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Best Practice for the Management of Local Government Concrete Pavements

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ABSTRACT: Concrete Pavements have been a foundation material for our civilisation for thousands of years. Their longevity and low asset lifecycle cost continue to provide our communities with transport and recreational pavements while contributing to the financial sustainability of a council.

Concrete Pavements are not an asset that local government can set and forget. These pavements require careful management and timely maintenance to ensure that they last forever.

This paper describes the following concepts and practices for best practice stewardship for municipal concrete pavements:

Construction

- Design
- Specification
- Quality Management

Asset Lifecycle Management

- Pavement Management Strategy
- Asset Accounting
- Protecting the Pavement
- Restoration Best Practice
- Pavement Maintenance

Application of Concrete Pavements

- Concrete Pavements for Urban Cooling
- Road Plaining - Diamond Grinding
- Recreational Pavements

Concrete Pavements described in this technical paper include road, footpaths and recreational pavements. Concrete road pavements are the predominate focus of this technical paper.

Guidelines and legislation referred to in this document refer to the State of NSW, Australia.

Best Practice Principles described in this paper are applicable to the management of other municipal assets. Concrete pavements which have a useful life of greater than 100 years are deemed as being a pavement that lasts "forever".

KEYWORDS: lifecycle management, quality, strategy, restoration, fast setting concrete, urban cooling.

1 Introduction

Concrete Pavements continue to be a municipal foundation in the provision of transport and recreational assets for our communities. Best practice stewardship is essential to maximise the return on investment and ensure the longevity of this infrastructure.

In the City of Canada Bay, the Current Replacement Cost (CRC) for its concrete pavements is $184 Million. This represents 61% of Council's $301 million road and footpath asset portfolio. This indicates the importance of these assets for our communities and Council's reportable financial performance.

Disciplines which contribute to best practice asset management include:

- Construction and Maintenance
- Strategic Asset Management
- Asset Accounting

1.1 History

The City of Canada Bay has a high proportion of concrete roads which is partially as a result our industrial past. Significant industry such as the Lysaght Wire Mills, Rail Carriage Works, Dunlop Rubber Factory, paint and chemical factories required hard wearing, low maintenance roads for the carriage of heavy goods and materials.

Many of our concrete pavements were constructed as depression employment schemes in the late 1920’s and the 1930’s and as return soldier employment schemes in the late 1940’s.

Prior to 1945 there were no unemployment benefit schemes in Australia. The high labour component of concrete pavement construction enabled an income for many families which would have otherwise gone without during the depression years.

There was strong competition for work on the employment schemes. This competition, focused workers upon the delivery of high quality pavements to retain their employment.

It is this attention to construction quality which has enabled these pavements to perform in service for nearly one hundred years. These pavements will last another hundred years if we continue to provide best practice asset management.

Figure 1: Great North Road, Five Dock Late 1920’s Concrete Pavement.

Figure 2: Great North Road, Five Dock Original Concrete Pavement

2 Pavement Planning, Design and Specification

New concrete road pavements are rarely constructed due to their high capital cost, despite having the lowest asset lifecycle cost. The decision to construct a concrete road is normally a result of a constraint, such as shallow services, which limits pavement depth and compaction required by flexible and stabilised pavements.

Another common constraint which favours the installation of concrete pavements is the presence of soft subgrades. Rigid pavements can bridge soft subgrades more so than a flexible pavement.

Councils need to manage their entire road network to ensure the overall condition doesn’t decline. Renewal budgets are tight which leaves little budget to reconstruct failed pavements as new concrete roads.

Municipal concrete roads are normally designed as Jointed Reinforced Concrete Pavements (JRCP) in accordance with the AUSTROADS Pavement Design Guidelines. The design failure mode is fatigue failure at the joints with a design useful life of 100 years. AUSPEC is the accompanying specification.

Curing of the Concrete Slabs in accordance with the specification is critical in achieving a quality pavement that will stand the test of traffic loading and time. Other factors include density of the concrete and cover to steel.

Municipal JRCP have a proven useful life of greater than 100 years. The key to their longevity is the quality provided in every respect of their construction.

The engagement of good, experienced contractors who employ quality systems for construction is essential for delivering enduring pavements.

Geoff Ayton, RMS Pavement Manager provided the following principle:

Good Contractor + Good Spec = Great Project

Good Contractor + Poor Spec = Good Project

Poor Contractor + Good Spec = Poor Project

Poor Contractor + Poor Spec = Bad Project.

