair has been found to contain locked-up joints, in which case it may be appropriate to introduce an expansion joint in a full-depth repair as long as it spans the full carriageway width.

A tied transverse joint functions differently from a tied longitudinal joint. Tied transverse joints between an original slab and a full-depth repair are intended to give as near as possible a monolithic action between the repair concrete and the original slab. Because load transfer is likely to be impaired by the tied joint, shear transfer should be improved by transverse tie bars of the same length and diameter as would be appropriate for dowel bars at a contraction joint. In this case, the bars should be of high-yield deformed steel to take advantage of the increased bond available compared with plain mild-steel bars and the polymeric coating required for dowel bars in movement joints should be omitted. A detail suitable for tied transverse joints is shown on the left of Figure 3.4. The movement joint on the right of the same figure is an expansion joint for which the dowel bars should be of plain round mild steel 25 mm in diameter for slabs less than 240 mm thick and 32 mm for slabs 240 mm or more. The detail for contraction joints is similar with the omission of the expansion filler board and dowel caps. For contraction joints, the bars are similar but the diameters may be reduced to 20 mm and 25 mm respectively.

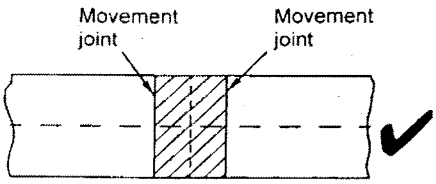
With all full-depth repairs every effort should be made to prevent debris, such as slurry from sawing or other repair material, from entering any joint. Cracks and grooves should be cleaned using oil-free compressed air if necessary and taped over with adhesive masking tape. It is also essential to prevent slurry from the sawing operation - which could solidify and block drains - getting into the drainage system.



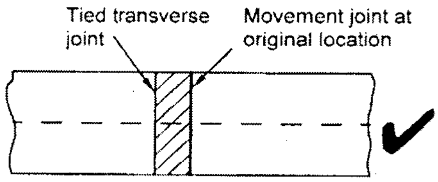
(a) Full-width repair in one lane only, adjacent to existing contraction or expansion joint. Repair may be to one or both sides of original joint.



(b) Not advised – reflective crack(s) likely in repair concrete aligning with retained original joint and/or in retained lane aligned with new movement joints in repaired section.



(c) Full-width repair to all lanes both sides of and adjacent to existing contraction or expansion joint. Omit original movement joint.



(d) Full-width repair to all lanes one side of and adjacent to existing contraction or expansion joint.

(a) Full-width repair in one lane only, adjacent to existing contraction or expansion joint. Repair may be to one or both sides of original joint.

(b) Not advised – reflective crack(s) likely in repair concrete aligning with retained original joint and/or in retained lane aligned with new movement joints in repaired section.

(c) Full-width repair to all lanes both sides of and adjacent to existing contraction or expansion joint. Omit original movement joint.

(d) Full-width repair to all lanes one side of and adjacent to existing contraction or expansion joint.

Figure 3.3 Full-depth repairs to unreinforced concrete pavements.

