Warringah Freeway Upgrade

Design & Construction

Peter Carson & Tim Hodge

March 2025

FLASH BACK TO 1968

- Mexico City held the Summer Olympics
- Robert F Kennedy was assassinated
- Vietnam War
- Mattels Hot Wheel toy cars were introduced
- Apollo 8 became the first human spaceflight to reach the Moon.
- Hugh Jackman and Will Smith were born
- Warringah Freeway in Sydney was constructed

AGENDA

01 Project Overview

02 Original Construction

03 Detailed Design

04 Construction

05 Lessons Learnt

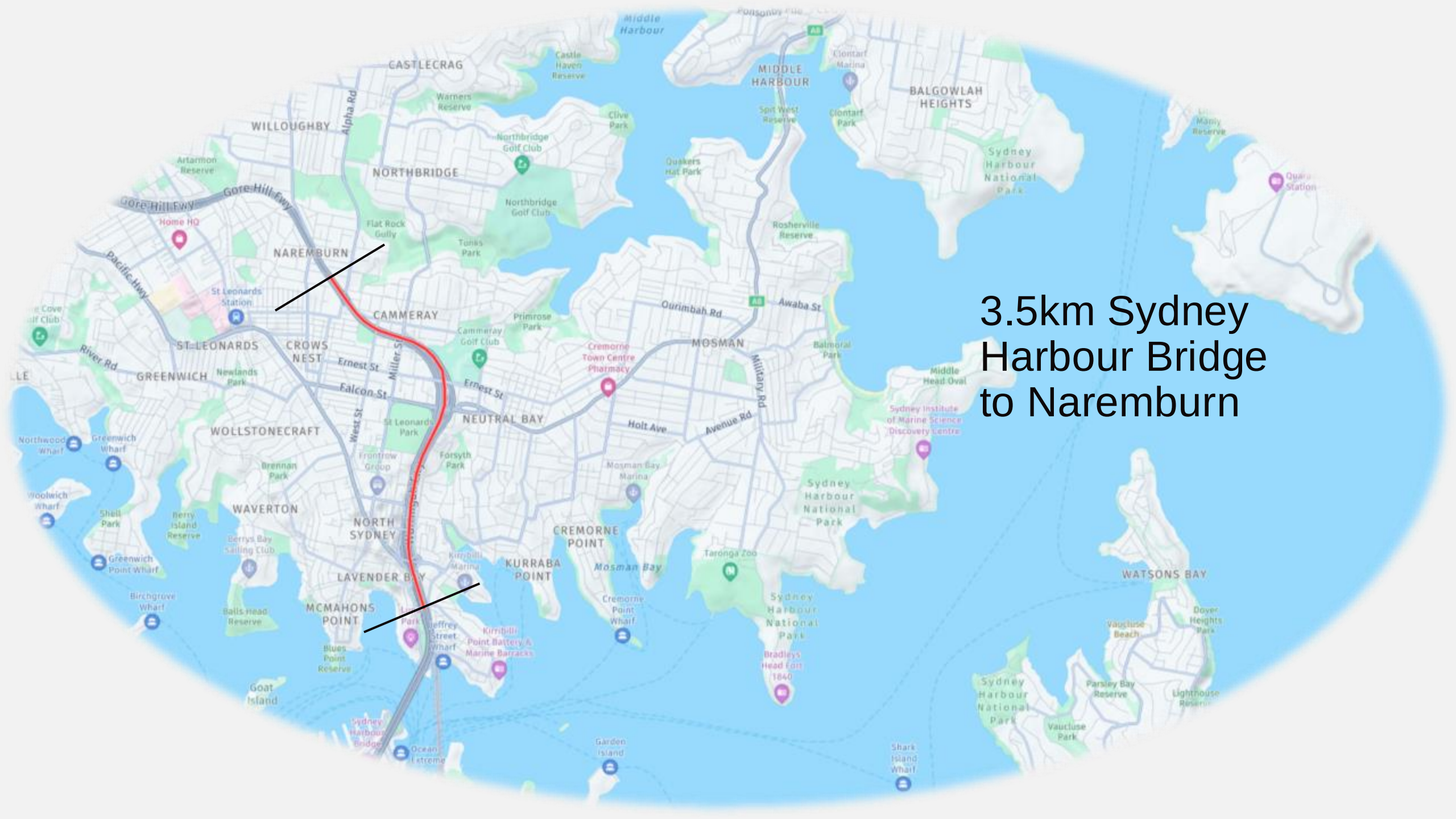
Acknowledgements

- Craig Hodder
- TfNSW
- Arvo Tinni (Resident engineer)
- John Hodgkinson
- CCAA
- Journals from DMR

PROJECT OVERVIEW

1. Location

- Warringah Freeway, Sydney, NSW, Australia
- 3.5 km divided freeway that extends from the Gore Hill Freeway at Naremburn in the north and ends at the Bradfield Highway (north of the Sydney Harbour Bridge)
- Aka M1 Motorway
- Current traffic volumes 100,000 per day (10% HV)


3.5km Sydney Harbour Bridge to Naremburn
Middle Harbour
CASTLECRAG
Castle Haven Reserve
Warners Reserve
WILLOUGHBY
Alpha Rd
Northbridge Golf Club
Clive Park
MIDDLE HARBOUR
Clontarf Marina
Clontarf Park
BALGOWLAH HEIGHTS
Spit West Reserve
Sydney Harbour National Park
Quakers Hat Park
NORTHBRIDGE
Artarmon Reserve
Gore Hill Fwy
Home HQ
Flat Rock Gully
Tonks Park
Rosherville Reserve
NAREMBURN
Pacific Hwy
St Leonards Station
CAMMERAY
Primrose Park
Cammeray Golf Club
Ourimbah Rd
Awaba St
Cremorne Town Centre Pharmacy
MOSMAN
Balmoral Park
ST LEONARDS
CROWS NEST
River Rd
GREENWICH
Newlands Park
Ernest St
Falcon St
Miller St
West St
Military Rd
Middle Head Oval
Sydney Institute of Marine Science Discovery Centre
NEUTRAL BAY
Holt Ave
Avenue Rd
St Leonards Park
WOLLSTONECRAFT
Northwood Wharf
Greenwich Wharf
Brennan Park
Frontrow Group
Forsyth Park
Mosman Bay Marina
Woolwich Wharf
Shell Park
Berry Island Reserve
WAVERTON
NORTH SYDNEY
CREMORNE POINT
Berrys Bay Sailing Club
Greenwich Point Wharf
Kirribilli Marina
KURRABA POINT
Mosman Bay
Taronga Zoo
LAVENDER BAY
Birchgrove Wharf
Balls Head Reserve
MCMAHONS POINT
Jeffrey Street Wharf
Cremorne Point Wharf
Kirribilli Point Battery & Marine Barracks
Blues Point Reserve
Bradleys Head Fort 1840
WATSONS BAY
Vaucluse Beach
Dover Heights Park
Goat Island
Sydney Harbour Bridge
Ocean Extreme
Garden Island
Parsley Bay Reserve
Vaucluse Park
Shark Island Wharf

2. Project timeline (WFU)

- **2014** Project identified in Infrastructure NSW State Infrastructure Strategy
- **2016** NSW Government budget allocated funding for planning of the Warringah Freeway Upgrade
- **2020** NSW Government released EIS for public exhibition
- **2020** NSW Government announced shortlist of 3 consortiums for the main works contract
- **2021** NSW Government awarded main works contract
- **2026** Expected construction completion

Project justification:

- Create connections to the Western Harbour Tunnel and Beaches Link projects
- Reduce traffic congestion - Improve traffic flow - Improve capacity
- Simplify a complex road corridor
- Take pressure off the Sydney Harbour Bridge, Sydney Harbour Tunnel, ANZAC Bridge and Western Distributor

2. Contract Award

- Awarded 2021
- Project Type: Incentivised Target Contract (ITC)
- Project Cost: ~ A$1.2B
- Main Contractors: CPB Downer JV
- Main Designers: Jacobs Arcadis JV
- Peak – 250 FTEng across 5 countries

3. The Project

- Freeway upgrade - Harbour Bridge to Naremburn
- Approximately 3.5 km zone of works
- 57.6 Lane/kms upgraded
- Road widenings and infills
- New & upgraded ramps
- Local road upgrades & adjustments
- Improvements to interchanges at Falcon Street, High Street
- Carriageway 18 lanes at widest point
- 9.3 km of drainage pipe and 760 pits
- 12 Bridges
- 7.2 km Retaining Wall (70 separate walls)
- 3 Tunnel Portals (cut and covers)
- 1.1 km of noise walls
- 170 ITS signage and 12 dynamic directional signs
- New and upgraded pedestrian and cyclist infrastructure
- Upgrades and modifications to bus infrastructure including a dedicated bus lane
- Active transport links for cyclists and pedestrians.
- Zipper barriers