This demonstrates that using good contractors is the principle factor in achieving great quality and enduring concrete pavements.

2.1 NSW RMS Specifications

Use of NSW Roads and Maritime Services (RMS) specifications are helpful in detailing the slab and reinforcement. However, RMS specifications have been prepared for their own applications such as unreinforced concrete pavements and continuously reinforced pavement with a lessor design useful lives of around 50 years.

RMS Maintenance Specifications also advise in their scope, that the specification compromises pavement quality to facilitate overnight slab replacement and the return of traffic prior to the morning peak.

Closure of traffic on classified roads is managed by NSW Transport with the use of Road Occupancy Licences. This overnight time restriction for the renewal of concrete slabs has influenced RMS maintenance specifications to permit the use of Calcium Chloride Salt as a concrete set accelerator.

The addition of salt to concrete is akin to using salt water to make concrete. The presence of chlorine ions, oxygen and water commences the corrosion of steel reinforcement. Top steel is particularly prone to corrosion as fine shrinkage cracking in the pavement surface permits ready access of oxygen enabling corrosion.

An alternative to using normal steel is the use of stainless steel to manage corrosive environments. The required reinforcement can be reduced by thickening the slab depth.

RMS Bridge Branch does not permit the use of salt set accelerators in bridge concrete. Bridges are designed to have useful lives greater than 100 years.

2.2 Standard Pavement

It is good practice to have a standard pavement design available to assist contractors to undertake slab repair and restoration.

The following pavement can be used for regional roads which has bus traffic.

- 150mm thick concrete sub-base, 50Mpa low slump concrete to match the set time of the concrete base before the opening to traffic.
- Builders plastic bond breaker to prevent reflective cracking
- 230 mm thick 50MPa Concrete base cured for a minimum of 50 hours before opening to traffic. Alternatively use Calcium Sulphoro Aluminate cement for a 6 hour curing time. The cost of the fast setting concrete is offset by the savings in the duration of traffic control.
- Two layers of SL81 steel reinforcing mesh.
- Steel reinforcement can be reduced by using a thicker pavement depth of 250mm utilising the formula provided in Austroads Pavement Design Guidelines.
- N16 ties every 600mm to adjoining slabs.
- 65mm cover
- Coved finish using helicopter coved float.
- Expansion Joint (Connelly Key) every 17.8 metres, corresponds with 3 sheets of reinforcement mesh.
- Crack control joints 30mm deep every 4.45metres

Figure 3: Full Slab Pavement Restoration Walker Street, Rhodes

2.3 Hints for Pavement Construction Success:

- Compact the subgrade in accordance with the AUSPEC specification.

- Use plastic sheeting to break the bond of cementitious service trench backfill with the concrete sub base. Upon future demolition of the slab this will prevent lifting and breaking the service.

- Similarly services that are located in the sub base zone must be either lowered or separated with sand and plastic to prevent bonding and loading by the slab. Refer to Streets Opening Co-ordination Council guidelines.

- All pavements require a jointing design which considers the location of joints in adjacent slabs and service lids which will initiate cracking in the new slab.

- Crack control joints must be cut approximately 5 hours after first set or when the slab can be cut without pulling stones. If the slab is left for 12 hours without cutting the shrinkage crack has already initiated and the slab will end up with two cracks, the shrinkage crack and the saw cut, side by side.

- Concrete is vibrated and a vibrating screed is used.

- Coving trowel finish using a helicopter concrete finisher is recommended in urban areas. Broom finish is not recommended as it brooms the harder wearing slurry from the surface.

-The concrete must be cured. Curing compounds are the easiest.

3 Asset Lifecycle Management

There is some industry misconception, that when an asset has reached its design useful life, that the asset is demolished and renewed, regardless of condition. Our industry needs to modify its view of pavement lifecycle management with the concept of: **pavements with an ongoing useful life, forever.**

When we perform a treatment on a pavement which extends its life, this should be recognised by improving the condition of the asset and extending its useful life in Councils Financial Assets Register. In doing so Council is able to reflect the reality of the asset lifecycle in the field with what is reported in Council's financial statements.

Similar, during Council's asset condition assessments, if it is found that a pavement will exceed the stated useful life in Council's asset register. Council should extend the asset useful life so Council's accounts can reflect the true asset lifecycle and recognise its financial performance.

These management methodologies permit concrete pavements to be recognised for their long term value to the community and supports the investment in timely maintenance.