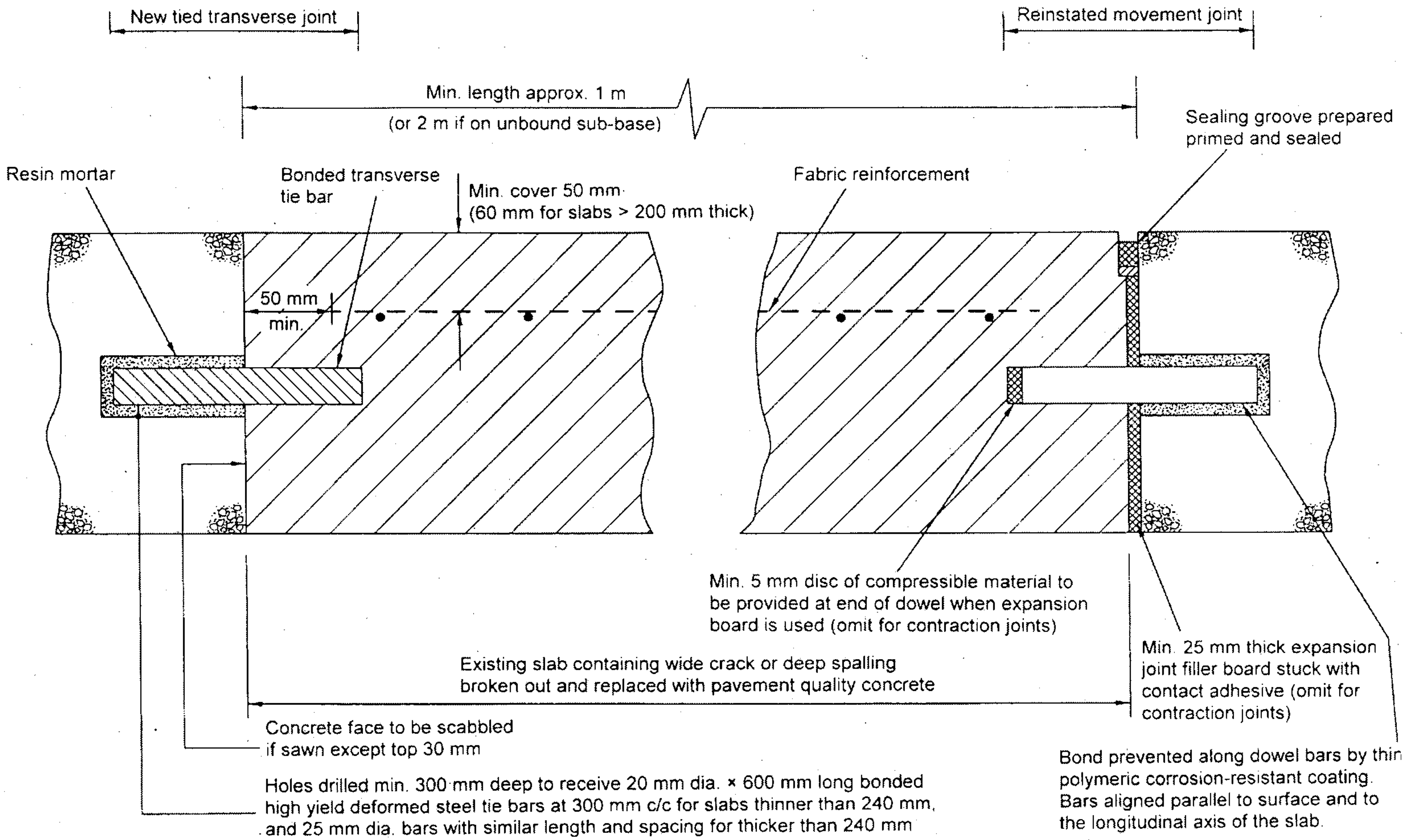


Figure 3.4 Longitudinal section through transverse full-depth repair adjacent to an existing transverse movement joint in URC pavement.

3.3 DIAGONAL AND CORNER CRACKS

The term diagonal cracks is intended to include all multi-directional full-depth cracks that are neither generally transverse, nor longitudinal, nor across bay corners. Corner cracks include single full-depth cracks about 0.3-2m long across the bay corners; if not repaired, they will lead to localised deterioration of the sub-base and perhaps subsequent mud pumping. The most likely causes and appropriate remedies are given in Table 3.5.

Table 3.5 Diagonal and corner cracks: causes and remedies.

Type of defect	Cause	Remedy
Diagonal cracks	Settlement or heave of sub-base or subgrade	Narrow cracks will need to be sealed or remedied by means of a stitched crack repair
Corner cracks	Lack of load transfer at joints Dowel bar restraint at edge of slab Ingress of solids into joint at edge of slab Acute angles in non-rectangular slabs Loss of sub-base support	Transverse full depth repair or corner repair. The latter may not achieve long life.

If a full-width repair is inappropriate, a corner repair may be carried out.

3.4 INADEQUATE SLAB SUPPORT

Vertical movement occurs either dynamically under passing traffic or permanently in the form of settlement of the slab or 'faulting' at joints or cracks. Dynamic movements may be associated with mud-pumping which, unless remedied, is likely to lead to multiple cracks. Mud-pumping probably also indicates poor pavement or sub-soil drainage; this should be corrected before any remedial work is undertaken. Seepage of water up through joints or along the edges of the slab may also indicate poor drainage.

