Technical Note 143

Rehabilitation Technique and Treatment Prioritisation Method of Plain Concrete Pavements (PCP)

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1 Statement

This technical note provides guidance for rehabilitation technique and treatment prioritisation method of the existing plain concrete road pavements (PCP) where the pavements are outside the defect liability and warranty periods. The details within this document have been compiled from:

- practitioners field experiences
- collated pavement testing data
- technical standards MRS39 Lean Mix Concrete Sub-base for Pavements and MRS40 Concrete Base in Pavements Jointed Unreinforced, Jointed Reinforced, Continuously Reinforced and Steel Fibre Reinforced Pavements
- supplementary specifications MRSS Concrete pavements – Slab Replacement, and
- supplementary specifications MRSS Supply of Concrete for Rapid Concrete Pavement Slab Replacement.
- Road Maritime Services NSW Concrete Pavement specifications and drawings for concrete pavement maintenance.

For comprehensive details on the rehabilitation of PCP’s refer to the 2012 Pavement Rehabilitation Manual.

2 Background

Major PCP projects (mostly un-dowelled) in Queensland are listed below:

- Ipswich Road (part of Cunningham Arterial Road, now part of the Ipswich Motorway) approximately 5.6 km long. This section was constructed in 1952 and by 1983 was in poor condition. The entire section was “cracked and seated” and overlaid with 125 mm asphalt in 1987.
- The Bruce Highway at Sippy Downs Sunshine Coast, approximately 5 km long, was constructed in 1986/1987.
- The Bruce Highway at Yandina Bypass Sunshine Coast, approximately 7 km long, was constructed in 1997.
- The Pacific Highway at Reedy Creek, approximately 3 km long, was constructed at 1982.
- The Pacific Highway from Reedy Creek to Tugun, approximately 9 km long, was constructed in 1997.
- The Pacific Motorway M1 Gold Coast (contracts two, three and four) approximately 34 km long. This is the largest PCP project (consist of the eight lanes) that was constructed from approximately 1997 to 2000.

These PCP’s are in various conditions. The Department of Transport and Main Roads carries out regular surveillance and maintenance to ensure their serviceability level.
3 Purpose of document

The purpose of this document is to assist inspection and diagnosis of plain concrete pavements (PCP). This documentation includes a decision flowchart to be used for guidance on the identification, evaluation and rehabilitation of PCP’s.

4 Existing condition evaluation

To understand which treatment methodology to apply to an existing PCP the following process of information gathering and evaluating should be considered. This process should be considered to assess the existing asset condition.

1. Pavement historical data – establish from past pavement rehabilitation and investigation reports, AMRIS data, as constructed plans, verbal information from local district engineers/technical officers.

2. Defect mapping survey – assess surface condition, classify and quantity the defects (refer Figure 1 example of distress modes).
   a. laser defect mapping, or
   b. manual pavement defect mapping / walkover defect mapping inspection.


4. Ground Penetrating Radar (GPR) survey – understand subsurface conditions such as pavement profile and thickness, existence of dowels, and existence of reinforcements, detect anomalies (possible voids and moisture).

5. Pavement investigation – understand pavement profiles and characteristic properties and calibrating the GPR survey results. Sample investigation method:
   a. concrete coring (minimum 150 mm diameter) – to calibrate concrete base and lean mix sub-base thickness and to assess concrete pavement structural condition
   b. augering – to calibrate unbound or fill layer thickness, collect unbound samples and to expose subgrade material for further in-situ Dynamic Cone Penetration test.

6. Void detection
   a. GPR survey and followed by concrete coring to verify true extent of voids
   b. falling weight deflectometer – adopt variable load corner deflection analysis methods (zero load deflections) and corner deflection profile methods
   c. steel crow bar – tap concrete slab and assess rebound sound.
It is important to clearly understand the distinction between the types of pavement failure mechanisms when identifying and assessing distress types, cause of failure and developing rehabilitation strategies. A rehabilitation project may not adequately correct the pavement deficiency with an incorrect classification of the failure mechanism.

5 Detailed treatment prioritisation and identification

Flowchart 1 below, has been developed by the department’s Pavement Rehabilitation Unit to handle and analyse the data collected during the existing condition evaluation. The flowchart assists with treatment prioritisation and also identify the likely suitable treatment method to rectify failed concrete pavements.

Within Flowchart 1, “C” is defined as the combined cracking length in a slab and “L” is the slab length as shown in Figure 2, below.