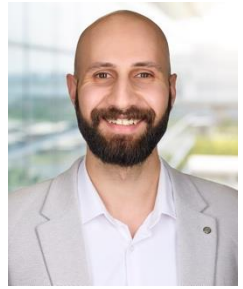
4. WFU Pavements Team

Detailed Design

Craig Hodder (Arcadis)
Discipline & South Zone Pavement Lead

Scott Minards (Arcadis)
Central Zone Pavement Lead

Brad Taylor (Jacobs)
North Zone Pavement Lead

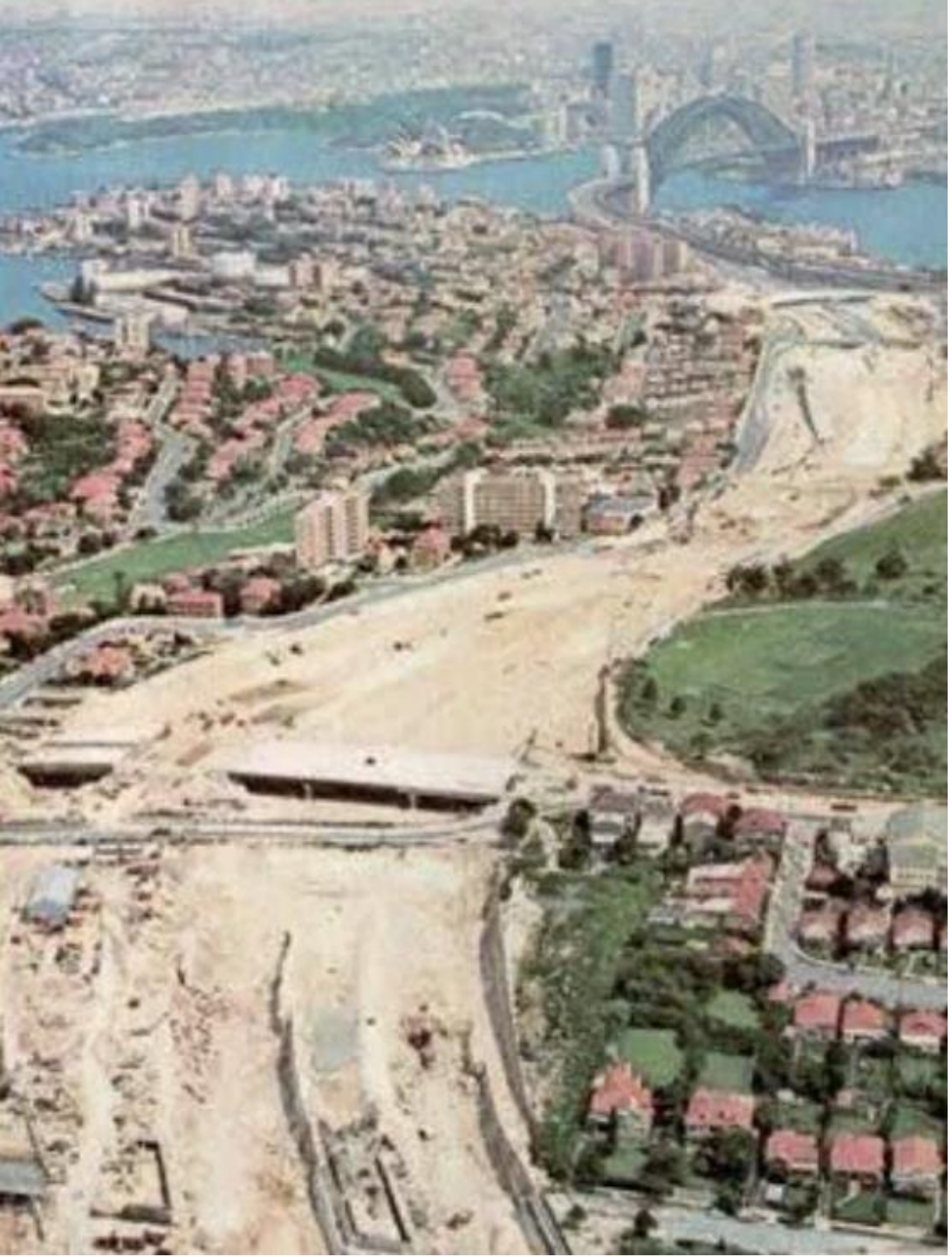


Albert Sultana (Jacobs)
Pavement Engineer

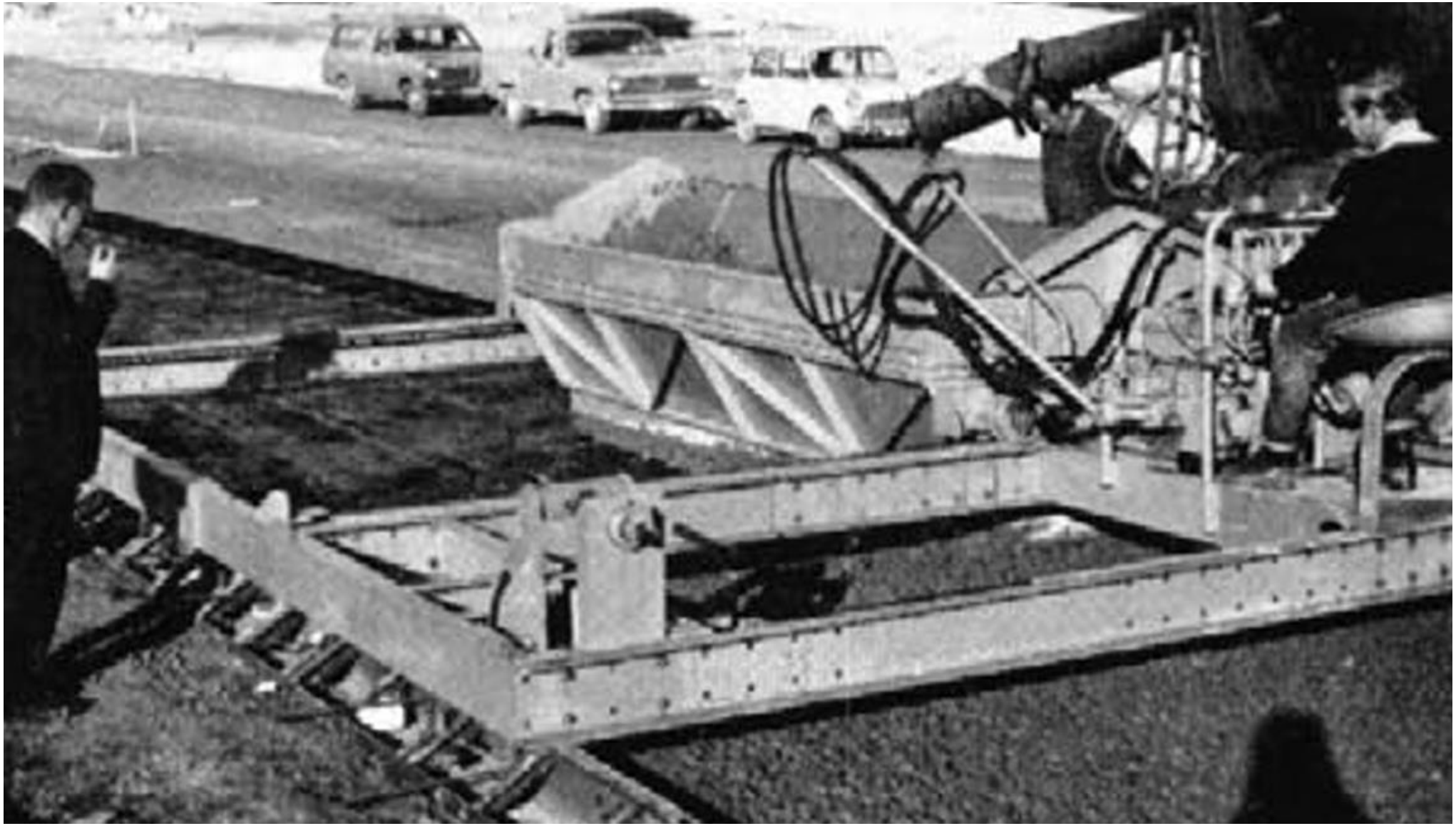
CPS & Construction

Peter Carson (Arcadis)
Pavements
Construction Phase Services

Tim Hodge (CPB)
Project Manager
Construction Delivery



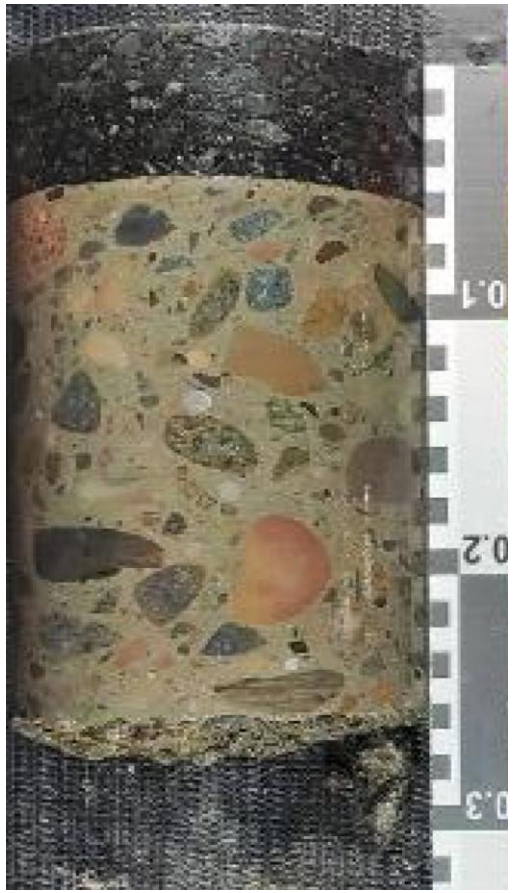

2024



Spreading first 100mm of concrete base

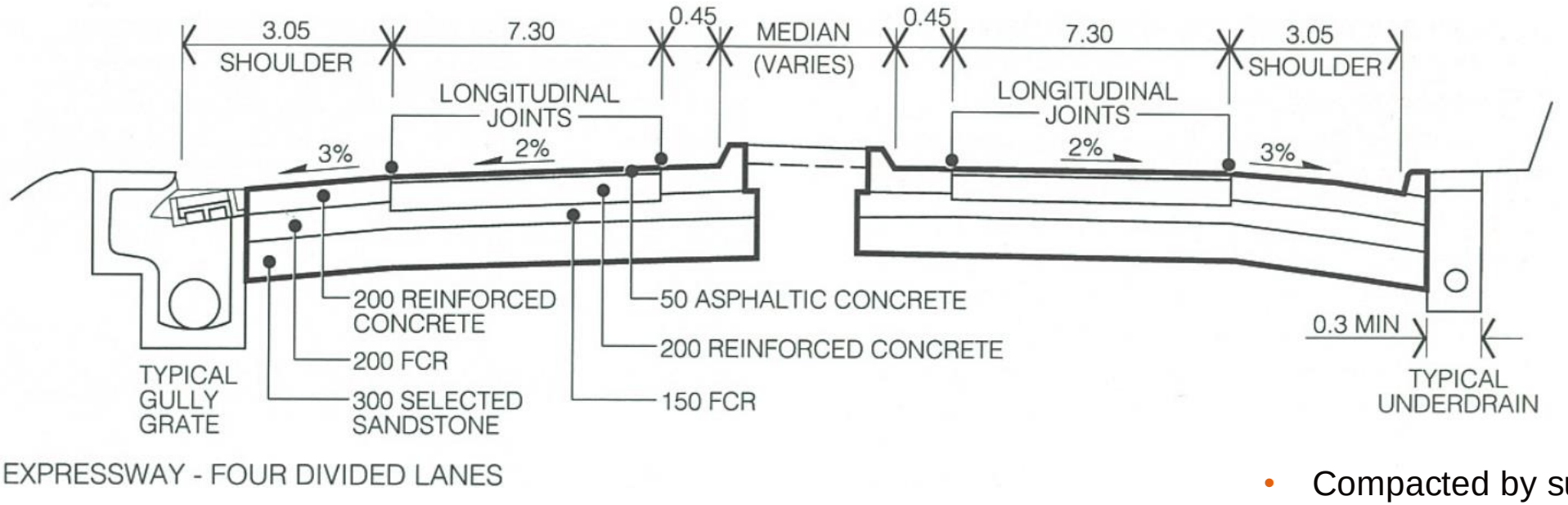
5. Construction of Original Expressway

- Original Warringah Freeway Pavement is mesh reinforced concrete pavement (continuous through transverse contraction joints i.e. hinge joints)
- Asphalt surfacing was used because they couldn't achieve good ride quality due to large amount of hand placed slabs



- Concrete slabs are 7.6 m long although reported elsewhere 6.6-7.5m
- Slabs are similar to JRCP in proportions, however, are substantially different in terms of the joints
- Kerb and gutters were tied to concrete base; kerb only was dowelled with 13 mm dia. bars
- We note that since construction was completed, some of the original pavement arrangement has been modified due to road widenings, road maintenance, or resurfacing. Therefore, in some locations lean-mix concrete subbase and/ or stabilised sand subbase and built-up asphalt surfacing was encountered.
- Majority of the existing pavement is MRCP, however there is a bus layover area consisting of JRCP, and from Miller Street overbridge northwards, the pavement changes from rigid to flexible ~1.2km.

Cross section of the Original Expressway



EXPRESSWAY - FOUR DIVIDED LANES

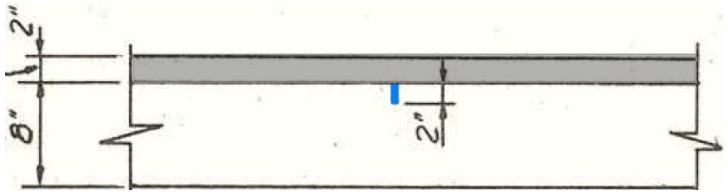
Profile details:

- 200mm Concrete 18MPa Lanes, 20.7MPa shoulders (SL82 mesh)
- 150mm Crushed dolerite/ picrite base
- 300mm Crushed sandstone subbase
- Sandstone subgrade

Original construction:

- Concrete received from ready-mix truck and paved between fixed forms
- Two-layer concrete paving i.e. Place 100mm concrete, mesh, then place final 100mm concrete
- Compacted by surface pan vibrator
- Cement content 280kg m^3
- 20mm max. agg size
- 50mm slump
- Cured with bitumen emulsion through lanes & Shell White Sealer on raised concrete shoulders
- Hessian drag through lanes, concrete shoulders broom finished

Jointing and reinforcement of the Original Expressway



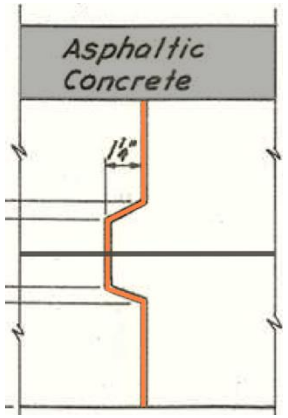
Transverse contraction joints

-Joints varied at 6.2-7.6m

-Skewed joints except in raised concrete shoulders

-Formed with steel T-bar, 50mm deep 10mm wide joints with temporary polystyrene fillers, later removed & filled with 20/30 bitumen

-Continuous wire reinforcing fabric in middle 1/3 of slab, 8mm round deformed bar, 200mm grid