3.1 Pavement Management Strategy

Given that there may be insufficient budget, for the renewal of all road pavements that require a treatment/renewal within the network in any given time. Funding priority must be given to those roads/ treatments that maintain the overall network condition at the highest level.

The following strategy maintains the road network at the greatest Pavement Condition Index:

- Treatments that prevent the deterioration of condition 1 assets becoming condition 2 assets are 100% funded
- Treatments that prevent the deterioration of condition 2 assets becoming condition 3 assets are 100% funded
- Treatments that prevent the deterioration of condition 3 assets becoming condition 4 assets are 100% funded
- The remainder of the funds are prioritised to prevent condition 4 assets reaching end of life and requiring reconstruction as condition 5 assets.
- Condition 5 pavements that do not pose a significant road safety risk receive the last priority for funding. Timing of the renewal requires consideration of level of service, risk and budget capacity. Reconstruction is considerably more expensive than rehabilitation treatments.

Preventing the deterioration of the overall network provides more value than reconstructing a few failed assets.

It is timely and regularly early treatments such as maintaining the bituminous joint sealing which rewards the asset custodian with the longest useful life.

3.2 Maintaining Concrete Pavements

Considering the failure mode of concrete pavements is failure of the joint from fatigue. It is paramount that the joints are monitored and sealed to prevent water ingress.

Water facilitates the pumping of the sub-base, at the joints, resulting is material loss damaging the joint. Loss of sub-base material will quickly fail the slab with the appearance of cracking a couple of metres away from the joint.

Early detection of pumping or moving joints, requires grout injection to replace the lost sub-base and support the concrete base.

Failed slabs can be lifted and supported with the use of expanding foam injection, although long term fatigue loading of the foam may cause it to compress. Sections of slab that have dropped excessively will require to be replaced inclusive of sub-base renewal and the joint reconstructed.

It is the integrity of the sub-base which supports the base slab, particularly at the joints, that enables the concrete pavements to achieve useful lives greater than 100 years. The dowels and tie bars may have corroded away but it is the sub-base which will continue to support the concrete base slab.

Steel reinforcement corrosion is another cause of slab failure. Concrete slabs in marine environments can fail where the top steel mesh corrodes and the expansive force of the formation of rust shears off the top layer of the slab. Similar failures can occur in road slabs to a lesser degree.

Use of Glass Fibre Reinforced Polymer (GFRP) reinforcement or stainless steel reinforcement are also means of ensuring concrete pavement longevity in corrosive environments.

Use of hot dipped galvanised reinforcement steel will protect the reinforcement from corrosion for 35-50 years. Bear in mind that the Zinc is acting as the anode to supply electrons to the steel to prevent corrosion.

Zinc oxide is formed when it supplies those electrons. Zinc oxide is more expansive than iron oxide and will ultimately contribute to pavement slab failure.

3.3 Protecting the Asset

The principal threats to concrete road pavements are water ingress and utility services.

Council's must inspect the integrity of the hot pour bituminous jointing material on an annual basis. If the integrity of the water proofing is failing then the old hot pour bitumen must be removed and replaced. The consequences of not conducting this timely maintenance is slab pumping and failure.

3.4 Restorations

Section 101 of the NSW Roads Act 1993 requires a utility to restore the pavement to the same condition that previously existed prior to the works and to Council's specification. It is very difficult for a sub-contractor employed by a utility to restore a concrete road pavement to achieve the same asset condition that a Council previously enjoyed. Considering the focus of the utility sub-contractor is getting paid, not the quality of concrete pavement restoration.

Key principles in management of Utility Services and achieving quality in restorations include:

- Monitor utility notifications and negotiate/ avoid trenching through concrete roads.
- Use IWORCS to better co-ordinate and manage of our pavements with respect to utilities (IWORCS is a GIS based utility/ council works planning tool)
- Before the excavation of the pavement a deed of agreement must be achieved for the restoration. The deed of agreement must include: the scope of work, use of a competent contractor, a road occupancy licence, slab and mix design, specification, quality system and supervision and certification by suitably experienced and qualified engineer. Without a deed of agreement the contractor will modify the specification for their own convenience.
- Utilise NSW Streets Opening Co-ordination Council Guidelines
- Utilise AUSPEC Specification
- Council issues its standard concrete pavement restoration designs and specifications.