Figure 2 – Cracking length (C) & slab length (L)
Flowchart 1 - Plain concrete pavement rehabilitation treatment prioritisation and identification

Evaluate existing condition.

- Multiple cracks
  - Does at least one of the following defects exist?
    1. Pumping stains
    2. Slab faulting
    3. Heave
    4. Voils
    5. C > 1.5 x L

  - Is C > 1.5 x L?
    - N: Refer to Figure 2
    - Y: Treatment is not required at this stage. Monitor cracked slab.

- Short list slabs to be partially or fully replaced.
  - Has any secondary cracking developed?
    - N: Treat only those slabs with the worst distress.
    - Y: Have any of the existing cracks been stitched?
      - N: Treatment is not required at this stage. Monitor cracked slab.
      - Y: Stitch the cracks and seal

- Review remaining slabs thoroughly to verify if slab replacements is warranted.
  - Full area repair
  - Partial area repair

- Verify slab areas for replacement to assess for full or partial area replacement.
  - Proceed with a suitable mix design and other associated works for slab replacement.

- Is there any time restrictions on rapid strength gain requirements of the concrete mix to be used for the slab replacement?
  - Y: Consider using a rapid set concrete mix for concrete base replacement and also for sub-base repair.
  - N: Conventional concrete mix.

- Contact a bridge engineer for advice prior treatment.

Notes:
- Spall, void, and joint seal repairs are to be undertaken on a case by case basis.
- Longitudinal diamond grinding may be required post slab replacement to ensure uniformity of roughness between new and existing slabs.

*Stitch repair refers to Staple bar and Diagonal bar repairs (Section 6)
6 Treatment summaries

Roads and Maritime Services (RMS) NSW has developed standard drawings\(^5\) and specifications\(^6, 7, 8, 9, 10 \& 11\) for the PCP treatments. These technical documents have been developed to suit New South Wales conditions. Upon discussion/approval from the Administrator, part of these standard drawings and specifications may be adopted for Queensland based projects. Alternatively, the Principal Contractor shall submit work method statements to the Administrator for approval. The following section defines the treatments as identified in Flowchart 1 above.

- **Spall repair** – spalling at joints can be caused from curling/warping stresses but also by the penetration of incompressible material into the joint causing cracking when the slab expands. Partial depth repairs may be used to repair spalled areas at joints and cracks. Spalls should be treated before they extend below the top third of the slab. As a general rule the ‘limits’ of a repair area for a spall should be made with a concrete saw, square or near square in shape and at least 50 mm beyond the limit of any spalling. The depth of sawing of the repair area should be greater than the depth of spalling at the edge of the spalled area and not less than 50 mm. All loose spalled material should be removed from the base of the spalled area prior to repair. Refer to\(^5\) and \(^9\) for technical guidelines.

- **Joint or crack sealing** – silicone sealing of exposed cracks or joints. Bitumen sealing is not recommended for this process as it is likely to be very temporary and unsightly. Refer to \(^5, 6\) and \(^8\) for technical guidelines.

- **Diagonal tie bar repair (Cross Stitch)** – insert reinforced steel rods diagonally and epoxy resin to hold the crack together. It is used only for cracks or joints that are not intended to open/close and is generally unsuited to concrete slab thicknesses less than 190 mm and when the cracking gap is greater than 25 mm. Refer to \(^5, 7\) and Figures 3, 4 and 5 below for technical guidelines.

![Figure 3 – Diagonal tie bar repair \(^5\)](image)

<table>
<thead>
<tr>
<th>Base thickness D (mm)</th>
<th>Offset: drill hole to crack Lc (mm)</th>
<th>Length of drill hole Lh (mm)</th>
<th>Length of stitch-bar Lb (mm)</th>
<th>Length of protection Lp (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>190</td>
<td>165</td>
<td>330</td>
<td>280</td>
<td>40 ± 5</td>
</tr>
<tr>
<td>200</td>
<td>175</td>
<td>350</td>
<td>300</td>
<td>40 ± 5</td>
</tr>
<tr>
<td>210</td>
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<td>45 ± 5</td>
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<td>430</td>
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<td>50 ± 5</td>
</tr>
<tr>
<td>250</td>
<td>215</td>
<td>450</td>
<td>400</td>
<td>50 ± 5</td>
</tr>
</tbody>
</table>

Notes:
1. To suit drill angle of 30° and cover t of 25 mm.
2. See Figure 4 below for protection details (Lp). Protection must be provided if the crack is wider than 0.5 mm. The suitable protection is by bituminous paint with a thickness of 0.2 to 0.5 mm\(^3\).
• **Staple tie bar repair** – tie slabs together at cracks or joints to evenly distribute the load across both the crack and un-dowelled concerned joint. The implementation of the staple tie bar repair in Queensland has been limited, when compared to the diagonal tie bar repair (cross stitching). This treatment has been undertaken on a number of existing longitudinal cracks on the concrete slabs on the Bruce Highway, Sippy Downs area.