These defects, their likely causes and appropriate treatment are described in Table 3.6. Note that the remedy for the immediate problem may not remove the original cause, e.g. ground softening due to water ingress. The cause must be understood and corrected before carrying out repairs.

Table 3.6 Inadequate slab support

Type of defect	Cause	Treatment
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
Faulting at joints and cracks	Lack of, or ineffective load transfer dowels or tie bars at joints	Slab lifting in conjunction with pressure or vacuum grouting Grinding after pressure or vacuum grouting

3.4.1 Slab lifting

Raising the level of slabs by lifting is a controllable process in which the slab is connected to a frame straddling the bay and hydraulically jacked to the required level a few millimetres at a time. While the slab is still connected to the lifting frame, the void created underneath should be filled by pressure- or vacuum-grouting. When a substantial length of slab is lifted, it may be necessary to stitch tie bars across the longitudinal joint to stop it opening subsequently.

3.4.2 Pressure-grouting

Pressure-grouting is used either to fill small voids and stabilise dynamic movement of the slab or to fill the voids created when slabs are raised to correct settlement or faulting at joints and cracks. As well as cementitious and resin grouts, a dry mix mortar may 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 under traffic. Fluid grout is more suitable for filling smaller voids under the slab.

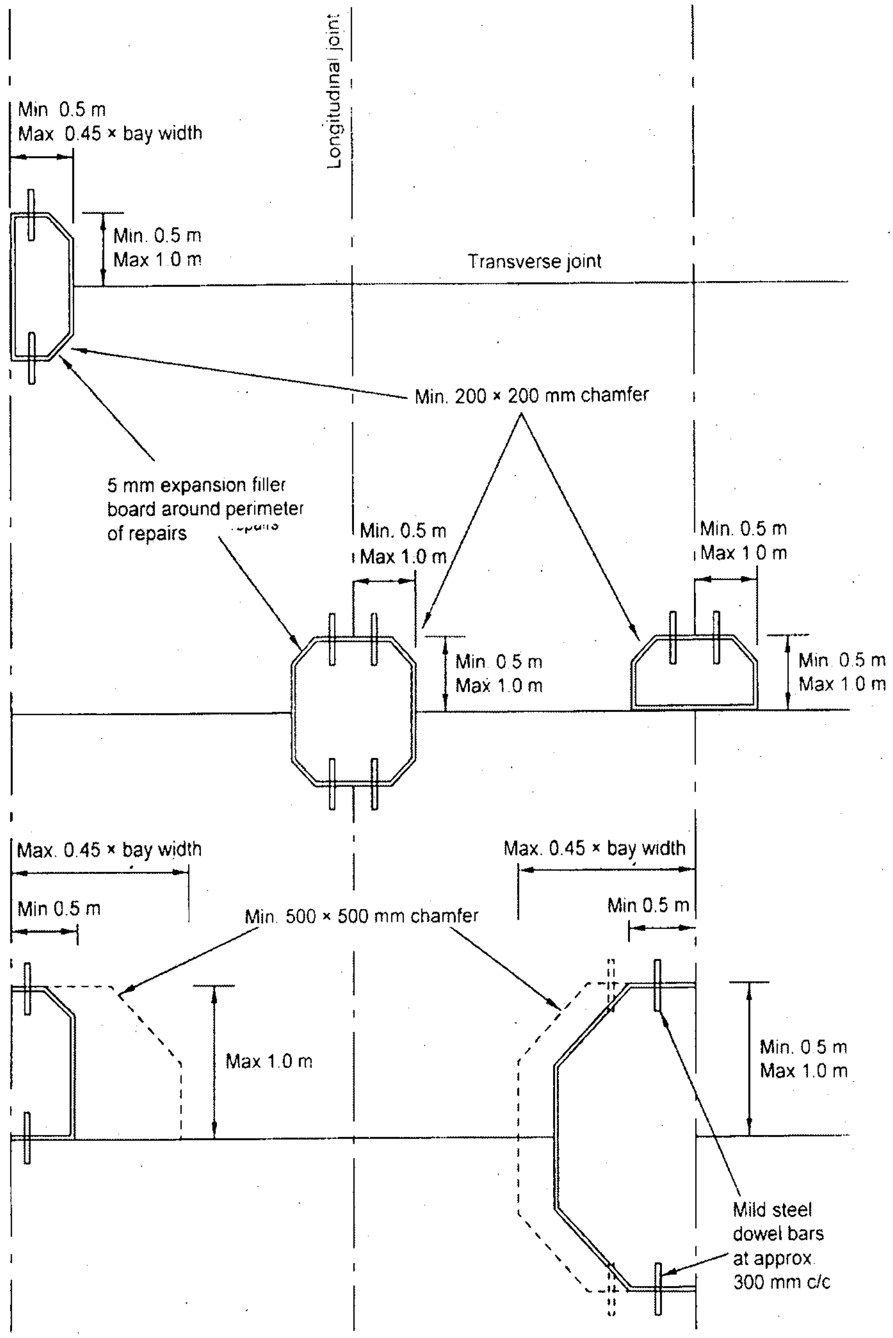
3.4.3 Vacuum-grouting

With vacuum-grouting, a low-viscosity resin grout is induced to flow into voids beneath the slab by applying a vacuum. Holes about 30 mm in diameter are drilled through the slab on a lm square grid for vacuum suction and grout injection. The advantages of the process are that any water beneath the slab is drawn off before the grout is injected and the low viscosity of the grout enables small voids to be penetrated. There is also little danger of inadvertently filling service ducts.

3.4.4 Full-depth corner repair

Full-depth corner repairs have been widely used and have often been regarded as long-term repairs. Full-depth corner repairs should not exceed the maximum dimensions given in Figure 3.5.