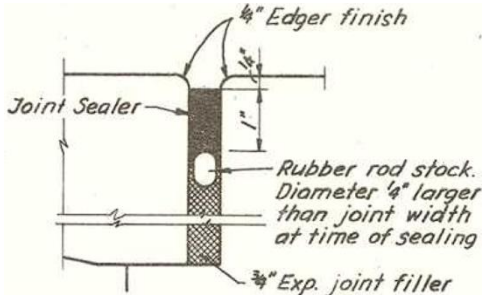
Longitudinal joints

-Keyed & Tied

-N12 tiebars 1.35m long at 760 mm centres

-If pavement width >11m one untied longitudinal joint provided

-Coincided with lane lines



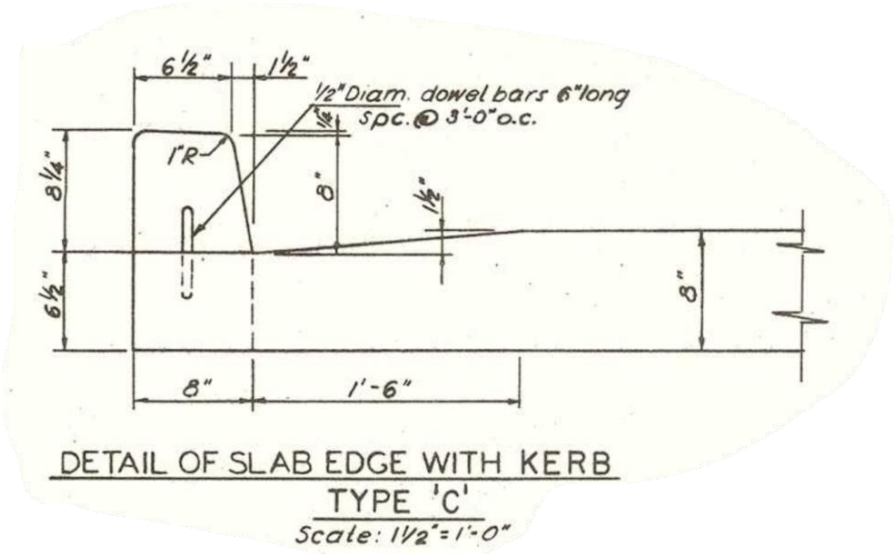
Expansion joints

-Where abutting structures

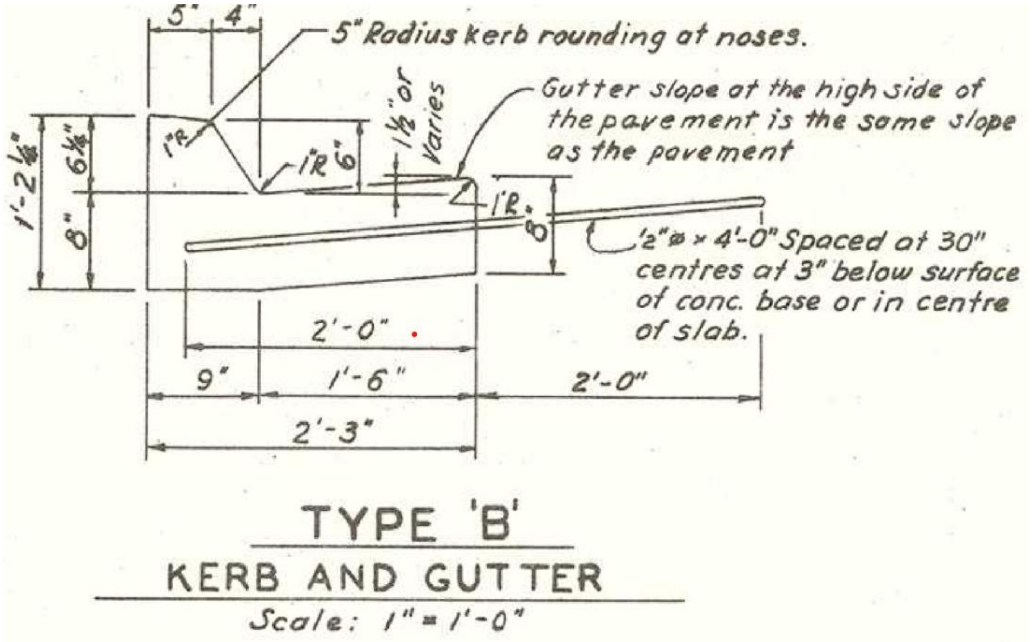
Construction joints

-End of day – Reported as doweled

5. Kerbs and raised concrete shoulders



DETAIL OF SLAB EDGE WITH KERB
TYPE 'C'
Scale: 1½"=1'-0"



TYPE 'B'
KERB AND GUTTER
Scale: 1"=1'-0"

the paver and extending over the full paved width. At each edge two immersion vibrators provided compaction around keyways and tiebars

- The surface was finished by a large reciprocating

straightedge. This was strictly enforced and considerable mechanical scabbling was required to bring the pavement to tolerance.

temperatures during which most of the concrete was placed, 'hot-weather' site precautions were employed. Commercial aliphatic alcohols were successfully used to reduce plastic shrinkag alcohol was sprayed on t possible after screeding t application rate was in th

Asphalt Surfacing

The principal reason for a surfacing was that-with th placed slabs with odd sh carriageway-width the rid been good enough for th travelling speeds on the freeway despite the monitoring of construction by a straightedge.

The 21 000 t of asphaltic concrete was placed in two layers using dense graded mixes with maximum aggregate sizes of 20 mm and 10 mm. The asphalt was manufactured and placed using the Department's own plant. This work saw the introduction of hot longitudinal joints with up to three pavers working in a staggered tandem pattern.

Freeway Traffic History

At the time of design and construction of this freeway the assessment of traffic in terms of equivalent standard axle loads (ESA) or measured axle-load distributions (such as CULWAY) were not in use. The design traffic loading is therefore not known in these terms.

Twenty-two years after construction the total average daily traffic using the freeway accounts for at least 75% of traffic using the Harbour Bridge or 150 000–160 000 vehicles per day depending on

evidence that the asphalt will have to be overlaid or replaced at least in the short term. In some locations where traffic crosses from the travelling lanes to

not to the extent that patching or other repair to the asphalt is necessary.

In the early 1980s some of these cracks were

stepping at the joints has either not occurred or is negligible. The absence of surface staining after extensive periods of rain is a good indicator that there is no pumping of fines from the subgrade/sub-base and that subgrade erosion is being effectively controlled.

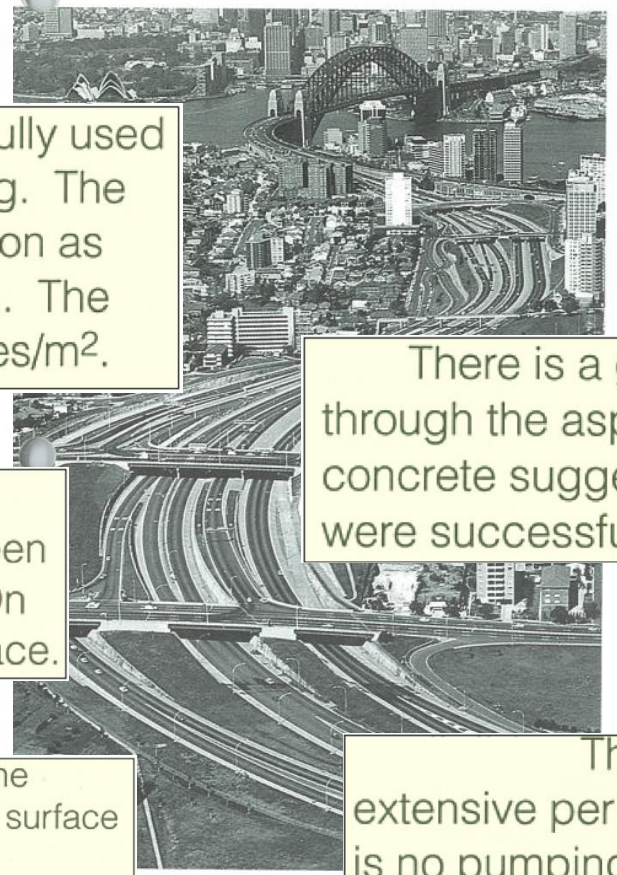
As part of the construction of the northern entrance to the Sydney Harbour Tunnel in 1989, some areas of the existing freeway pavement had to be removed. This provided an opportunity to assess the condition of the pavement. In general there was no corrosion evident in the steel reinforcement and dowels despite the freeway being located within half a kilometre of the salt water environment of the harbour. This can be attributed to the effective compaction achieved in the concrete and the sufficient cover provided to the reinforcement (viz not less than about 65 mm).

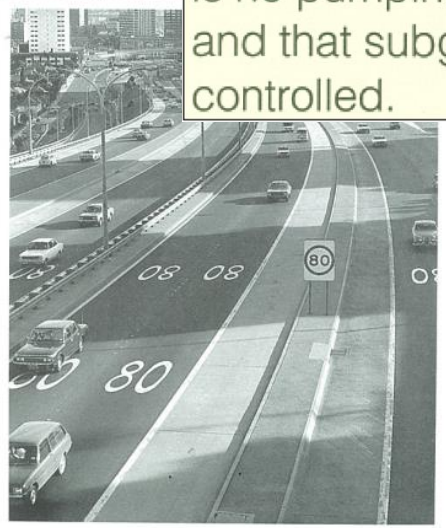
Commercial aliphatic alcohols were successfully used to reduce plastic shrinkage or setting cracking. The alcohol was sprayed on to the concrete as soon as possible after screeding to retard evaporation. The application rate was in the range 0.12–0.2 litres/m².

Current Pavement Condition

The pavement is in excellent condition and has been virtually maintenance free over its first 22 years. On the travelling lanes the original asphalt is still in place.

Each transverse and longitudinal joint in the concrete reflected through the 50-mm asphalt surface within the first 12 months. When viewed from overbridges these reflection cracks are obvious but at typical driver eye-height they are not so obvious and have not affected the riding quality of the pavement.





The Engineer's View After 22 Years

Mr Arvo Tinni, currently Director, Priority Projects with the NSW Roads and Traffic Authority (formerly Department of Main Roads), who was the Resident Engineer during the construction of the Warringah Freeway including the pavement works, has made the following observations in reflecting on the construction and life of the freeway to date:

Probably the most challenging task at the time was to keep the 100 000 vehicles per day flowing whilst 'slipping the freeway under it'. During the three years of construction 15 major and 60 minor detours were needed - averaging one every 10 days. This was quite an exercise to co-ordinate traffic, bus routes, public notices, police, streetlighting, public utility

There is a general absence of reflection cracking through the asphalt surface between joints in the concrete suggesting that the construction methods were successful in avoiding unplanned cracking.

- *Subsoil drainage as standard procedure in cuttings*
- *Deliberately designed contraction joints*
- *Tied-on kerbs with 'gutters' formed in slabs*
- *Use of aliphatic alcohol as an evaporation inhibitor*
- *Use of bitumen emulsion for curing where asphalt was to be placed*
- *'Wet formed' contraction joints*
- *Coloured open graded concrete median tapping*

The absence of surface staining after extensive periods of rain is a good indicator that there is no pumping of fines from the subgrade/sub-base and that subgrade erosion is being effectively controlled.

demonstrated what can be achieved with well-designed and closely supervised concrete pavements carrying large volumes of traffic over long periods. It has clearly provided a good long-term return on the investment of public funds.

This performance can be directly attributed to:

- careful subgrade/sub-base specifications;
- the inclusion of concrete shoulders;
- close attention to the basics of concrete construction, good mix design, effective placing, compaction and curing techniques;
- professional engineering supervision.

Acknowledgement

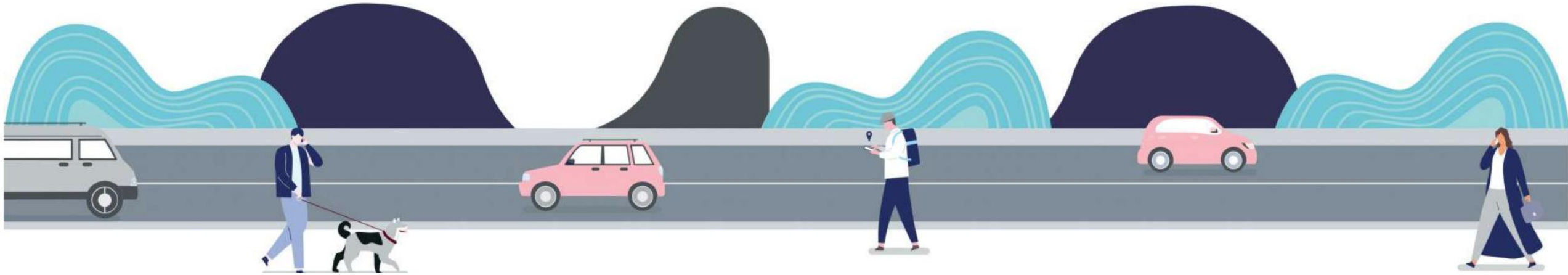
The assistance given by the Roads and Traffic Authority of NSW in providing information and construction records for the preparation of this article is gratefully acknowledged.

