AUSTROADS BRIDGE CONFERENCE 2025
Brisbane | 25-27 June 2025

Peer reviewed paper

To waterproof bridge decks or not

George Vorobieff, Head to Head International

Abstract

The common practice of waterproofing road bridge decks with a membrane and asphalt has been a common design approach for many decades. However, if older bridges with concrete decks performed well in rural areas, why does asphalt need to be used? Today, with better access to technology in Australia and the push for road agencies to procure more sustainable practices, it may be better to use concrete surfaces again, negating the need for asphalt as the waterproofing layer.

There are clear benefits of a concrete-wearing course, such as the concrete-coloured surface reflects more light, reducing energy costs for nighttime lighting, the exposed concrete surface absorbs carbon, and the minor reduction in dead load without asphalt slightly reduces member sizes for small-span bridges. The issues raised by designers of poor ride quality and skid resistance from an exposed concrete surface for the bridge deck can be easily overcome with conventional diamond grinding.

This paper explores conventional diamond grinding practices and highlights the application of diamond grinding on several road bridges on the Pacific Highway in northern NSW as an alternative to a bitumen membrane and asphalt surfacing to waterproof the bridge deck. It also provides practical design advice for use with the design drawings to allow asset managers to achieve long-term outcomes for a waterproof deck without the need for asphalt.

Keywords: bridges, waterproofing, diamond grinding, ride quality, sustainability

1. Introduction

The conventional approach in NSW for waterproofing highway bridge decks is to place a waterproofing membrane on the completed concrete deck and a thick layer of asphalt to protect the membrane and allow regular replacement of the asphalt wearing course. Another approach is to apply a sprayed seal wearing surface on the bridge deck. However, well-compacted and cured concrete should be sufficient to waterproof the bridge deck.

There is no mandatory requirement in AS 5100 for waterproofing membranes for concrete bridge decks.

This paper explores an alternative approach to waterproofing bridge decks using conventional diamond grinding applied to the finished concrete deck, thereby saving the requirement for membrane and asphalt layers.

In NSW, over a million square metres of conventional diamond grounding has been undertaken on concrete pavements between 2009 and 2022. Diamond grinding has also been applied to concrete pavements at airports, carpark ramps and dragways.

The paper will address the following:

- how diamond grinding is applied to bridge decks,
- the delivery of deck geometry, texture and safety requirements similar to using a waterproof membrane,
- explain the environmental benefits of an exposed concrete deck, and
- lessons learned from USA and NSW practices for this treatment type.

Although the author has worked on road projects in various jurisdictions in Australia, the focus of experience for this paper is NSW.

2. Waterproofing bridge decks

Waterproofing is defined in the Austroads Glossary of Terms as “The process of rendering surfaces or materials impervious to water” (Austroads, 2015). A waterproof membrane is simply a membrane applied to the concrete deck as part of several layers of materials, to achieve an overall waterproof layer from the road surface to the concrete deck surface. In Austroads Specification ATS 5350, a waterproofing membrane is the main part of a waterproofing system which is either a preformed waterproofing membrane or a liquid-applied membrane. Given that these membranes cannot be trafficked by wheels, asphalt surfacing is applied over the membrane. If these membranes do not adhere to the concrete deck, delamination of the membrane is likely to occur due to temperature effects or the braking force from heavy vehicles. If delamination occurs, it is unlikely that the concrete deck is still waterproof.

Figure 1 shows the typical composition of the waterproof membrane and asphalt wearing course on a bridge in NSW. Once asphalt is applied (see Figure 2), it must be thick enough to allow the asphalt wearing course to be milled without touching the membrane and a new asphalt wearing course is placed to replace the deteriorated asphalt.

