REPORT

CEMENT CONCRETE & AGGREGATES AUSTRALIA

Concrete Pavement Maintenance/Repair

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June 2009

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1 INTRODUCTION

1.1 Scope

Concrete is used in roads, highways and airport pavements because of its load carrying capacity and low maintenance. Better knowledge of speedy repair techniques would be a further advantage in supporting the use of concrete pavements.

This report examines the repair and restoration of concrete pavements systematically by distress classification and the underlining objectives of each concrete repair and restoration technique. It also covers the composition and characteristics of a broad range of repair materials for cracks, spalling, potholes, rough patches and sunken slab. The review covers techniques used in *routine maintenance* of concrete pavements but excludes slab replacement. Emphasis will be given to road pavements but they are also applicable to other concrete pavements.

1.2 Definitions and Abbreviations

Base concrete The upper (structural) layer of portland cement concrete with varying in-situ strengths, typically 25 to 50 MPa. The plain or reinforced concrete may contain various forms of steel reinforcement, dowels and tiebars. In some instances the concrete may contain steel-fibre reinforcement. The four common types of concrete pavements are:

PCP Plain Concrete Pavement

CRCP Continuously Reinforced Concrete Pavement

JRCP Joint Reinforced Concrete Pavement

SFCP Steel Fibre Reinforced Concrete Pavement

Crack An irregular, unplanned opening in base concrete which is essentially vertical and of various widths and which may intersect with others, typically orientated longitudinally (in the direction of traffic), or transversely or a combination. The crack may be straight or meandering.

Cross-stitch A process of drilling alternately inclined holes into concrete across a crack or joint and affixing a tiebar for the purposes of tying adjacent concrete panels to prevent joint/crack from further widening.

Joint A planned joint in base concrete which runs either parallel (in the case of longitudinal joints) or transverse to the direction of traffic flow. They are either formed or induced.

Routing A mechanical process where a cutting bit is mounted on a vertical rotating shaft, with or without a vertical oscillating action, which is manually pushed or self propelled along the crack at a pre-set depth to form a surface reservoir in the base concrete for the purposes of installing a sealant.

Reservoir A uniform rectangular (in cross section) crack channel resulting from routing operations.

Spall A small broken or chipped segment of concrete normally occurring at the edge of a joint or a crack.

Rehabilitation reinstating failed pavements to the original design standards, including large scale patching, re-sheeting and re-construction.

Routine maintenance Regular maintenance of roads and shoulders, including pothole repairs, crack resealing and edge repairs.

1.3 Maintenance cost

A study[1] was conducted in 2002 of concrete and asphalt pavements with similar traffic and in a similar environment on the Hume Highway over about 100 km between Mittagong and Goulburn in New South Wales. Both concrete (CRCP and PCP) and asphalt pavements were used in various sections of the highway. The maintenance costs projected over 20 years show significant cost savings in concrete pavements compared to asphalt pavements.

The variability in concrete pavement maintenance costs was up to a factor of 9, varying from \$3 to \$28/m^2 when treatments were costed in 2002 dollars. The lowest cost represents routine maintenance while the highest cost reflects continuing expenditure and disruption over the 7.5-km length of the original Marulan Bypass. While asphalt pavement expenditures on maintenance was higher, ranging from \$55 to \$77/m^2, their variability was lower and some of these costs are reflected in scheduled resurfacing taken into account in life-cycle costing.

2 DISTRESS CLASSIFICATION

In examining the engineering principles used in the development of repair techniques and selection of repair materials, the classification of pavement distresses and corrective techniques outlined in the 'Concrete Pavement Restoration Guide' in the ACI *Concrete Repair Manual*[2] and the US Federal Highway Administration's *Pavement Rehabilitation Manual*[3] are adopted in this review.

The *Concrete Pavement Restoration Guide* suggests that the best way to identify the cause of pavement distress is to conduct site-condition surveys on a regular basis. The two goals of the condition survey and the structural assessment are to determine the root cause of the pavement's distress and the rate of pavement deterioration. Both will determine the best time and the appropriate repair technique to be implemented.