ARCADIS

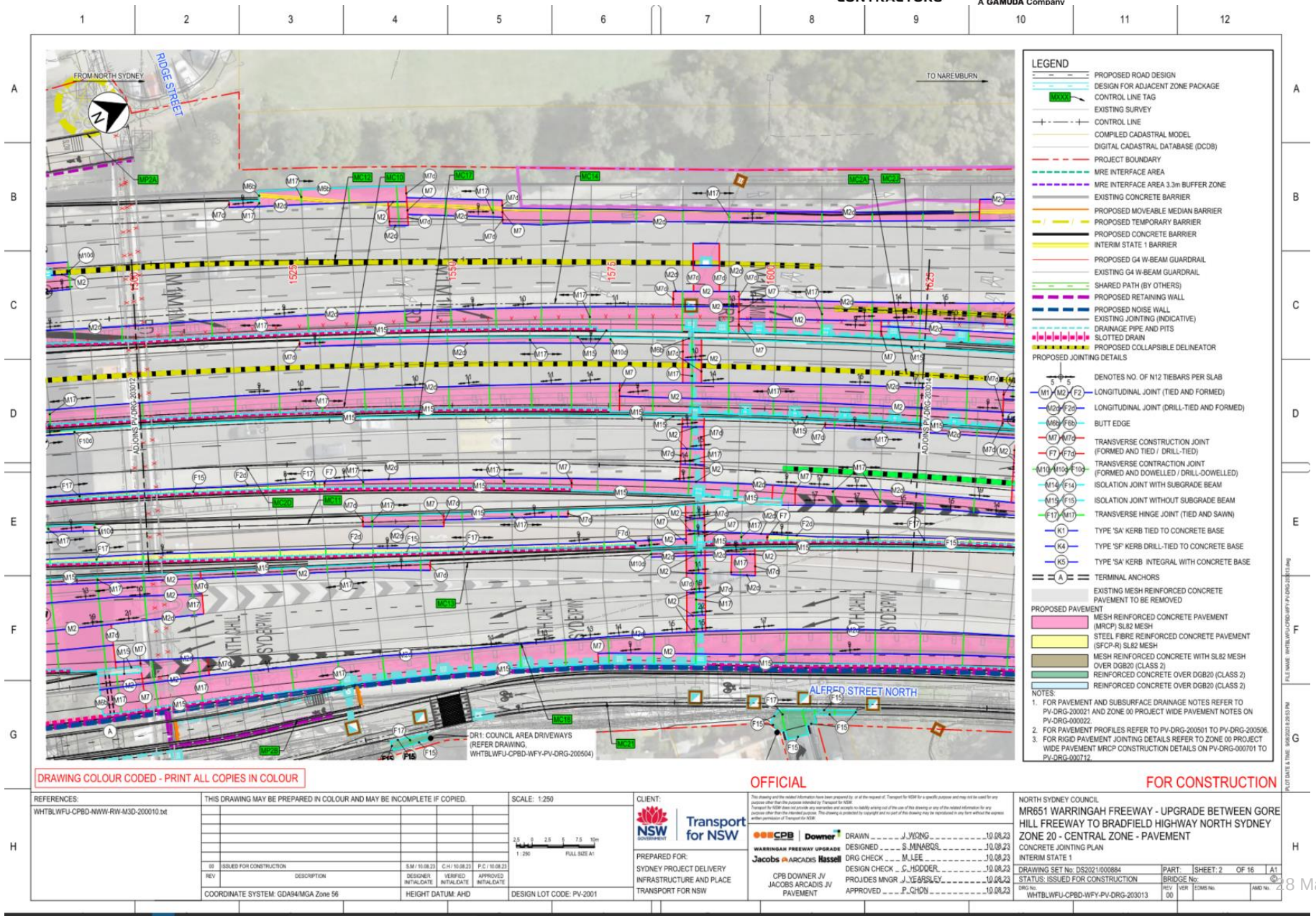
DETAILED DESIGN

Pavement investigations

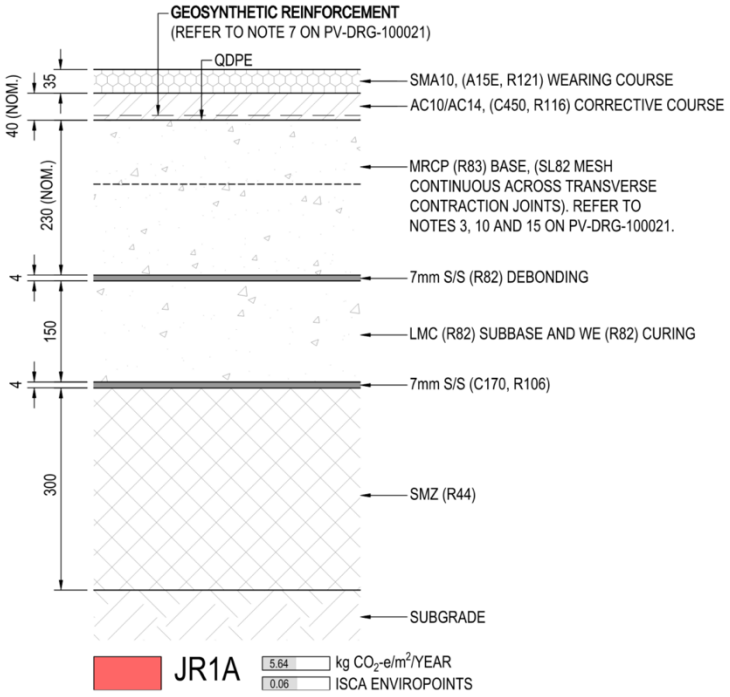
- Coreholes
- Boreholes
- Laboratory testing
- Compressive strength
- Deflection testing
- Remember WFU wasn’t about upgrading the road, it was about widening and modifying to suit the WHT connection and keeping as much pavement as possible

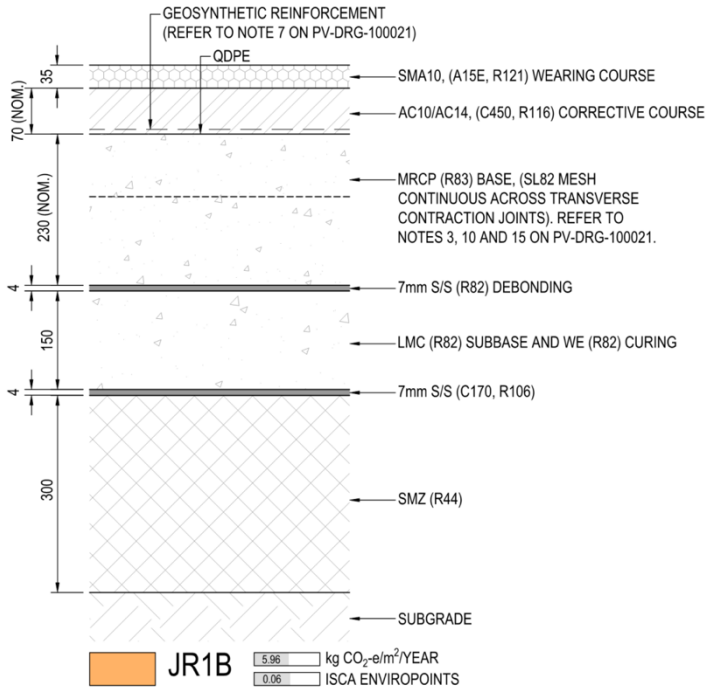


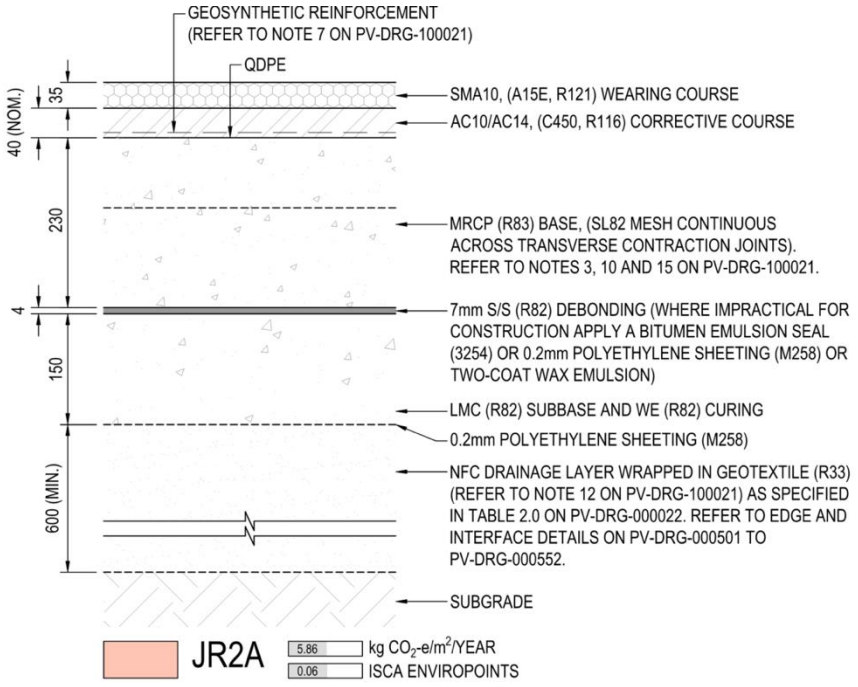
Pavement Plan



Mainline Pavement Profile – Detailed Design

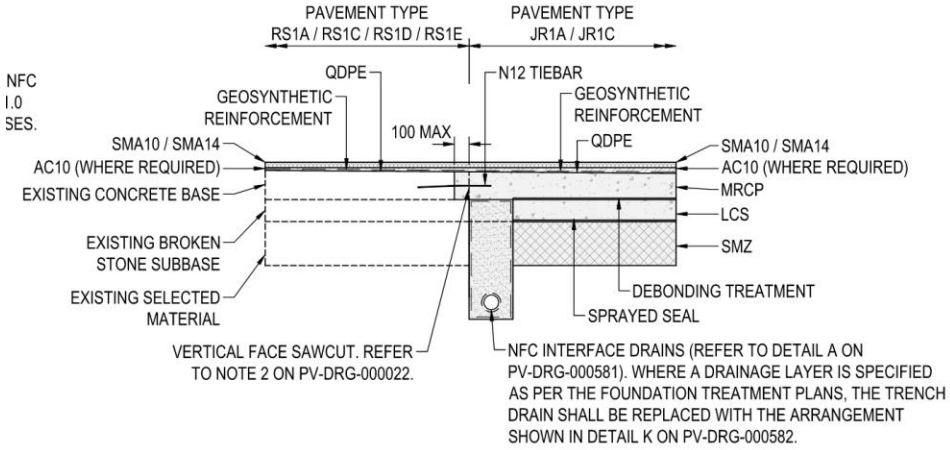




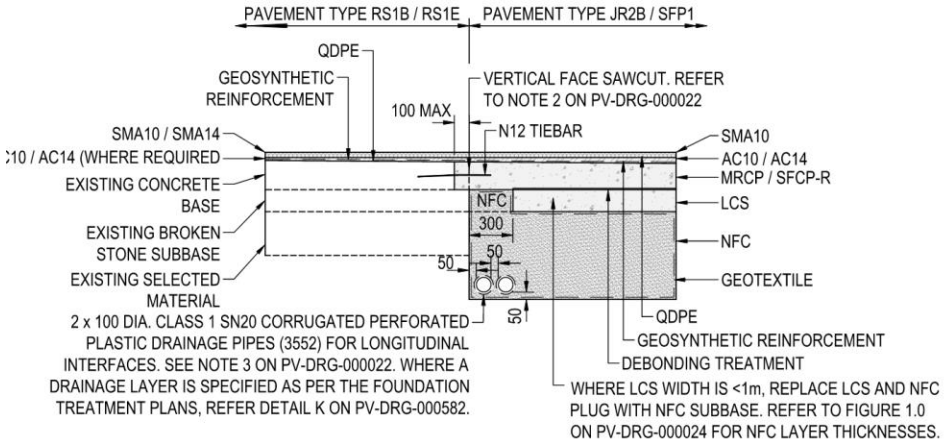


Non-standard concrete pavement – coined ‘MRCP’