With corner repairs, as large a chamfer as possible should be provided across the corner as shown in Figure 3.5 to reduce the risk of a crack subsequently developing across the slab from that point. It may therefore not be possible to extend the saw cuts around the corners of the repair through the full slab depth - necessitating careful breaking out to achieve the vertical face required in the corners. Particular care should be taken to avoid damaging the remaining top edges of the slab.



(Longitudinal edges of repairs should not occur in wheel tracks)

Figure 3.5 Full depth corner repairs

3.5 POLYMER-MODIFIED REPAIR MATERIALS

There are various proprietary materials for filling cracks and making good surface defects. Most of them incorporate polymer-modified cement and/or bitumen as the binder. In addition to conventional sand or gravel aggregate, these repair materials may also incorporate glass fibres and rubber granules. In general, those with polymer-modified bitumen binders are applied hot and those with polymer-modified cement are applied cold. All are capable of sustaining strains significantly greater than conventional repairs using Portland cement. Depending on the particular formulation and repair depth, the surface may be opened to traffic between 10 minutes and 2 hours after laying. In all cases, it is important to comply strictly with the manufacturers' recommendations.

Polymer-modified materials are available suitable for sealing cracks that have been routed to form a sealing groove that may be up to about 30 mm wide and 25 mm deep. Again, it is important to follow manufacturers' recommendations: some advise the use of an elongated patch repair 300-400 mm wide over the crack and this may be preferred for cracks that have branched into two (cracks), or are difficult to follow with a mechanical router.

3.6 PARTIAL-DEPTH CEMENTITIOUS REPAIRS

Partial-depth cementitious repairs are used for spalling etc. that exceed the maximum depth for which thin-bonded repairs may be used and include surface repairs no deeper than one-third of the total slab depth. Such repairs have become possible with the advent of polymer-modified cements, particularly the rapid-hardening varieties.

Figure 3.6 shows an appropriate procedure for a partial-depth joint repair with polymer modified material. Here, a partial-depth repair is defined as deeper than the joint groove but not exceeding one-third of the slab depth. The finished surface of the repair should have a uniform surface texture and appearance and should be free from droppings, excess overlapping, damage by rain or frost, or other deposit.