2.1 Structural Distress

Structural distress affects the pavement capacity to carry the traffic. Cracking and joint deterioration are typical structural distresses.

Cracks that extend through the depth of a slab are structural cracks. They are unplanned and can occur as longitudinal, transverse, corner, or intersecting cracks. They can be caused by loading, excessive joint-spacing, shallow or late joint sawing, base or edge restraint, and joint lock-up. Pumping of the subbase/subgrade, curling and warping of the slab, or culvert or utility trench subsidence can also cause cracking. Corner breaks and intersecting cracks indicate that a slab has marginal support developed when heavy loads cause large vertical deflections at the slab edges or corners, and pump fines from beneath the slab. Other causes including curling and warping of the slab because of temperature and moisture gradients; heaving and swelling of frost- or moisture-susceptible soils; and settling of backfill over culverts or underground utility structures.

Joint deteriorations such as spalling, breaking, cracking, chipping, or fraying of the slab edges usually occur within 50 mm of joints. Such deterioration starts when incompressibles enter and become lodged in the joints or cracks during cool weather. As the temperature rises, the slabs expand, causing high compressive stresses in the concrete which results in joint deterioration. The deterioration results in more incompressibles entering the joint or crack causing further deterioration.

Punchouts mainly occurs in continuously reinforced concrete pavements (CRCP). They occur between two closely spaced transverse cracks that split at the longitudinal edge or joint. They develop when high deflections at the pavement edge or longitudinal joint pump subbase material from beneath the slab and cause a loss of support. Further loading creates a cantilever action, which eventually ruptures the longitudinal steel at the crack faces. Continued loading pushes the small segment of concrete into the subbase and causes a punchout.

2.2 Durability Distress

Durability distress is caused by the premature deterioration of concrete such as D-cracking and alkali-aggregate reaction (AAR).

D-cracking is D-shaped hairline cracks that occur near joints, cracks, and free edges when certain aggregates in a concrete become saturated, freeze, and expand. The expansion causes the surrounding concrete matrix to crack.

Alkali-Aggregate Reaction is caused by a chemical reaction that occurs when free alkalis in the concrete combine with certain siliceous aggregates to form an alkali-silica gel. As the gel forms, it absorbs water and expands, which cracks the surrounding concrete. For further information on minimising the risk of AAR damage to concrete, see *Alkali Aggregate Reaction: Guidelines on Minimising the Risk of Damage to Concrete Structures in Australia* (T47) CCAA,1996.

2.3 Functional Distress

Functional distress affects the ride quality and safety of the pavement. It includes roughness, noise and surface polishing.

Roughness is mainly caused by faulting – a difference in elevation between slabs at joints or cracks. Faulting is caused by differential load transfer inducing high deflections at the slab corners, resulting in the support material being pumped from under the slab or moved from one side of the joint to the other. Roughness can also be built into a pavement during construction. Two other sources of roughness are heaving/swelling of frost- or moisture-susceptible soils and settlement over culverts or underground utilities.

Surface polishing is the wearing away of the surface texture to expose the concrete coarse aggregate on heavily trafficked pavements. It leaves the surface smooth and reduces the pavement's skid resistance and surface friction capabilities.

Noise is defined as 'unwanted sound' and is typically described as a high-pitched sound. The main source of the noise is the surface/tyre interaction that develops when a vehicle speed exceeds 55 km/h on pavements with certain surface texture such as uniformly spaced transverse tining.

Surface defects comprise scaling, popouts, crazing, and plastic shrinkage cracking. Scaling is caused by overworking the surface; popouts are due to reactive or absorptive aggregates; while crazing and plastic shrinkage cracking are usually the result of poor curing procedures. Such distresses may affect the pavement's ride and noise characteristics.

3 REPAIR METHODS

There are a range of concrete repair and restoration techniques which are used as corrective, preventive, and corrective-and-preventive measure. They can be used individually but are typically more effective when several are used together. Although concrete repair and restoration does not necessarily increase structural capacity of a pavement, it does extend the pavement's service life.

3.1 Corrective Techniques

Corrective techniques are used to repair a given distress and improve the serviceability of the pavement.