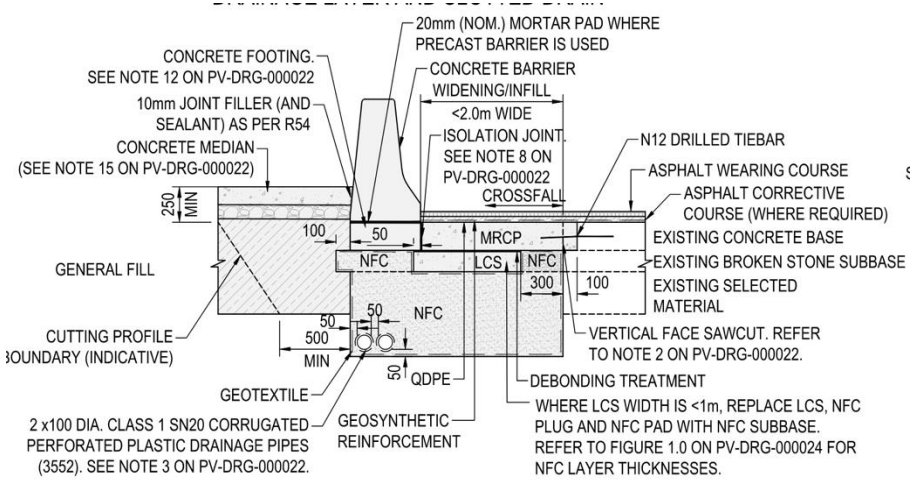
Mainline Interface Details – Detailed Design



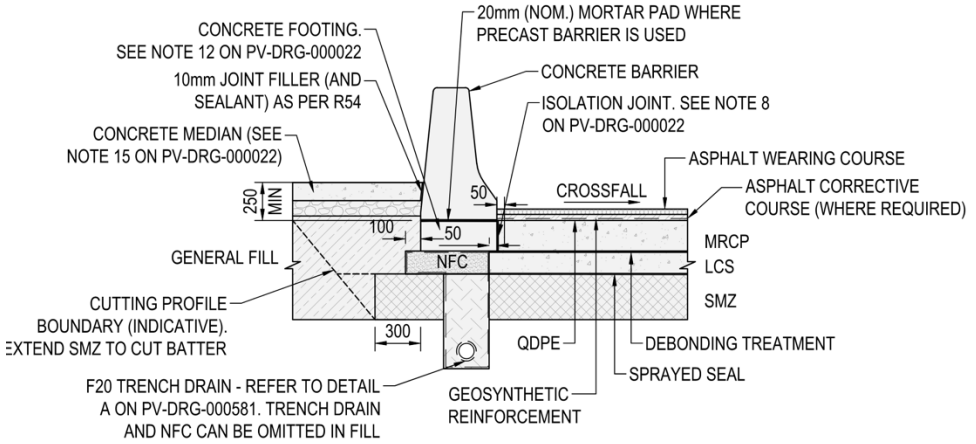
IF12 PAVEMENT TYPE RS1A / RS1C / RS1D / RS1E TO JR1A / JR1C TRANSVERSE / LONGITUDINAL INTERFACE



Mainline Edge Details – Detailed Design



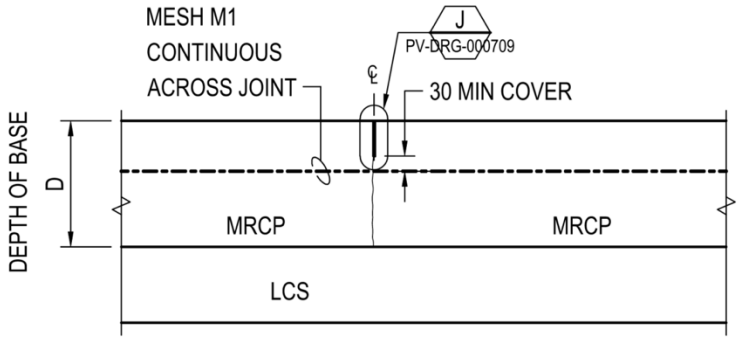
RM14 RIGID - HIGH / LOW SIDE EDGE WITH NARROW WIDENING TRENCH, CONCRETE BARRIER AND MEDIAN



RM27 RIGID - HIGH SIDE EDGE, WITH CONCRETE BARRIER

Jointing Details – Detailed Design

- Modified TfNSW JRCP Rigid Pavement Standard Details



JOINT TYPE M17
HINGE: TIED AND SAWN

CONSTRUCTION

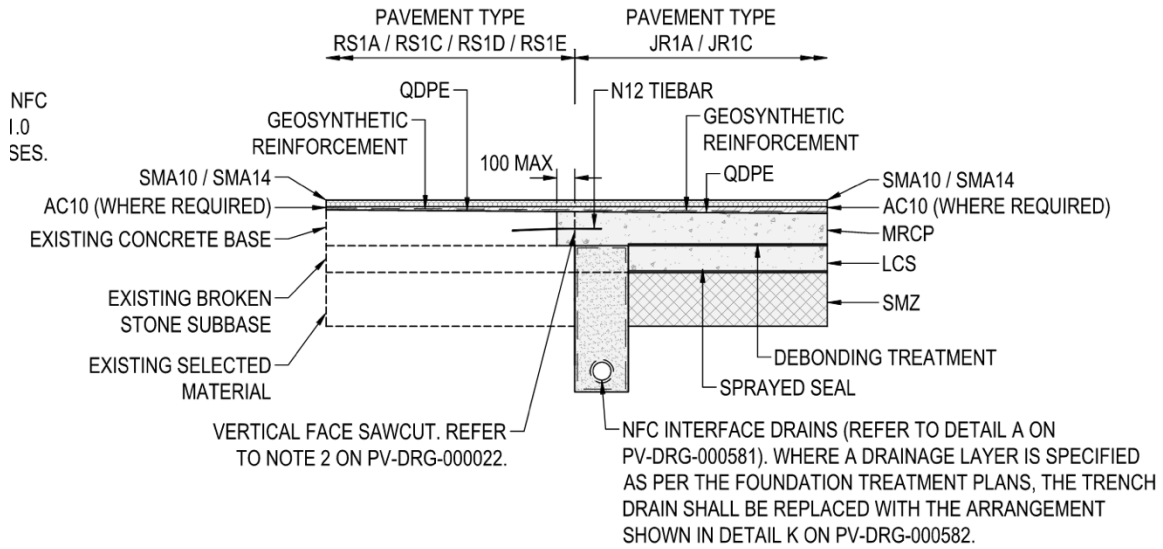
Construction phase

- Warringah Freeway Upgrade:
  - Upgrade of traffic configuration & enabling of WHT
  - Not an upgrade of the pavements
  - Widening and re-sheeting of existing

- Project Pavement Makeup:
  - MRCP South of West St Bridge, Cammeray
  - FDA North of West St
  - 81% within South Zone of project (South of Falcon Street)
  - 19% within North Zone of project

Construction phase

- What we expected to find onsite:
  - 200-220mm jointed reinforced concrete base
  - 150mm broken (Crushed) stone subbase
  - 300mm select material backfill



- What we did find was surprising!

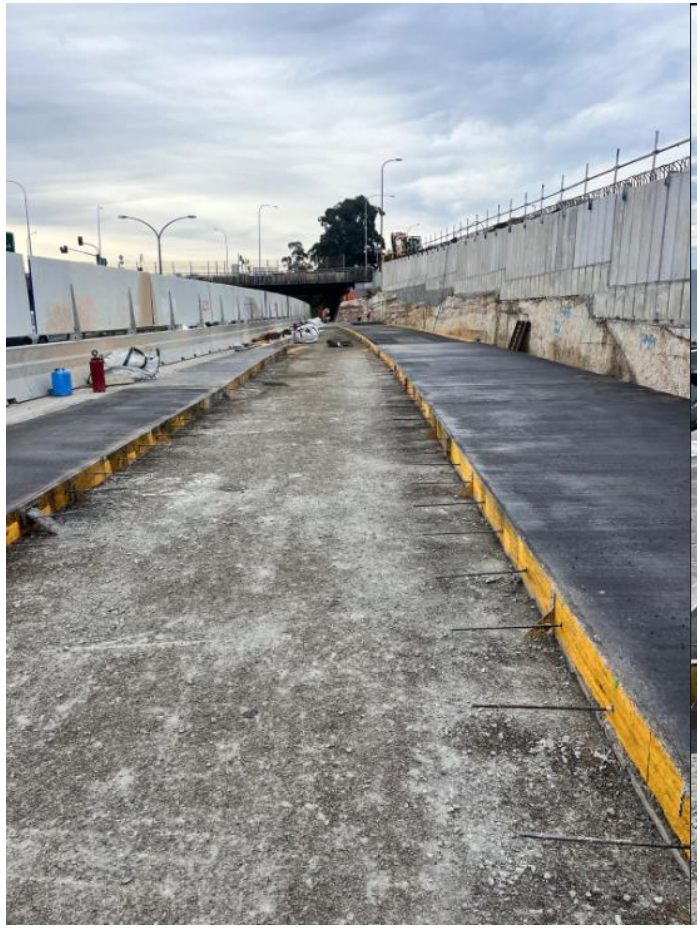
  Well for an almost 60 yo pavement

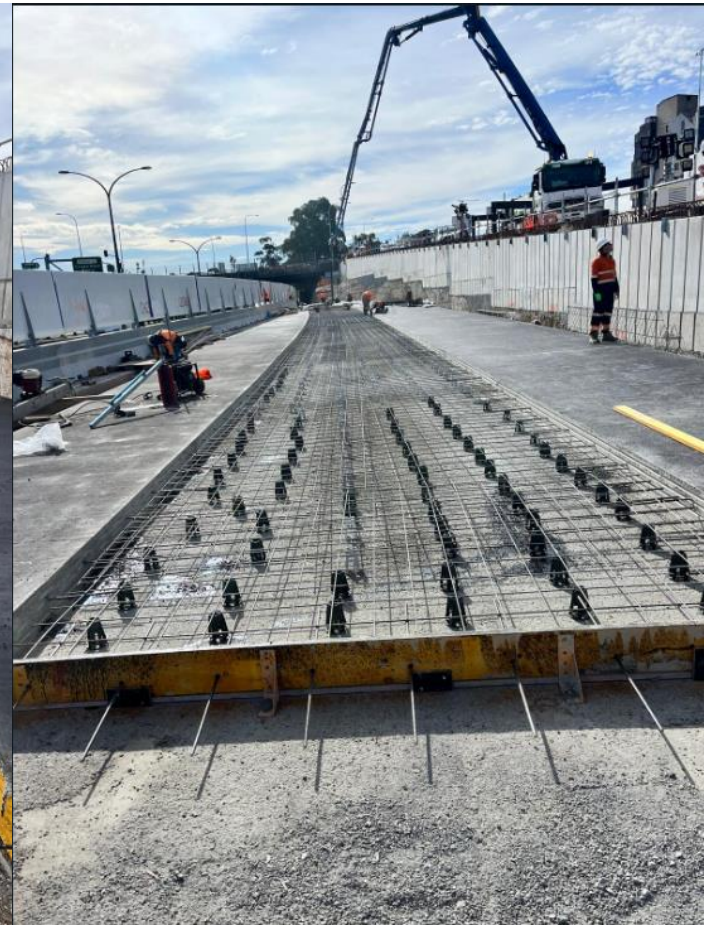
  - Pretty much what we were told to expect
  - ~220mm concrete base
  - ~150mm stone subbase
  - ~300mm clay/select material backfill

Construction phase

- Main construction constraints
  - Limited closures
  - Tight out of hours/noise constraints
  - Heavy daytime traffic
  - Piecemeal/Staged Construction

- Conditions in our favour
  - Consistent pavement type
  - Consistent rigid pavement thickness
  - Consistent jointing (reduction in dowels with MRCP)
  - Reasonable quality base pavement





Construction phase

- Conservative paving method utilised
  - Manual fixed form paving
  - Allowed for the piecemeal, variable width paving that was necessitated by the traffic staging constraints.

- Innovations
  - Adjusted pavement model (MRCP)
  - Access to site?