Common pitfalls which decrease the quality of restored slabs include:

- The substitution of inferior contractors by the utility to save costs
- Concessions for the convenience of the subcontractor
- Use of Calcium Chloride salt as a set accelerator (rusts the steel)
- Use of the wrong specification
- Poor joint design and joint location
- Late crack control saw cutting

3.4.1 Scope of Work for Restorations

Longitudinal trenches cut along a trafficable lane will require the entire trafficable lane width to be wholly restored. Considering that the mass, shape factor and length of joints significantly influences the longevity of the slab. Restoration of the trench only, does not fulfil requirements of Section 101 of the Roads Act to restore the pavement to its previous condition.

For perpendicular trench crossings a minimum slab restoration length between 3 metres and 4 metres, measured longitudinally along the road, is required. Care must be taken to ensure existing cracks in the slab are no closer than 3 metres to any new joint. Otherwise the length of the restoration must be increased to remove the presence of the existing cracks.

Slabs must be sufficiently substantial enough to enable them to exist on their own well after the dowels and tie bars have rusted and offer no support.

Arguments with the utility will often be focused around the scope of the restoration. This reinforces the need to achieve a deed of agreement with the utility before the trenching occurs.

3.5 Fast setting Concrete

The City of Canada Bay was the first Council in Australia to use fast setting concrete to replace concrete road slabs on a classified road with a road occupancy licence restricting works between 9 pm and the return of traffic at 5 am.

Fast setting Concrete utilises Calcium Sulpho-aluminate cement and is mixed in a volumetric mixing truck. The concrete has a twenty minute setting time and requires double the number of tradesman needed to lay, vibrate, screed and finish the concrete slab.

Sewerage Authorities such as Sydney Water use this type of cement to repair concrete sewerage culverts and pipes.

Calcium Sulpho-aluminate cements will enable local government engineers to construct/ restore concrete pavements within short road occupancy time frames.

Importantly use of this type of fast setting concrete will match the useful life of the surrounding concrete slabs, forever.

Fast setting concrete achieves a tensile strength of 4.1MPa and a compressive strength of 35MPa in 4 hours. It has a compressive strength of 80MPa at 28 days.

It has an engineered PH greater than PH 10. Concretes which maintain a PH greater than PH 10 will protect steel reinforcement from rusting, provided the steel is fully encased by the concrete.

Keys to the success of this concrete for pavements are:

- Use of Quality Contractors utilising strict quality systems.
- Use of volumetric mixing truck
- Use of well-designed concrete mix and curing to control shrinkage cracking.

Figure 4: Volumetric Mixing Truck

3.6 Asphaltic Concrete Overlays

There was a trend in the 1980’s and 1990’s to overlay concrete roads with asphaltic concrete. This treatment was applied by Council’s to reduce the noise and vibration of vehicle tyres slapping over the expansion joints. The overlays also improved the ride for traffic.

Pavements laid on subgrades with a high moisture content transmit vibrations better than dry subgrades due to the incompressibility of water. Resident complaints are the greatest with saturated sand subgrades as they transmit vibration readily.

Asphalt overlays provide temporary relief of noise and vibration. Regular joint maintenance treatments are required to maintain this relief.

Reflection cracks will appear in the asphalt overlay, at the expansion joints, regardless of the use of bituminous crack control membranes. The resultant reflection crack quickly widens in the relatively soft asphalt resulting in a worse noise than the concrete. The widened crack also acts as a water reservoir and accelerates pumping of the concrete base slab.

Asphaltic overlays are not recommended for the following reasons:

- Reflective cracking requires continual joint maintenance.
- The costs of maintaining the overlay removes the lifecycle cost advantage that a concrete pavement provides.
- The overlay increases the difficulty in maintaining the concrete joints and the slab beneath.

Road Planing is now the preferred method of reducing noise and vibration whilst improving the ride ability.

Figure 5: Reflected crack in Asphalt Overlay. Lyons Road West, Five Dock

3.7 Road Planing - Diamond Grinding

Road Plaining is used to improve the road smoothness/ride ability, reduce joint noise and vibration. RMS has removed many of its asphalt overlays and implemented road plaining to great success.

Removal of the asphalt overlays has the added benefit of reducing the urban heat island effect caused by the dark asphalt. Uncoloured concrete pavements are significantly cooler than asphalt.

Figure 6: Trachyte used to protect the edge of the 1920’s concrete at intersections. Note the larger aggregate of the 1920’s concrete compared to the smaller sized aggregate possibly laid in the 1930’s or 1940’s. Pavement was planed in 2018 by NSW Roads and Maritime Services to reduce road noise and improve the ride. Lyons Road at Gipps Street, Drummoyne.