Full-depth repairs Full-depth repairs fix cracked slabs and joint deterioration by removing at least a portion of the existing slab and replacing it with new concrete. This maintains the structural integrity of the existing slab and pavement. Full-depth repair is also appropriate for shattered slabs, corner breaks, punchouts in CRCP, and some low-severity durability problems. It involves marking the distressed concrete, saw cutting around the perimeter, removing the old concrete, providing load transfer, and placing new concrete. Each repair must be large enough to resist rocking under traffic, yet small enough to minimize the amount of patching material. More-detailed information can be found in the ACPA *Guidelines for Full Depth Repair*[4] or the Queensland Transport Pavement Rehabilitation Manual[5].

Full-depth precast concrete slab repairs were trialled by the Ministry of Transportation Ontario (MTO) in 2004 using three proprietary methods and are reported on by Lane and Kazmierowski[6]. The methods differ in how the base is prepared and how the precast slabs are installed and dowelled to the adjacent concrete slabs. Following the construction, non-destructive testing was undertaken to assess the load transfer efficiency at the pavement joints and detect loss of support beneath the slab. The overall assessment by the MTO was that the precast trials went well. The work was carried out within the required time frames and seems to be performing well. The precast repairs are similar in both ride and appearance to fast-track repairs made along the same section of highway. Some surface tolerance requirements were not met, but diamond grinding would improve the ride. The report includes recommendations were given to help future precast concrete repairs go as smoothly as possible.

Partial-depth repairs Partial-depth repairs correct surface distress and joint/crack deterioration in the upper third of a concrete slab. When the deterioration is greater in depth or reaches embedded steel, a full-depth repair must be used instead. It involves removing the deteriorated concrete, cleaning the patch area, placing new concrete, and reforming the joint system. More-material detailed information can be found in the ACPA *Guidelines for Partial Depth Repair*[7].

RTA QA Specification M224[8] was developed specifically for the non-structural repair of surface spalls in concrete pavement. The area to be repaired should have dimensions of at least 100 mm and extend 20 mm beyond the deteriorated concrete. M224 specifies that the repair must: have its largest aggregate no greater than one third of the minimum depth of the repair; bond permanently with the base concrete without cracking; be UV stable, non-shrink and none expansive; cure and harden within the time specified; and be of similar colour to the surrounding wearing surface when cured.

Cracking and seating This technique is used prior to placing an asphalt or concrete overlay to control reflective cracking in the overlay. It is sometimes referred to as pavement breaking

or pavement shattering. It is intended to create concrete pieces that are small enough to reduce horizontal slab movement to a point where thermal stresses which contribute to reflective cracking will be greatly reduced, yet still be large enough and still have some aggregate interlock between pieces so that the majority of the original structural strength of PCC pavement is retained. It is used to re-establish support between the subbase and the slab where there may be voids.

A nationwide survey conducted by the Florida Department of Transportation (FDOT[9]) indicated that most states have a relatively-small number of cracking and seating (rubblized) sections, although three states have over ten sections each. The construction techniques, overlay thicknesses, and field performance varied from state to state. However, it was clear that most states were highly satisfied with rubblization as a means of eliminating reflected cracks. Problems were mainly due to weak subgrade. Guidance on design, construction and specification of cracking and seating, is given in the Queensland Transport Pavement Rehabilitation Manual[5] and the US Federal Highway Administration Pavement Rehabilitation Manual[3].

3.2 Preventative Techniques

Preventative techniques are proactive activities that slow or prevent the occurrence of a distress in order to maintain serviceability.

Joint and crack resealing Joint and crack resealing minimizes the infiltration of surface water and incompressible material into the joint system. Minimizing water infiltration reduces subgrade softening; and slows pumping and erosion of subgrade or subbase fines. Minimizing incompressibles reduces the potential for spalling and blow-ups.

RTA QA Specification M215[10] was prepared specifically for the routing and sealing of cracks in concrete pavement as a combined activity. It applies where the width of cracking (or longitudinal joint opening) is at least 1 mm or the surface arris is spalled. It suggests the use of urethane as a substitute for silicone sealant where distillate fuels are likely to be in concentration.