Construction phase

- Access Innovation
  - Example median worksite
  - Minimal room available not able to fit an agi + equipment adjacent to pour
  - Typically requires closure of at least 2 live lanes
  - Hard to get ROL approvals & can expose workers to live traffic
  - So just make more room quicker, simple

Construction phase

- Access Innovation
  - Zipper Barrier + BTM from Lindsay

18" RTS Barrier

RTS Barrier Transfer Machine

ABSORB Crash Cushion

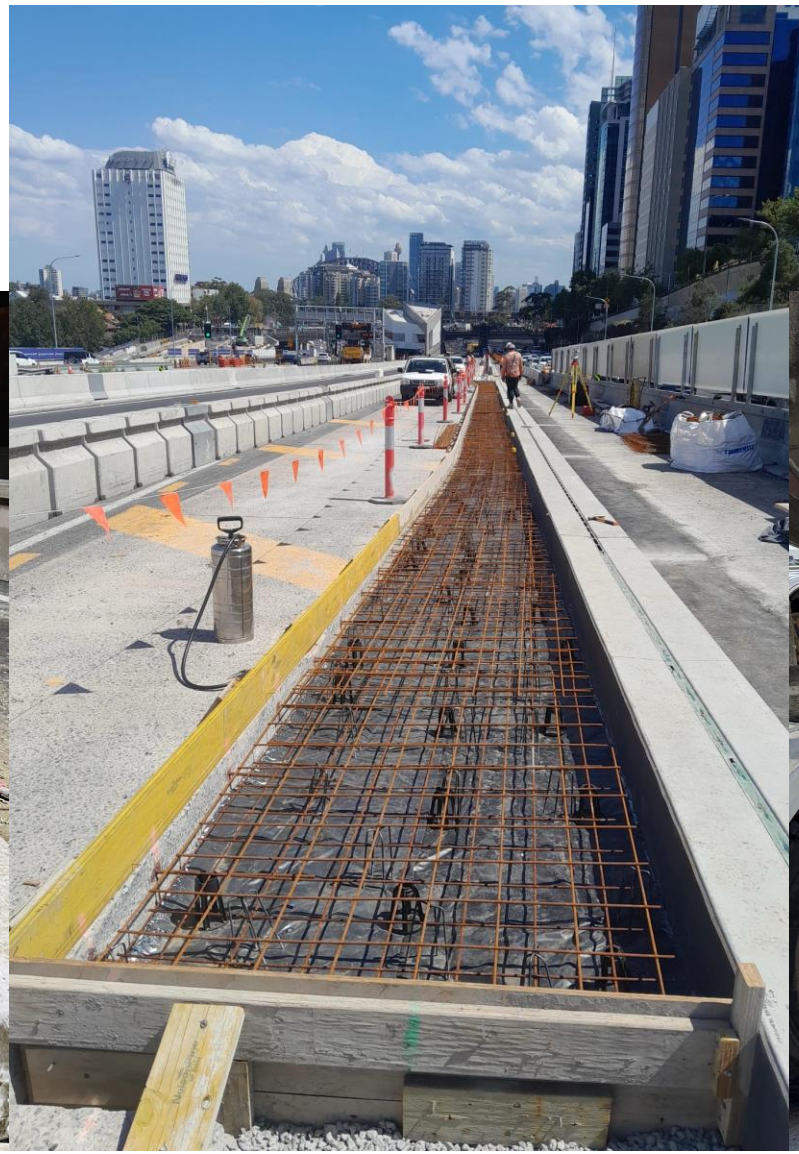
Variable Length Barrier (VLB)

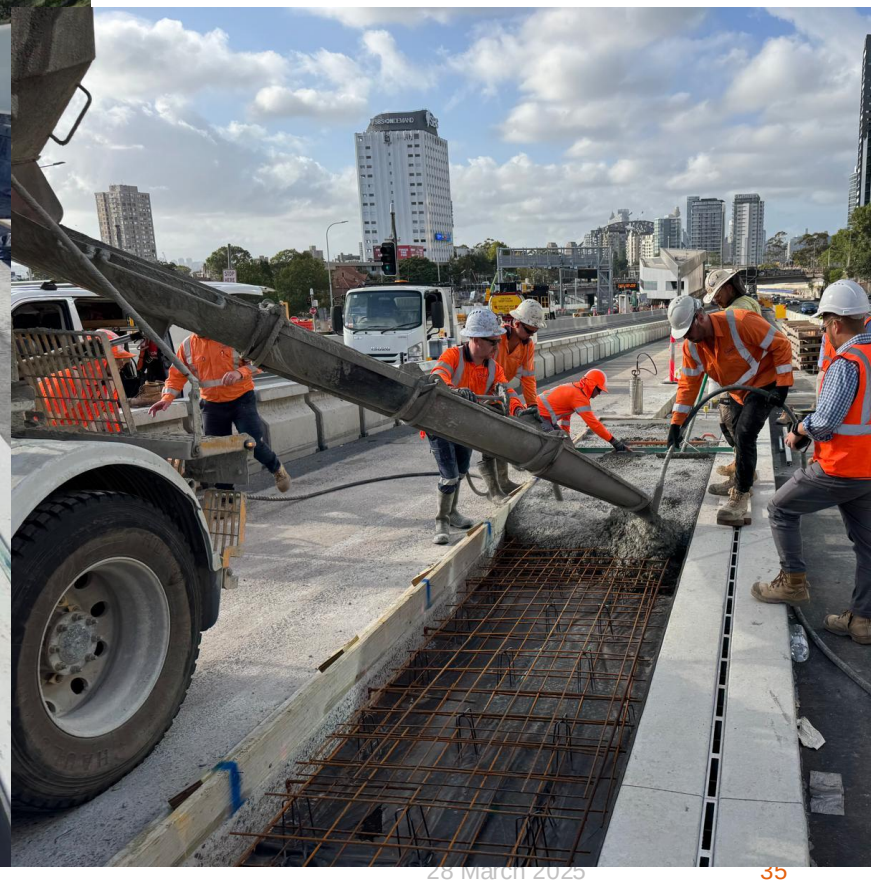
- Reactive Tension System (RTS) Barriers (concrete)
- Barrier Transfer Machine (BTM) lifts barriers by the "T-Top"
- Variable Length Barriers (VLBs) allow for barrier relocation, radius curves & expansion joints (VLB ratio is determined for each project individually)
- Absorb crash cushion - unanchored & transfers through the BTM with barrier

LINDSAY

Construction phase

- Access Innovation
  - Zipper Barrier + BTM from Lindsay





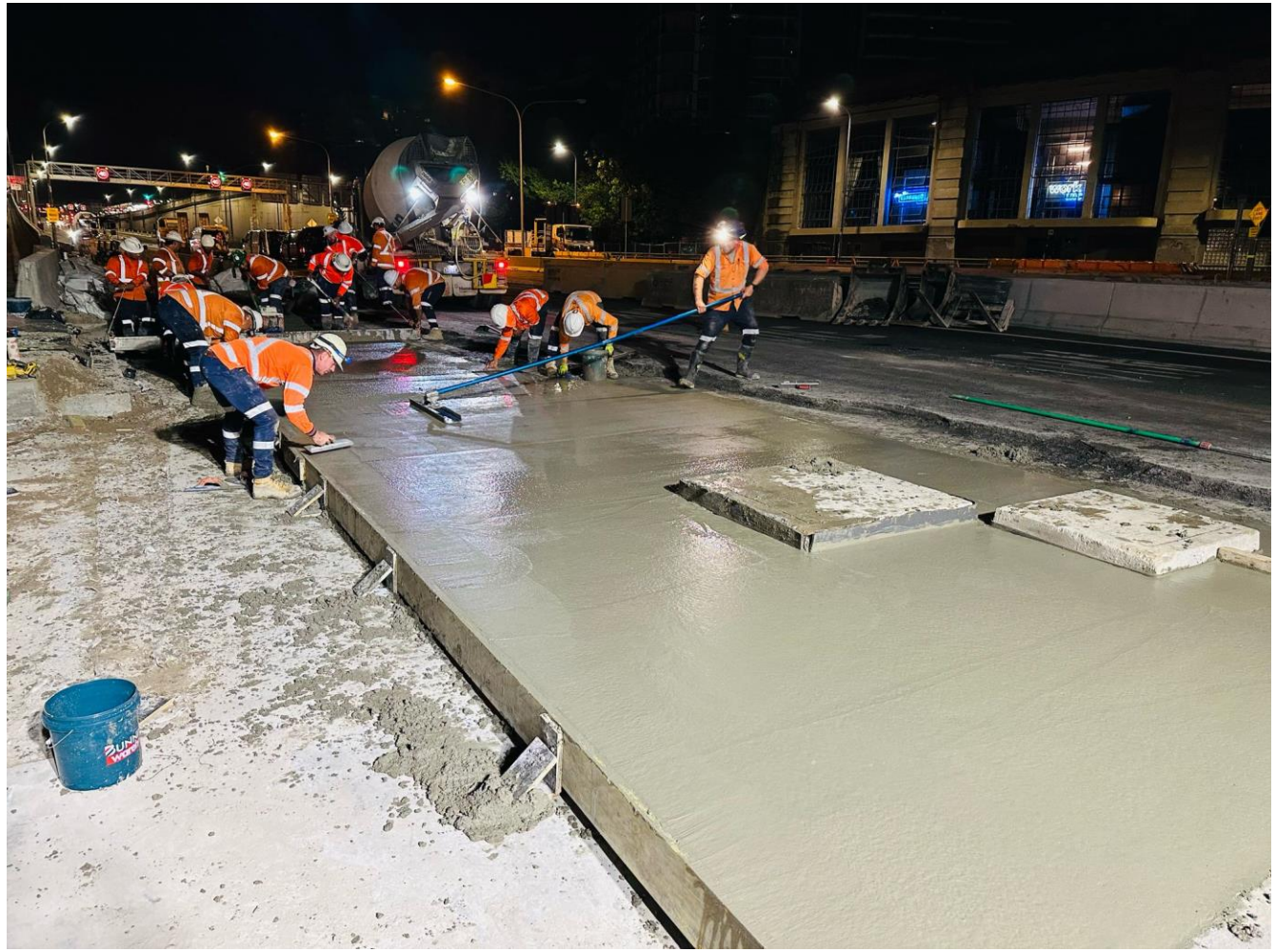

PER
GUNA

Construction phase

- Issues uncovered to date have been consistent with pavement widening projects:
  - Unknown pavement faults
  - Variable subbase quality, some erosion
  - Undocumented historic utility crossings
  - Existing infrastructure within pavement e.g. structural footings & utilities
  - Compromised (undocumented) practices in some areas

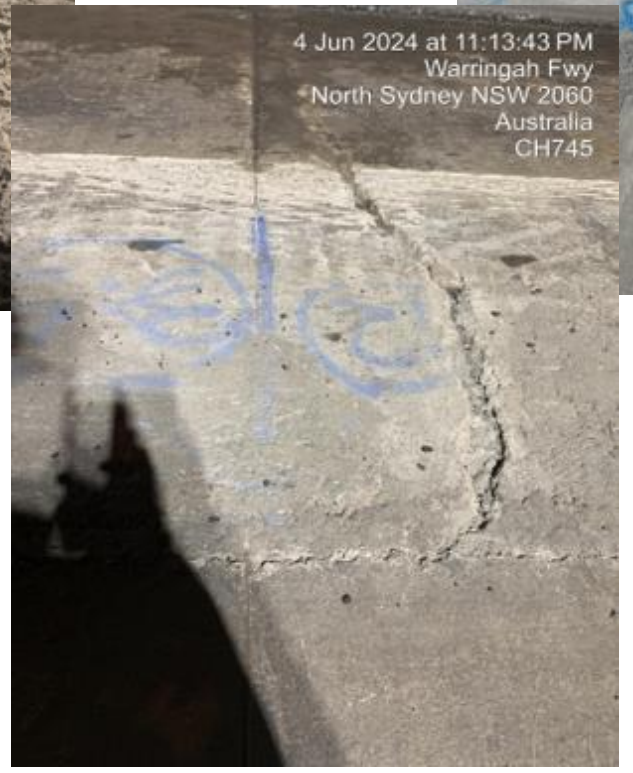
Construction phase

- Issues uncovered to date have been consistent with pavement widening projects(cont'd):
  - Existing jointing layout could only be accurately verified once milling had been completed.
  - Be careful what you wish for. Low level reflective cracking through AC regulation layer has restricted ability to confirm exact joint locations.
  - Inconsistent/undocumented asphalt overlay depths. Pavement level redesign on the fly.