3.8 Concrete Slab Demolition

Removal of concrete slabs in urban areas is best done by saw cutting into pieces that can be removed by an excavator the following night. Use double cut saw cutting to protect against chipping adjoining slabs.

It is recommended not to attempt to grind out slabs with road profilers or use rock breakers. This generates unacceptable levels of noise and vibration in urban areas and stimulate resident claims of damage against Council.

3.9 Crack and Set

Concrete pavements that are completely beyond repair, can be reused by a crack and set method. This involves cracking the concrete into small pieces and stablishing the pieces in a bituminous matrix before overlaying with 100 mm or more of asphaltic concrete overlay.

The presence of steel reinforcement in a concrete pavement renders this process unsuitable.

Immense energy is required to fracture the concrete, which generates a lot of noise and vibration. The presence of underground services laid in the pavement zone and nearby buildings would make this treatment unsuitable in urban areas.

It is better to maintain the existing concrete pavements, than to let them decline to the condition where a crack and set treatment is considered. However, crack and set is a good option for unreinforced concrete pavements where it is unviable to maintain the pavement as a rigid concrete pavement.

Crack and set is not suitable option where the subgrade has unacceptable deflection.

3.9 Concrete Pavers as Pavements

The use of small format interlocking concrete pavers as a road pavement has many successful applications.

Their decorative patterning and colours contribute to transforming shopping villages and sporting precincts into "places for people".

Keys to their success include:

- Use of trained and prequalified contractors by the Concrete Masonry Association of Australia (CMAA)
- Strict adherence to the CMAA specifications.
- Preparation of a sound and well drained subgrade.

Some common causes of paver pavement failure:

- Use of large format and/or non-interlocking pavers, which fail as a result of paver movement under traffic.
- Use of round shaped sand which act as a lubricant (ball bearings) enabling the movement of pavers.
- Use of a smooth concrete base which prevents the frictional bite of the angular bedding sand.
- The underside of the paver must have good frictional properties with its angular sand bedding.
- Pavers laid on mortar will eventually delaminate and "chatter", under traffic loading.
- Pavers laid in storm water overland flow paths or shopping areas will have their jointing and bedding sand removed by the action of flowing water or mechanical footpath sweeping.

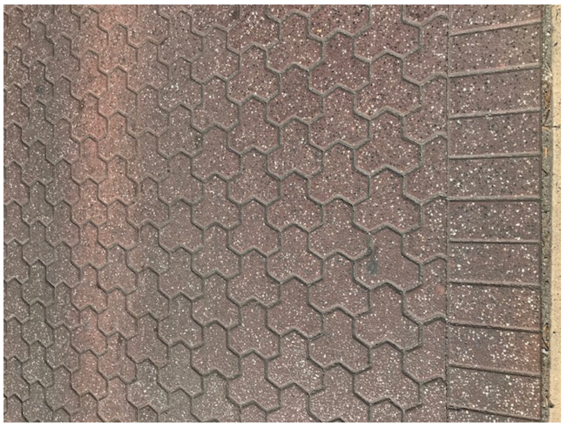

Figure 7: Small format interlocking concrete pavers George Street, North Strathfield. Laid 1990's in very good condition.

4 Concrete Pavements for Urban Cooling

The City of Canada Bay has used concrete pavements to cool shopping villages in order to:

- Encourage village patronage and alfresco dining
- Encourage local residents to walk to the village instead of driving to an air conditioned shopping mall.
- Create community belonging by residents connecting with each other and shop keepers as they walk, meet, eat and shop locally.

The City Canada Bay Council cooled the Concord West Shopping Village by 2 degrees Celsius, measured 1.5 metres above the footpath under the shade of the shop awnings, by paving the road with "White Asphalt". The white asphalt surface was 15 degrees cooler than standard asphalt.

White Asphalt is an open grade asphalt with a plasticised white cement slurry spread through the matrix which provides a light coloured concrete surface.