The Queensland Transport Pavement Rehabilitation Manual[5] summarises some of the proprietary crack filler products commonly available and their properties.

Retrofitting concrete shoulders Retrofitting concrete shoulders adds a tied concrete shoulder to an existing pavement. It is similar to dowel-bar retrofit because it decreases the critical edge stresses and corner deflections and reduces the potential for transverse cracking, pumping, and faulting. On CRCP, retrofit concrete shoulders can decrease the outside pavement edge deflection and cantilever action, which reduced the potential for punchouts.

Retrofitting edge drains Adding a longitudinal drainage system to a pavement aids in the rapid removal of water and may prevent pumping, faulting, and durability distress from developing.

3.3 Corrective-and-preventative Techniques

Corrective-and-preventative techniques are used to repair and slow down or prevent the occurrence of a given distress and improve the serviceability of the pavement.

Diamond grinding Diamond grinding improves a pavement ride by creating a smooth, uniform profile by removing faulting, slab warping, studded tyre wear, and patching

unevenness. This extends the pavement's service life by reducing impact loadings, which can accelerate cracking and pumping. More detailed information can be found in the ACPA *Diamond Grinding and Concrete Pavement Restoration 2000*[11].

Dowel-bar retrofit Dowel-bar retrofit increases the load transfer efficiency at transverse cracks and joints in PCP and JRCP pavements by linking the slabs together so that the load is distributed evenly across the joint. Improving the load transfer increases the pavement's structural capacity and reduces the potential for faulting.

Slab undersealing Slab undersealing is a means to stabilise existing pavement slabs by filling small voids beneath the slab and base or base and subbase. The undersealing is intended to restore slab support and does not include the lifting of the pavement slab (slab jacking) to a prescribed elevation or to an original profile. Several grouts have been trialled and portland cement grout was found to produce best results. Guidance on design, construction and specification of slab undersealing is given in the Queensland Transport Pavement Rehabilitation Manual[5] and the US Federal Highway Administration Pavement Rehabilitation Manual[3].

Cross-stitching Cross-stitching is used to repair longitudinal cracks that are in a fair condition. It increases load transfer at the crack by adding steel reinforcement to restrict widening of the crack. It is not an alternative for cracks that are severely deteriorated or functioning as a joint.

Grooving Grooving restores skid resistance to concrete pavements. It increases the surface friction and surface drainage capabilities of a pavement by creating small longitudinal or transverse channels that drain water from underneath the tyre, reducing the hydroplaning potential.

4 REPAIR MATERIALS

A range of concrete repair materials are available. Portland cement concrete can be proportioned for use as a reliable patching material for concrete pavement. It is most effective for full-depth patches or complete slab replacement. A high density very low slump concrete or mortar patching mix, properly placed, thoroughly compacted by vibration and thoroughly cured, has proven very successful for partial-depth patches. Mixed results have, however, been reported[12]. By using portland cement and accelerators, concrete mixes can be produced that will enable the pavement to be trafficked after 6 to 24 hours. A wide variety of special products for patching concrete are sold under proprietary names. These include both organic and inorganic materials such as epoxies, methacrylates, magnesium phosphate cements and gypsum-based cements. Care should be taken to restrict the use of impervious materials (eg epoxies) in areas large enough to block vapour coming up from below and trapping moisture which can cause further damage.

The compositions and characteristics of portland and other rapid set and high early strength cements are reviewed. They are widely used as the main constituent in pavement repair materials. Their typical characteristics are summarised in **Table 1**.

4.1 Rapid Set Portland Cement with Accelerator

Modern portland cement concrete develops higher early strength than that shown in **Table 1**, while accelerators can be used to further enhance the early strength. There are three groups of accelerators: highly alkaline chemicals, finely ground calcium aluminate glass and some specific anions[13].