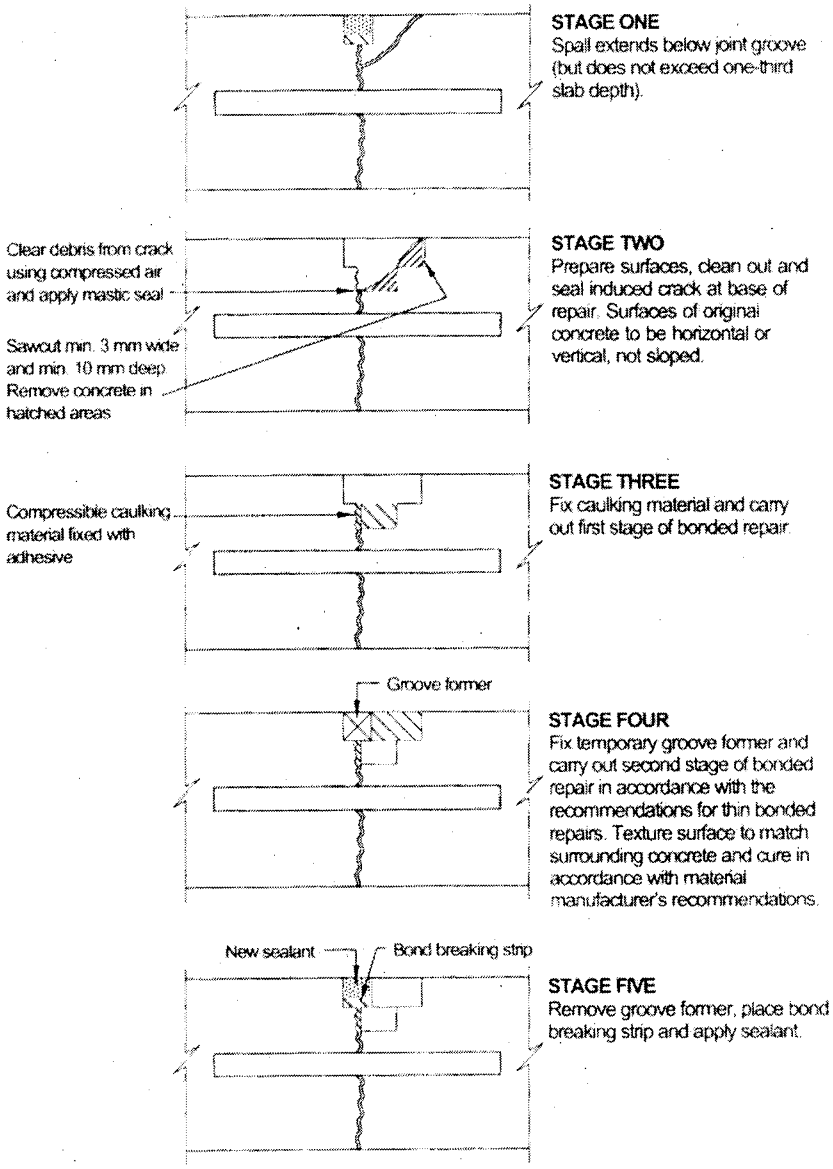


Figure 3.6 Partial-depth repair at a joint using polymer-modified material.

4.0 THIN HOT MIXED ASPHALT (HMA) OVERLAYS

Maintenance of the network of concrete roads has often been confined to simply overlaying roads with thin layers of Hot Mixed Asphalt concrete (HMA). These overlays have been used to either restore the uneven surface on relatively new pavements or to maintain more deteriorated pavements. In some cases these overlays have been relatively successful. However the defects in the underlying concrete pavement layer can rapidly cause failures in the new HMA overlay.

4.1 ASSESSMENT OF THE EXISTING CONCRETE PAVEMENT

The development of reflection cracking in thin HMA overlays has been found to be controlled by the condition of the underlying unreinforced concrete pavement and its support as measured with the FWD. The condition codes are given in Tables 4.1 and 4.2.

Therefore, prior to a HMA overlay, a visual survey and mid-slab deflection survey should be carried out. Each concrete slab should be visually assessed. Ideally all slabs should be tested with the FWD, however, if resources are limited, testing can be restricted to those slabs having condition codes 3-5 (See Table 4.2). All FWD deflection should be normalised to a load of 50kN.