![Staple tie bar repair](image)
• **Slab replacement**: removing partial or full area of the existing slab to the full concrete base depth and replacing it with new concrete. Refer to the Concrete Pavement Maintenance Standard Drawings Volume MP: Plain Concrete Pavement (PCP) for detail slab replacement procedures for technical guidelines. Consideration to any time restrictions or rapid strength gain requirements should be taken into account when deciding concrete mix design (i.e. rapid set concrete or conventional concrete mix).

• **Pressure Grout injection for slab stabilisation**: it restores support to concrete slabs by filling voids that develop underneath the concrete slab at joints, cracks or the pavement edge. Slabs that have "dropped" can be lifted by the grout pressure to restore the surface profile to match surrounding slabs. In general, voids can be formed at different pavement strata which determine the target grouting depth as follows:
  - Shallow grouting: target voids between concrete base layer and a sub-base layer.
  - Deep grouting: target voids below the sub-base layer i.e. granular layer, fill, subgrade replacement layer or subgrade layer.

Currently, there are two common grouting techniques in Queensland:

1. cementitious grouting, and
2. expanding polyurethane foam grouting.

The cementitious grouting mix is prepared on site. A site setup should allow a working space for on-site grouting mix production i.e. stack of cement bags, mixing chamber and a grouting pump. Upon grouting completion, a specified curing time is required prior to opening for traffic. The required
grouting holes are generally of minimum 30 mm in diameter and need to be plugged using an epoxy material.

For the expanding polyurethane foam grouting, the premix grouting liquid is stored in a vacuumed tank and is delivered on site in a tanker truck. The truck is equipped with a pressure pump to inject the expanding polyurethane directly to the grouting holes. The required site preparation is minimum compared to the cementitious grouting, but usually costs more than the cementitious grouting. The grouting holes are generally 10 to 15 mm in diameter and can be plugged using the same grouting material (the expanding polyurethane foam grouting). The grouting shall have a sufficient curing time to achieve the required strength prior to opening for traffic.

Depending on project specific requirements and site condition, the adopted grouting technique in a proposed project (cementitious vs polyurethane) shall be consulted and approved by the Administrator.

The following is a brief procedure of pressure grouting10:

1. Carry out a one day production field trial to establish a site specific working procedure.
2. Submit proposed nominated grouting mix for approval. The minimum grout compressive strength shall be 8 MPa at 24 hours.
3. Set up locations of grouting holes to ensure vertical and horizontal filling of voids is achieved. The radius between grouting drill holes is usually between 1.5 to 2 m. The grouting hole must not exceed 50 mm diameter. Refer to Figure 7 for details.
4. Determine the grouting depths. Inset a sleeve into the grout holes for a deep grouting below the sub-base concrete layer. The sleeve shall pass completely through the base concrete and sub-base concrete. Remove the sleeve after the grouting is completed.
5. Monitor the slab level regularly during void grouting or slab jacking using a survey level equipment.
6. For the slab jacking, when the matching levels cannot be achieved without damage/unstable to the surrounding slabs, stop slab jacking immediately and advise the Administrator immediately.
7. Upon grouting completion, plug the grouting holes properly.

Refer to10 for technical guidelines.

*Figure 7 – Typical grout hole arrangements for PCPs*10
• **Longitudinal Diamond Grinding**: it restores or improves skid resistance, removes faults at joints or cracks by levelling the pavement surface and also reduces traffic noise.

**Figure 9 – Diamond grinding in progress**

Courtesy of George Vorobieff, RMS, NSW

7 Monitoring

As is the case with any pavement rehabilitation works, consistent monitoring is required post restoration works to ensure treatments perform as intended and also do not continue to deteriorate further.

8 Acknowledgement

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9 Author

Transport and Main Roads Pavement Rehabilitation Unit.

10 References