TABLE 1 Typical characteristics of selected repair materials[21]

	Application					**Compressive strength** (MPa)						
Material	Thickness limitation (mm)	Instal temp	Curing	**Drying shrinkage***	**Coefficient thermal expansion**	1 hr	24 hr	3 days	28 days	**Elastic modulus** (GPa)	**Permeability** (% of concrete)	**Exotherm**
RTA Spec	–				–	5 (6 hr)	20	–	40	–	–	–
Portland cement concrete	> 44	5–32°C		low	Similar to substrate	0	5	20	35	26	90	low
Microsilica-modified PC concrete	> 30	5–32°C	7-day wet	low	Similar to substrate	-	25	30	50	28	60	low
Magnesium phosphate cement concrete	> 19	–18 to 40°C	air	low	Similar to substrate	14	44	50	60	22	90	high
Epoxy mortar	4-12	10–32°C	air	low	1.5–5 x concrete	0	70	80	85	11	10	high
Methyl methacrylate (MMA) concrete	6-13	–6 to 50°C	air	moderate	1.5–5 x concrete	30	85	85	85	14	10	high
Calcium aluminate cement concrete[17]	–	20°C 30°C 50°C 70°C		low		40 (6 hr)	70	77 78 55.5 34.5	–	Similar to portland cement concrete	Low	high

* Very low <0.025%, low 0.025–0.05%, moderate 0.05–0.1%, high >0.1%

Highly alkaline accelerators act by increasing the pH of the liquid phase and thus accelerate the hydration of tricalcium aluminate (C_3A). If alkali silicates are used, soluble SiO_2 is immediately available to react with calcium hydroxide to form additional amounts of the C-S-H phase.

Finely ground calcium aluminate glass mixed in portland cement causes a reaction with the calcium sulfate present in cement to form ettringite, and hence accelerated setting. The setting time of the mix shortens with increasing CaO/Al_2O_3 molar ratio of the glass used, whereas the short-term compressive strength declines.

Some anions such as halides, nitrate, nitrite, formiate, thiosulfate, and thiocyanate exhibit an acceleration in the hydration of alite and hence development of early strength. The setting time is also shortened, but less effectively than with admixtures that increase the pH of the liquid phase.

An investigation sponsored by the Oklahoma Department of Transportation and the Federal Highway Administration[14] showed that it was possible to produce very early strength (VES) with compressive strength as high as 30 MPa at six hours with ASTM type III portland cement and a commercially available accelerator, high range water reducer and air entraining agent. The early heat of hydration and drying shrinkage properties can also be optimised. A concrete mix with a cement content of 357 kg/m^3 at water-cement ratio of 0.35 and 5.4% air content gave a VES of 21.5 MPa at six hours and very good finishing and workability characteristics.

4.2 Calcium Aluminate Cement

Calcium aluminate cement or aluminous or high-alumina cement covers a range of binders characterised by the presence of monocalcium aluminate ($CaO•Al_2O_3$) as their main constituent. The chemical composition of calcium aluminate cement may vary over a wide range, with Al_2O_3 contents ranging between about 40% and 80%. The trade names Ciment Fondu and SECAR, for cements with lower and higher contents respectively, are also widely used. Calcium aluminate cement gains strength much faster than portland cement.

Calcium aluminate cement must be used at low water-cement ratios (<0.40) to minimize the conversion of less stable hexagonal calcium aluminate hydrate (CAH_{10}) to the stable cubic tricalcium aluminate hydrate (C_3AH_6), hydrous alumina (AH_3), and water[15]. At low water-cement ratios, there is insufficient space for all the calcium aluminate, to react and form CAH_{10}. The released water from conversion reacts with more calcium aluminate partially compensating for the effects of conversion. Concrete design strength must therefore be based on the converted strength. Calcium aluminate cement must be used with caution in structural applications[16].Calcium aluminate cement concrete has been reported[17] to be used for repair work of runways and hard standing areas at airports, eg London Heathrow, Glasgow, Paris Charles de Gaulle and Stuttgart.

By combining portland cement with 5–20% of calcium aluminate cement a binder that exhibits a very short setting time and rapid strength development may be obtained. The rate of setting and hardening may be controlled by the mutual ratio of both cements. It increases with increasing proportion of the minor constituent. Further acceleration may be achieved if a small amount of a lithium salt is added to the system. Examples of application of such cement include highway or runway repair works, plugging of water leaks, and the production of prefabricated elements without the necessity for steam curing.