Construction phase

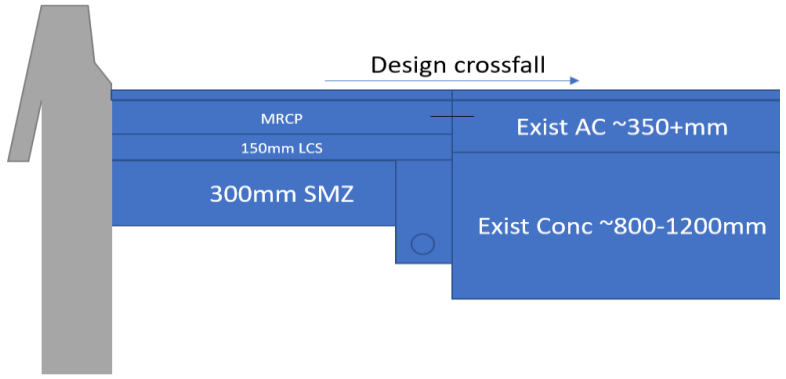
- Unknown pavement faults
  - Part & full slab replacements
  - Joint repairs & re-sealing



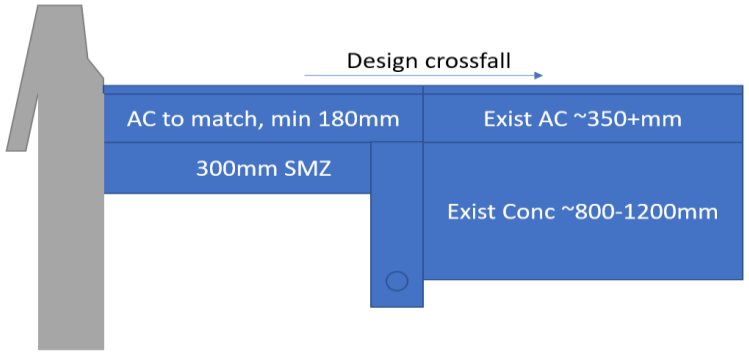
Unexpected surprises during construction

- Berry St On Ramp:
  - Design anticipated shallower AC & to tie into existing rigid pavement;
  - During construction revealed that the pavement profile was an existing AC thickness ~350mm over an overly thick concrete base ~ 800-1200mm thick in places;
  - Initially thought we'd expose a series of anchors, not so;
  - Changed pavement type to flexible.

Current Design for MRCP

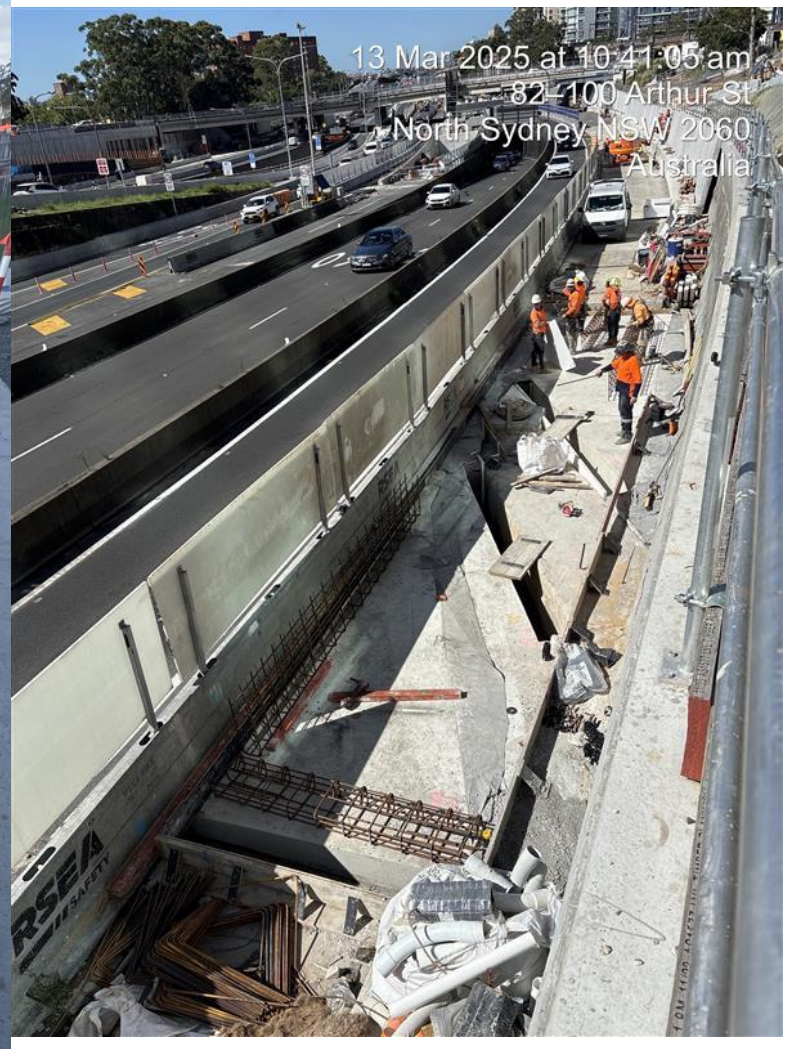


Proposed Design



Unexpected surprises during construction

- Careening Cove Culvert:
  - Careening Cove Culvert runs diagonally under Warringah Freeway, Nth Sydney;
  - Information indicated there was rigid pavements over and on approach to culvert;
  - When exposed only a thin layer of AC found over culvert;
  - Compromised pavement design incorporating existing condition required to be created to resolve problem.



Construction phase

- Warringah Freeway Upgrade Status:
  - 171 of 272 TMP’s implemented;
  - Structures 65% complete;
  - Drainage 65% complete;
  - Rigid pavement 55% complete;
  - On track for 2026 completion.

WARRINGAH FREEWAY UPGRADE
MRCP: Planned Cracks
Design Advice Note
Ver 6, 1/11/2024

DESIGN ADVICE NOTICE (DAN)

Subject: Proposed supporting information for WFU TfNSW Specification R83 to facilitate the WFU Contractors implementation of quality assurance for construction of MRCP pavements.

1. Purpose of DAN.

A significant component of the Warringah Freeway Upgrade (WFU) is the existing Mesh Reinforced Concrete Pavement (MRCP). The detailed design undertaken by the JAJV on behalf of CPBDTI mimics the existing design in pavement widenings and median infills.

MRCP does not fit neatly into any of the existing standard rigid pavement designs and treatments defined in TfNSW Model Drawings and Specifications, which are:

1. Plain Concrete Pavement (PCP),
2. Jointed Reinforced Concrete Pavement (JRCP),
3. Continuously Reinforced Concrete Pavement (CRCP), and
4. Steel Fibre Reinforced Concrete Pavement (SFCP).

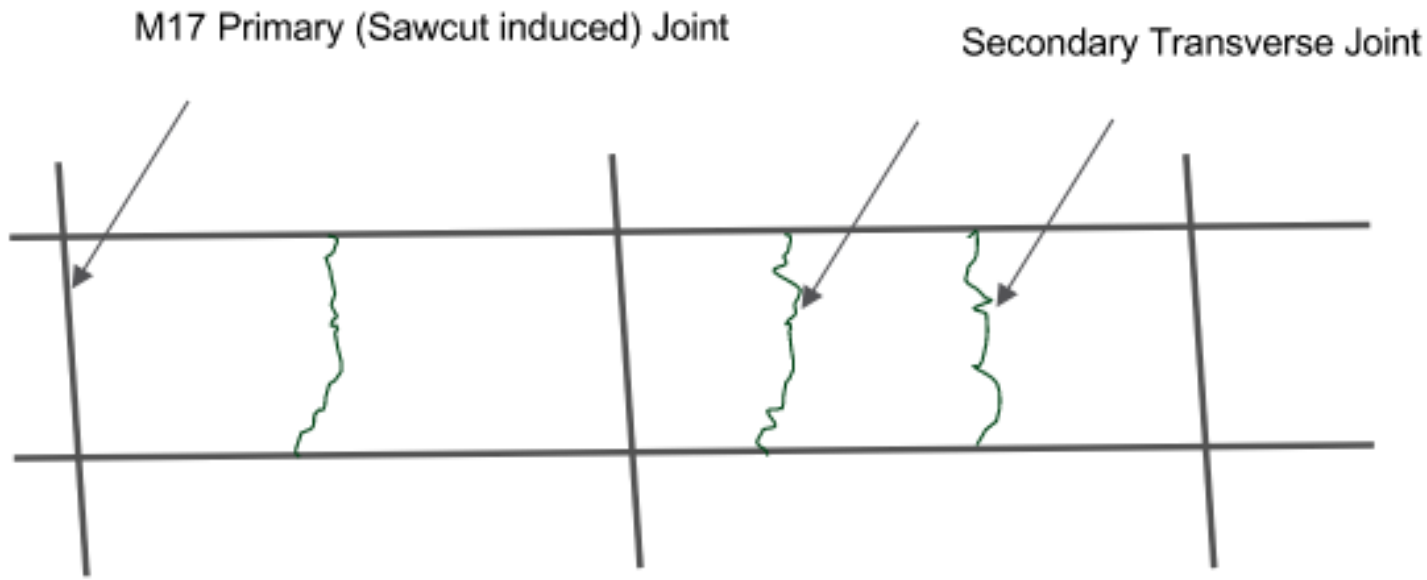
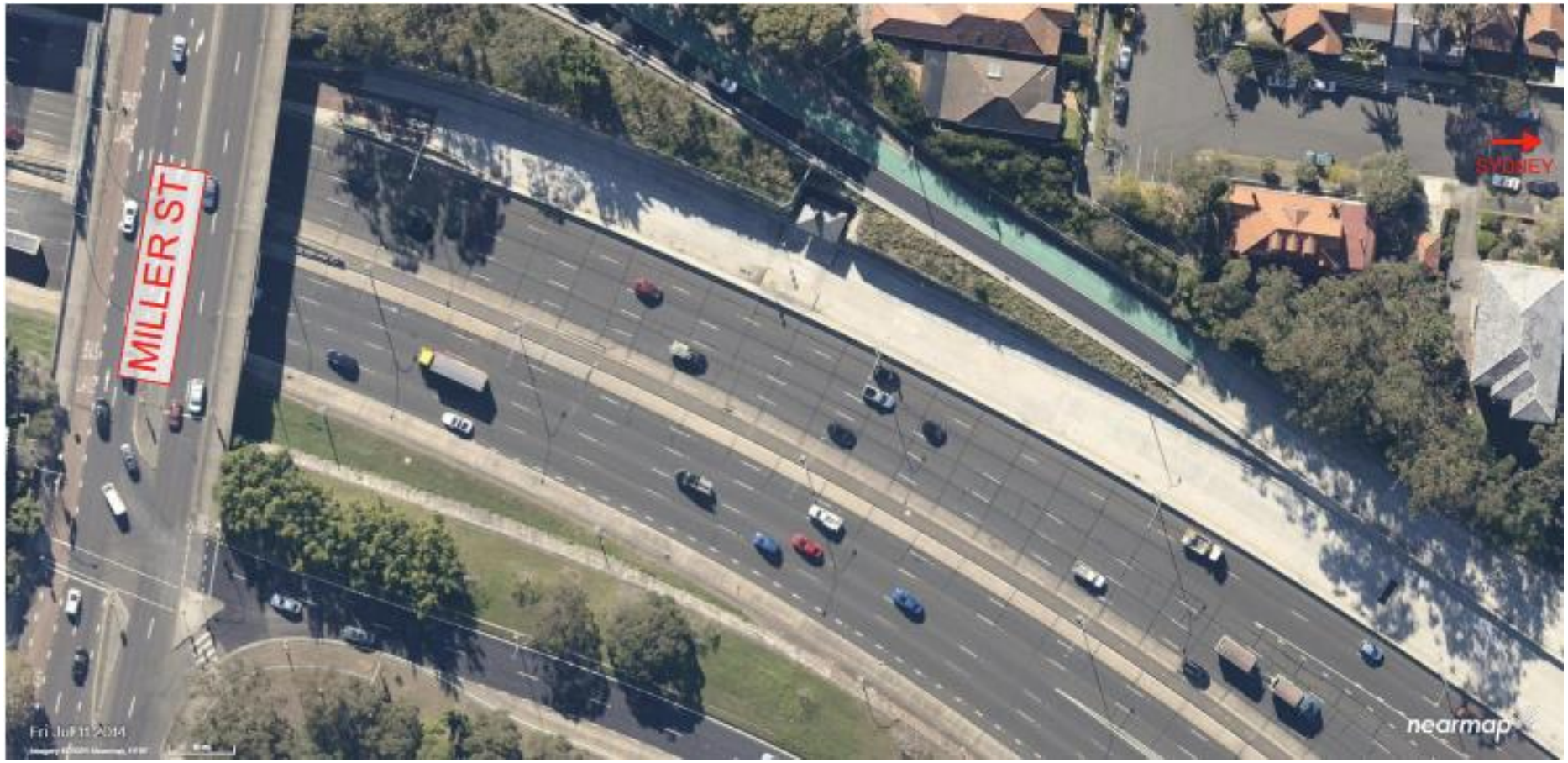