Figure 8: “White Asphaltic Concrete”

The City undertook time /temperature /patronage/ duration of stay surveys which produced the following results:

- Alfresco dining areas were two degrees cooler measured at a seated head height.
- Concrete roads heat up slower, which delays achieving the peak heat of the day from 1pm to 2pm. The prime alfresco dinning time is between 12pm and 2pm so the cooling effect significantly improved the diner comfort and influences a longer stay.
- Concrete roads cool down faster and achieve similar temperatures to the overnight ambient air temperature.
- Asphalt pavements do not have sufficient time to cool down over night and commence heating up from a hotter base temperature. During multi day heat waves, asphalt pavements were measured to pump up the peak heat achieved each day by 5 degrees as they start each progressive day 5 degrees hotter.
- Local patronage and duration of stay is markedly improved for air temperatures in the 26-30 degree range.
- Once ambient temperatures achieve temperatures greater than 32 degrees then most depart the shopping village and do not return until temperatures drop below 32 degrees late in the afternoon.
- The cooling of ambient air temperatures above 32 degrees has no real benefit as it doesn’t matter whether it is 33 degrees or 38 degrees, the patrons have moved their shopping and dining to air conditioned premises.
- The cooler environment reduces the air conditioning demand of the shops, and the need for additional shading which obscures street presence.
- Canopy street tree shading achieves the greatest amount of streetscape cooling. The use of light coloured surfaces such as concrete pavements and roofing makes a significant contribution to urban cooling when used in combination with street trees.
- The light colour of concrete footpaths also provide a cooling effect, particularly if associated with canopy trees. The community is more inclined to walk to local shops or recreate longer if provided with a cooler walking environment.

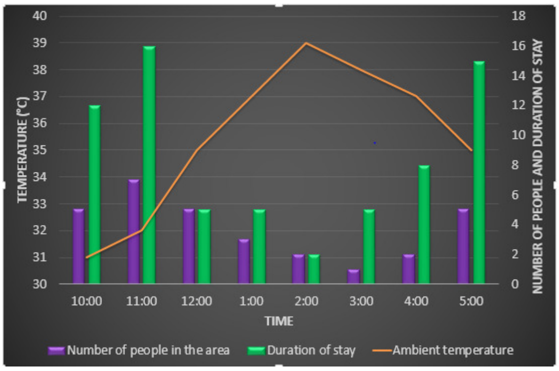

Figure 9: Concord West Village Place Activation with respect to Time and Temperature.

5 Recreational Pavements

The Clovelly Promenades, in Randwick City Council, are a unique application of concrete pavements to provide a popular ocean swimming platform. The rock platforms on two sides of Clovelly Bay were encased in concrete to provide bathing areas similar to the sides of a municipal pool.

Originally constructed in the 1930’s the concrete promenades were wholly restored/renewed in 2002 and 2004. This restoration paid great attention to concrete slab detailing inclusive of rock bolting, slab shape factor, jointing and stainless steel reinforcement.

The slabs are designed to withstand 1% Annual Exceedance Probability storm wave loading comprising the wave uplift of 4 metre waves breaking on the promenade for an extended duration.

High strength concrete was utilised to enable the slabs to be poured during low tide and set before they were inundated at high tide and subject to wave impact. The slabs were cured with a curing compound which protected from early moisture loss in the windy seaside environment.

The density of the concrete also assists in resisting salt crystal erosion of the slab surface. As the slabs dry after every high tide salt crystals form in the surface of the slabs. The crystal growth erodes the slab surface by pushing and breaking concrete particles.

Figure 10: Clovelly Promenades.

Figure 11: Clovelly Promenades slab joints showing little surface erosion after 15 years of service.

5.1 Skate Park Pavements

The precision of the finished surface and the durability of the surface is critical to the ride of skate parks. High density (40MPa) well cured concrete is important to maintain a durable and consistent friction for the surface.

Jointing design of the park is critical so as not to impact ride quality. Joints must be filled with silicon sealant.

Expansion joints locations should be carefully chosen to minimise ride impact.

Figure 12: Five Dock Park Skate Park. Laid 2006.

Conclusions

Concrete Pavements provide our community with extremely long lived transport and recreational assets. Keys to their longevity are:

- The quality of design and construction.
- Timely maintenance and ongoing protection.
- Management of threats to the pavement particularly utility service installation and restoration is critical.

Road Occupancy Licence Working times can be met by using fast setting concrete or high strength concrete. Use of Calcium Chloride salt to achieve fast setting times for concrete pavements must be avoided as this significantly reduces the useful life of the pavement.

Road plaining should be utilised to improve the noise and ride quality instead of asphalt overlays.

It is the initial quality given to concrete pavements which significantly increases the useful life as well as reducing the lifecycle maintenance requirements. Failure to proactively manage these pavements increases the lifecycle costs and community disruption.

Concrete pavements will remain a foundation structure supporting our communities transport and recreational needs forever.

Hooray for Concrete Pavements