4.3 Calcium Sulfoaluminate Cement

Calcium sulfoaluminate cement contains anhydrous calcium sulfoaluminate as an important constituent[18]. Anhydrous calcium sulfoaluminate is a very reactive compound which combines with calcium sulfate to form ettringite, which can provide rapid setting and high early strength. Alternatively, in the presence of free lime, ettringite formation will be slower but more expansive, and forms the basis of expansive or shrinkage compensating cements.

The strength development at later ages of calcium sulfoaluminate cement will depend mainly on the calcium silicate phases present in the particular cement. In those that contain tricalcium silicate (C_3S), a renewed intensive strength development gets under way after a short period of slower strength gain. In sulfobelite cement, which contains only the dicalcium silicate phase (C_2S) but not the C_3S phase, the strength development after the initial phase of fast setting and strength increase is much more moderate since C_2S hydrates much more slowly.

4.4 Magnesium Phosphate Cement

Magnesium phosphate cement consists of magnesium oxide (calcined magnesia, MgO) and a water-soluble acid phosphate. The initial rate of reaction at ambient temperature is rather fast and associated with intensive heat liberation. Typically, setting occurs in a few minutes, unless retarders are added to the mix. Measurable strength is attained within the first hour after mixing and more than half of the ultimate strength is attained within 4 hours. The ultimate 28-day strengths of well-produced magnesium phosphate cement mortars may exceed 50 MPa. Magnesium phosphate paste and concrete exhibit an excellent bond to old portland cement concrete and are suitable for repair works on existing concrete structures.

The strength performance of two formulations of magnesium phosphate cement has been evaluated in comparison to an aluminium phosphate cement and regulated set cement[19]. The results revealed that magnesium phosphate-based cements exhibit the most rapid strength development. The measured 1-hour strength was more than 35 MPa with low water content at room temperature, which is unnecessarily high strength for repair. At higher water content enough to produce flowing consistency, its 1-hour strengths are regularly over 14 MPa.

4.5 Latex or Polymer-modified Cement

Polymer-modified cement refers to the addition of a latex (powder or liquid) to a portland cement-based mortar. When cured, the resulting concrete contains a continuous, interconnected matrix of latex polymer particles. Polymer concretes and repair mortars are generally thermosetting plastic materials, usually containing an aggregate filler. Materials such as epoxies, polyesters, vinyl esters and methyl-methacrylates are the polymers commonly used.

Very-early-strength latex-modified concrete (LMC) has been reported to have been successfully trialled in overlay installations for the Virginia Department of Transport[20]. This LMC was prepared with a blended cement rather than with portland cement used in conventional LMC. Styrene butadiene latex particles suspended in water were used to replace a portion of the mixing water. LMC is reported to be more resistant to the intrusion of chloride ions, to have higher tensile, compressive, and flexural strength, and to have greater freeze-thaw resistance. It has been used on highway bridges in the US over the past 35 years. The very-early-strength latex-modified concrete has compressive strengths of 25, 30 and 33 MPa after 3, 6 and 24 hours respectively. It was demonstrated that the very-early-strength LMC can be placed and the pavement opened to traffic with as little as 3 hours of curing time, and that the initial condition of the overlays is as good as that of the more proven high-early-strength LMC and conventional LMC overlays.

4.6 Other Materials

There are fast-setting cements containing calcium fluoroaluminate phase ($11CaO{\cdot}7Al_2O_3{\cdot}CaF_2$) which reacts with calcium sulfate to exhibit a very fast setting and initial strength development owing to the formation of ettringite. Other fast-setting cements include gypsum-free portland cement, alkali-activated slag cement, alkali-activated fly ash cement, zinc phosphate cement, magnesium oxychloride and oxysulfate cement, and alkali silicate binder.