Table 4.1 Classification of crack width

Crack definition	Width[1] (mm)	Condition
Narrow	< 0.5	Full aggregate interlock and load transfer
Medium	0.5 – 1.5	Partial interlock and load transfer. May permit entry of water
Wide	> 1.5	No load transfer. Ingress of water and fine material

Note 1 Width of crack where there is no spalling

Table 4.2 Classification of crack severity

Code	Slab definition	Condition
1	Good	Slab which has no cracking
2	Fair	A slab which has some cracks but no cracks which are full slab width or length (either transverse or longitudinal)
3	Average	A slab which has cracks that include *one* full slab (width or length) crack of medium width but less than two full slab (width or length) cracks of medium width.
4	Poor	A slab that has cracks that include *two* full slab (width or length) cracks of medium width. Also a slab that has at least *one* full slab (width or length) crack of medium width plus minor asphalt repair (e.g. one corner patch etc)
5	Very poor	A slab that has multiple cracks with *three or more* full slab (width or length) cracks of medium width. Also a slab that has *two* full slab (width or length) cracks of medium width and substantial asphalt patching or lengths of sealed cracks.

Table 4.3 gives recommendations based on the severity of cracking and FWD central deflection which can be used to identify which slabs should be stitched or replaced prior to overlay.

Technical recommendations for stitching and slab replacement are given in Sections 3.2.1 and 3.2.2 respectively.

4.2 HMA OVERLAY THICKNESS

Results to date show that providing the recommendations in Table 4.3 are followed then a 50mm HMA overlay can be used to rehabilitate jointed unreinforced concrete pavements up to a design traffic of one million esa and 100mm HMA overlays can be used to rehabilitate jointed unreinforced concrete pavements, up to a design traffic of 3.0 million esa.

Table 4.3 Interim recommendations for remedial works

	FWD deflection d_1 (microns) @ 50kN		
Condition Code	$d_1 < 300$	$300 < d_1 < 400$	$d_1 > 400$
1	Leave	Investigate[1]	Investigate[1]
2	Leave	Investigate[1]	Investigate[1]
3	Leave	Stitch cracks[2]	Remove and Replace
4	Stitch cracks[2]	Stitch cracks[2]	Remove and Replace
5	Remove and Replace	Remove and Replace	Remove and Replace

Notes
1. Unlikely event – Investigate whether poor support is cause of high FWD deflection
2. Stitch full width/length cracks
3. d_1 is the central FWD deflection

5.0 CONCRETE OVERLAYS

Where the condition of the road results in it being uneconomic to remove the necessary slabs that are in poor condition (See Table 4.3) prior to using a thin HMA overlay, then either the road will need to be reconstructed or a concrete overlay will be required, if road levels permit.

5.1 CHOICE OF OVERLAY TYPE

Concrete overlays are normally at least 150 mm in depth and may be either 'jointed unreinforced' concrete, 'jointed reinforced' concrete or 'continuously reinforced' concrete. Advice on the thickness of overlay should be sought elsewhere.

Jointed unreinforced and jointed reinforced concrete overlays should be unbonded. This does not constrain the designer to the same slab shape and size as the underlying pavement, however, the design must ensure that debonding occurs by some positive means. When a jointed concrete overlay is used, plastic sheeting is the most appropriate way of ensuring the overlay is not bonded to the existing road. When continuously reinforced concrete (CRC) is used, the overlay should be uniformly bonded to the underlying layer.

5.2 CRACKING AND SEATING

Before overlay, the cracked concrete should be seated with a pneumatic-tyred roller with a ballasted weight of at least 20 tonnes. Tests elsewhere have shown that six passes over every point of the cracked and seated concrete is sufficient to seat the pavement.

The overlay itself may be either a jointed unreinforced or jointed reinforced concrete overlay. However, continuously reinforced concrete (CRC), in particular, offers good load-spreading properties that enable it to accommodate some localised variation in support from the underlying materials. Where the existing unreinforced concrete pavement is both particularly distressed and the joints exhibit poor load-transfer characteristics, a combination of crack-and-seating and a CRC overlay is strongly recommended.

GLOSSARY

Adhesion failure: Joint sealant rendered ineffective through loss of adhesion between the sealant and the vertical faces of the concrete in the joint groove.

Cohesion failure: Joint sealant within which cracks have occurred at right-angles or parallel to the joint groove.

Compression ('blow up') failure: Crushing failure of a slab at a joint or crack caused by excessive compressive stress resulting from thermal expansion of a pavement containing joints that have locked up and/or have filled with incompressible detritus.

Construction joint: A joint made in a concrete pavement at the end of a working day. Similar joints may have to be introduced in an emergency when plant breaks down or paving is stopped by bad weather.