Figure 1: Typical MRCP jointing detail showing typical Primary and Secondary planned joints

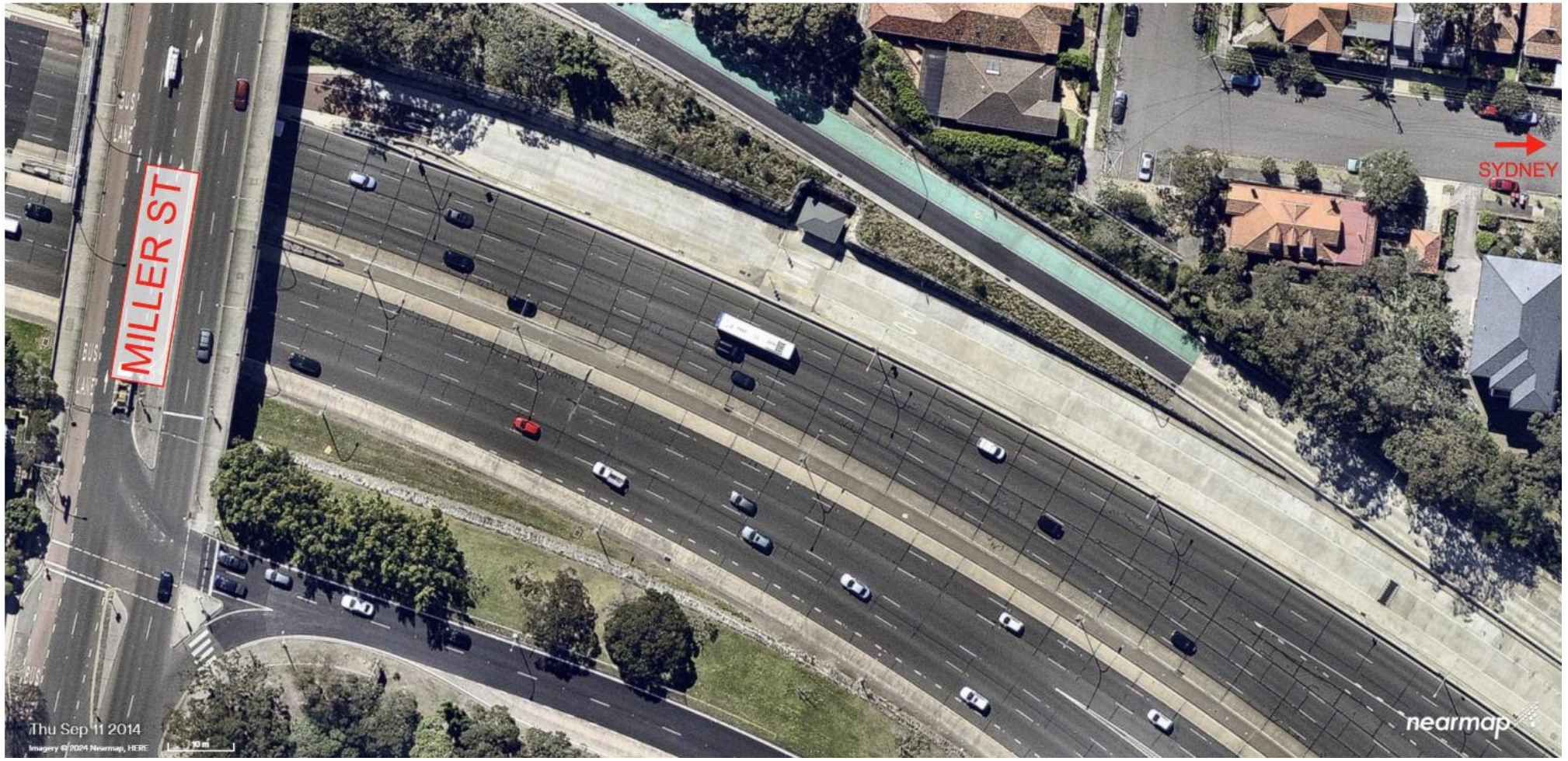
How Active/Dormant are MRCP Joints/Cracks?

14 Nov 2009: SB carriageway has been sawcut & sealed

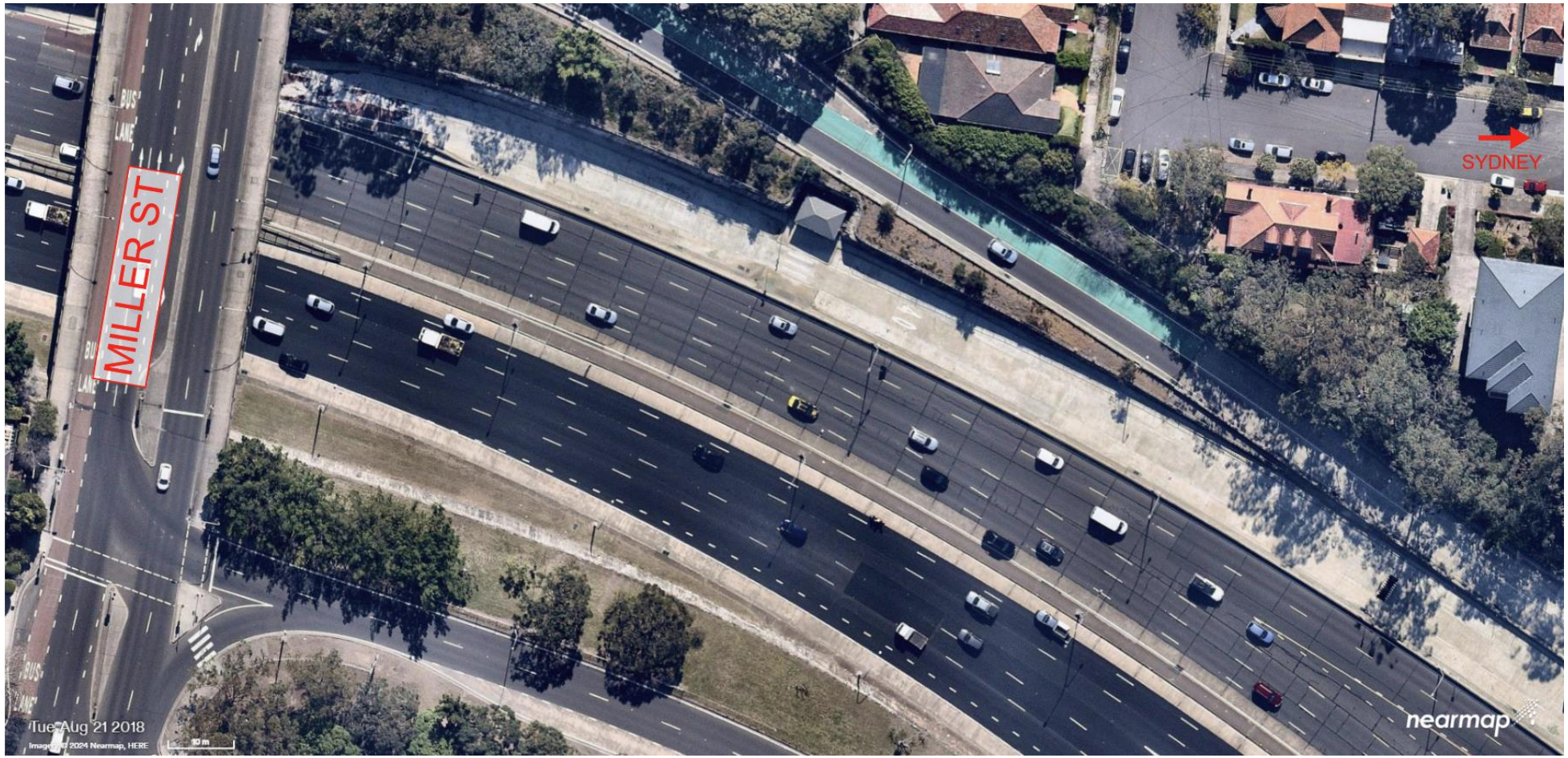
11 July 2014: No change, no maintenance for 5 years



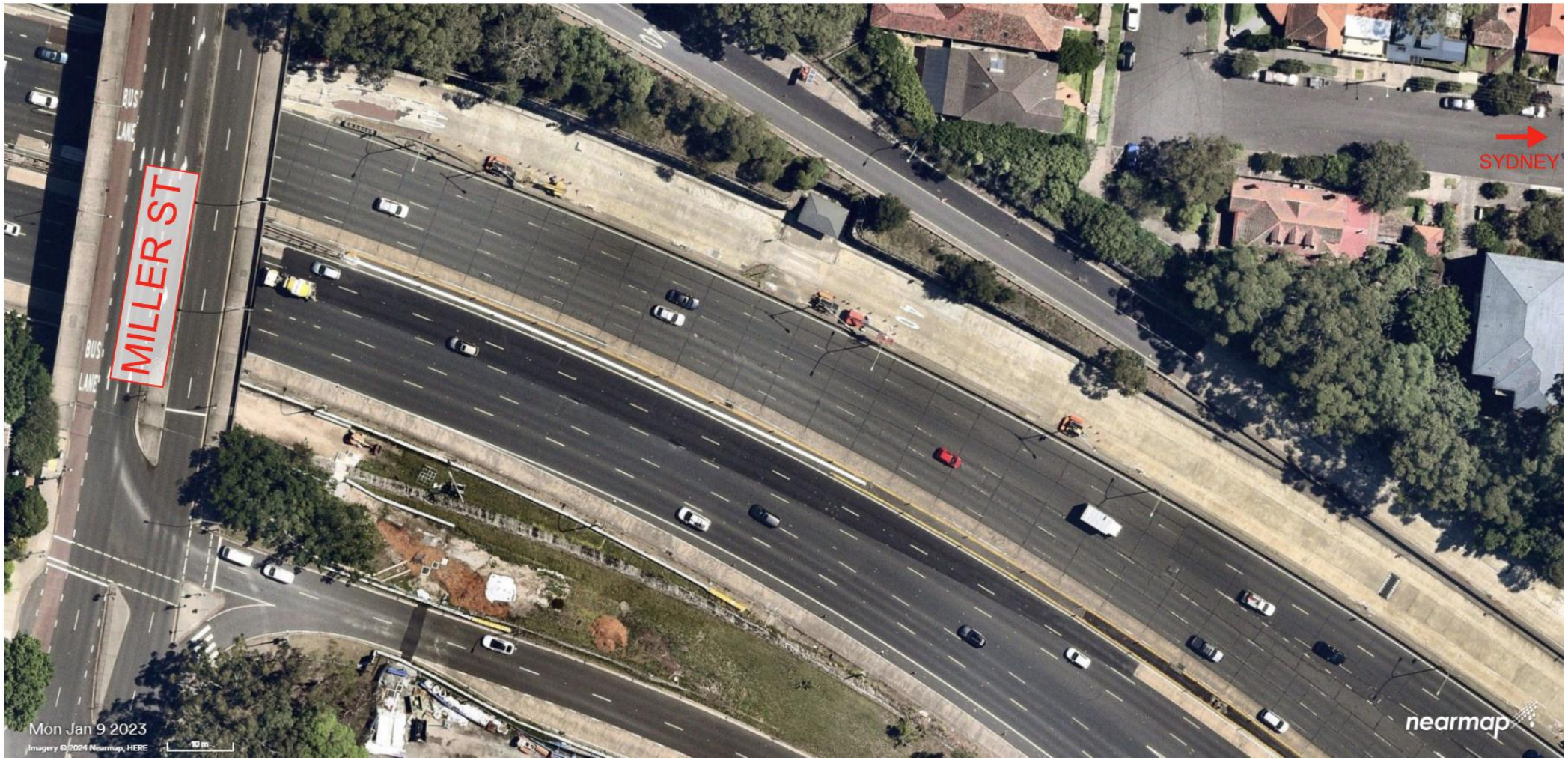
11 September 2014: NB carriageway has been sawcut and sealed



21 August 2018: NB carriageway has been milled and re-sheeted



9 January 2023: 5 years later NB carriageway has no evident reflective cracks and concrete shoulder milled and AC wearing course added



February 2024: >15 years after sawcutting and sealing the SB carriageway it has had no maintenance. 6 years after re-sheeting NB it has had 1 patch & is in good condition

Completion and Opening to Traffic 2026


CPB
CONTRACTORS
DT
INFRASTRUCTURE
A GAMUDA Company
JACOBS
ARCADIS
Thank you