A cementitious rapid hardening binder and corresponding polymer fibre concrete have been developed and applied at Zurich airport[22]. The concrete with high modulus polymer fibres has a pot life of about 60 minutes, reaches 20 MPa compressive strength within 60 minutes and has low drying shrinkage. The new binder is industrially modified rapid-set cement with chemical composition between blast furnace cement and portland cement. The fibres used consist of high crystalline 0.4-mm-diameter 20-mm-long polyvinylalcohol. They have good bond to cementitious matrices of 3 MPa and high Young's modulus of 30 GPa. The concrete can be used without steel reinforcement.

4.7 Laboratory Tested Materials

A range of advance partial-depth repair materials was evaluated[23] using the large-scale-pavement accelerated-testing facility developed by the University of Central Florida (UCF) Circular Accelerated Test Track (CATT). The three major material types used to meet high strength and fast set criteria are: polymer concrete, elastomeric concrete and cementitious mortar. They are commercially available for partial-depth repair of potholes and spalls, and are meant to be applied without the need for square-cutting the edges of the distress. The first three, A to C shown in **Table 2**, were materials recommended by FDOT.

TABLE 2 Placement, characteristics and strengths of patching materials

Material						**Strength** (MPa)	
No.	Type	**Mixing procedure**	**Workability**	**Aggregate additives**	**Curing time** (hr)	Compressive	Tensile
A	Polymer	moderate	moderate	pre-packaged	2–4	10.3 (2 hr)	6.21
B	Cementitious	easy	moderate	10 mm clean	2	20.7 (3 hr)	5.52
C	Cementitious	easy	moderate	10 mm clean	4	24.1 (4 hr)	2.62 (7 hr)
D	Elastomeric	easy	N/A	Pre-packaged	4	9.65 (2 hr)	4.14
E	Elastomeric	moderate	moderate	Pre-packaged	4	18.2 (3 hr)	4.14
F	Cementitious	N/A	N/A	N/A		N/A	N/A
G	Elastomeric	N/A	N/A	N/A		17.2 (24 hr)	N/A
H	Cementitious	easy	moderate	10 mm clean	2	16.9 (2 hr)	2.52

N/A *Not available*

After a total of 500,000 repetitions of a 44.5-kN wheel load applied to test sections, no signs of major cracking on any patching materials were observed. However, the debonding of some of concrete patching materials from the concrete was the main problem observed in this study. From the results, it became evident that elastomeric patching materials have a greater tendency to debond with the concrete than the cementitious patching materials. The feather-edged patched potholes with cementitious materials have performed well and show that the conventional square-cut procedure before patching may not be necessary with high strength and fast set patching materials.

4.8 Current Specifications

The Roads and Traffic Authority of New South Wales (RTA) M209 *Road Openings and Restoration* specifies materials for concrete pavement restoration. The minimum design compressive strength of the concrete for slab replacement, conforming to RTA 3201 *Concrete Supply for Maintenance*[24] must be:

5 MPa at 6 hours (for time-critical work only, where calcium chloride set accelerating admixtures are approved for use)

20 MPa at 24 hours; and

40 MPa at 28 days.

RTA 3201 encompasses concrete for slab replacement, kerb-and-gutter, drainage structures, revetment mattresses and general purposes. Section 5.3 provides a range of standard concrete mixes for slab replacement in compressive strength classes of 40 MPa or flexural strength of 5.5 MPa, and strict control on the use of calcium chloride ($CaCl_2$) and the addition of water or admixture on site.

Other RTA and Queensland Transport specifications are cited in the relevant section of the repair technique.

5 SUMMARY

Concrete is used in roads, highways and airport pavements because of its load carrying capacity and low maintenance. With appropriate maintenance strategy, concrete pavements will provide good service life. In selecting the most appropriate repair/maintenance technique, the cause of distress must be first identified. A range of corrective and/or preventative repair and restoration techniques can then be applied. The compositions and characteristics of a broad range of repair materials for spalling, potholes, rough patches and sunken slab are reviewed. They consist mainly of rapid set portland cement, calcium aluminate cement, calcium sulfoaluminate cement, magnesium phosphate cement, and latex or polymer-modified cement. Fibre reinforcement is also used in specific applications.

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