Continuously reinforced concrete (CRC): A concrete running surface that does not include transverse joints but in which the slab contains sufficient reinforcing steel to control transverse thermal contraction/shrinkage cracks.

Crack-and-seat: Process in which a distressed concrete pavement is broken into small slabs and rolled before overlaying in order to inhibit reflective cracking of the subsequent overlay. Aggregate interlock is maintained between the small slabs. (See also Rubblise.)

Cracks: Structural fractures in the pavement categorized Wide (unspalled width exceeding 1.5 mm), Medium (unspalled width between 0.5 - 1.5 mm), Narrow (unspalled width less than 0.5 mm) or hairline (present, but detectable only with difficulty).

Crack inducer: An insert put in the concrete to create a plane of weakness where subsequent thermal contraction/shrinkage cracking will occur in a controlled manner.

Deep spalling at joints: Multiple cracking and breaking away of concrete adjacent to a joint, often semi-circular in plan and extending down below the bottom of the joint groove.

Deflection: The recoverable movement of the surface of a pavement under a transient load.

Design period: The number of years for which a pavement is designed.

Design Traffic: The traffic predicted over the design period, usually expressed in millions of standard axles (mesa).

Elastic modulus: A measure of the material stiffness properties.

Faulting: An abrupt change of level in the running surface at a joint between two bays, also known as stepping.

Fatigue: The formation of cracks in pavement materials under repeated loading.

Formation: Level upon which sub-base is placed.

Foundation: All materials up to the top of sub-base.

Grinding: Mechanical removal of out-of-tolerance surface concrete projecting above the required finished level.

High-early-strength concrete: Pavement-quality concrete designed to achieve 25 MPa at ages from three days to less than six hours, depending on the urgency of opening the pavement to traffic.

Induced crack: A full-depth crack intentionally induced in a concrete slab by providing a joint groove in the top surface and (sometimes) a crack-inducing insert in the underside.

Joint groove: The groove provided at the top of a joint to receive the sealant.

Joint seal: Flexible sealant material that adheres to the vertical faces of the joint groove to exclude water and detritus while accommodating opening and closing of the joint.

Load transfer: The distribution of load to an unloaded slab that occurs when the slab on the other side of a joint is loaded.

Load transfer efficiency: The ratio (expressed as a percentage) of vertical deflection of an unloaded slab (adjacent to a joint) to the deflection of an abutting loaded slab.

Overlay: New material placed directly onto the surface of a pavement.

Partial depth repair: Repair to a spalled joint at which the depth of spalling exceeds the depth of the joint groove but does not exceed one-third of the slab depth; repair at a location remote from joints where the depth of repair exceeds 40 mm but does not exceed one-third of the slab depth. The repair is fully bonded to, and becomes monolithic with, the original concrete slab.

Partial reconstruction: Pavement rehabilitation that re-uses some of the existing layers.

Pavement: All layers above formation.

Plastic cracking: Surface cracks that form before the concrete hardens in a pattern of short cracks usually approximately parallel to each other, oriented diagonally to the bay sides and not extending to the edges of the slab.

Polymer mortar: A cementitious mortar modified by adding a polymer such as styrene butadiene rubber.

Reconstruction: Replacing all layers of an existing pavement with new (or recycled) materials.

Reflective cracks: Cracks in a concrete slab or asphalt overlay induced by movement in joints or cracks in an underlying layer.

Rigid Pavement: Pavement-quality concrete road base with concrete running surface.

Road base: Main structural layer of pavement, placed above sub-base.

Rubbilise: Process by which a distressed concrete pavement is broken up to such an extent that there is no significant aggregate interlock between adjacent pieces. (See also Crack-and-seat.)

Shallow spalling at joints: Cracking, breaking away or erosion of concrete alongside the joint and extending no deeper than the depth of the joint groove.

Standard axle: An axle with an 80kN total force.

Stepping: see faulting.

Sub-base: A platform layer upon which the main structure of a pavement may be laid.

Subgrade: Soil underlying a pavement. It may be fill material.

Sympathetic crack: A crack induced in a slab by movement at a joint or crack in an abutting slab.

Thin bonded repair: A shallow cementitious patch – usually to a joint groove and not more than 40mm deep – that is fully bonded to, and becomes monolithic with, the original concrete slab.

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