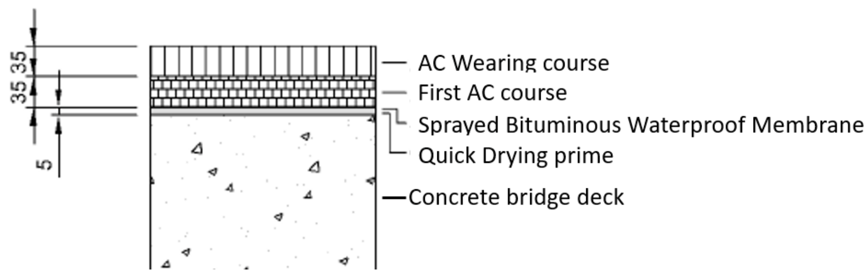

Figure 1: Typical bridge deck profile in NSW showing the various layers (TfNSW, 2016)

Figure 2: View of the completed waterproofing and asphalt treatment of a bridge deck with the concrete supporting and protecting the expansion joint

3. An alternative approach

In rural Australia, most concrete bridge decks have a concrete-wearing surface, as the source for a small quantity of asphalt makes it cost-prohibitive or impractical to have an asphalt-wearing surface. In some situations, a sprayed seal-wearing course is applied, as shown in Figure 3.

Figure 3: View of concrete deck with sprayed seal surface finish

So why does a well-compacted concrete with a conforming concrete mix design and with no cracking at the time of construction need a waterproof membrane? According to some bridge designers, bridge contractors can no longer cast-in-place concrete to the design requirements in concrete bridge specifications. Other engineers report that the hardened concrete surface is too rough for vehicles, or the surface texture depth is too low to allow it to become an effective wearing surface for bridges. However, there are many examples of exposed concrete bridge decks in NSW that are over 40 years old.

Low texture depth and poor ride quality can be easily resolved with conventional diamond grinding (CDG). CDG will not resolve poorly compacted concrete, but equally, this is nonconforming concrete and should not be accepted by the road agency. If minor plastic shrinkage cracking occurs, several proprietary sealants could be applied to the concrete cracks before and after diamond grinding (refer to CPTECH, 2022).

Conventional diamond grinding is undertaken using a specialised mobile plant with a long wheelbase and sufficient power (greater than 450 kW) to apply uniform pressure to the 1.2 m wide grinding drum.

The first bridge deck in NSW to have conventional (longitudinal) diamond grinding was at Bakers Swamp Creek, on the Mitchell Highway (see Figure 3), about 42 km north of Molong. A sprayed seal surface was applied, as required by the Bridge Branch (Roads & Traffic Authority, NSW). The rationale for CDG was to correct poor ride quality even though ride quality limits were set for the surface of the concrete deck before placing the waterproof membrane. After grinding was completed, a sprayed seal was applied.

The most extensive application of CDG on bridge decks occurred in 2020 with the grinding of 12 bridges on the Woolgoolga to Ballina (W2B) project on the Pacific Highway, NSW. The bridges consisted of Super T or wing planks prestressed girders with cast-in-place reinforced concrete deck superstructure and 2 to 3 spans, with the bridge length varying from 50 to 100 m. Figure 4 shows the finished grinding treatment and prominent line marking on the bridge just north of Glenugie.

Figure 4: View of CDG on the 4-span bridge to the SB carriageway of the Pacific Highway, NSW

The diamond grinding work was carried out by Seovic Civil Engineering using the same drum that would be used for typical concrete pavement diamond grinding.

It is noted that using a fine milling drum on a road profiler is not a substitute for CDG, as milling drums are likely to damage the expansion and other joints in the bridge deck.

Some engineers may be aware from USA literature that bridge decks are sometimes grooved, as shown in Figure 5. These grooves are typically 3.2 to 4.8 mm deep and approximately 2.5 mm wide, with a spacing of 19 mm centre-to-centre. In mostly cold climatic conditions, grooving is used on bridge decks as an effective method to increase traction, reduce hydroplaning and minimise splash and spray during heavy rainfall events (IGGA, 2020).

Figure 5: View of longitudinal bridge deck grooving (IGGA, 2020)

4. How has CDG been applied?

Conventional diamond grinding is a simple process of using a stack of standard 3.2 mm thick diamond-tipped blades spaced apart at 2.54 mm intervals by dedicated metal spacers (see Figure 6). The common drum width is a nominal 1.2 m, and 0.9 m drums are also used. The wider drum results in fewer passes required across the bridge deck and less overlapping strips.

To avoid any transverse steps and unground surfaces between grinding passes, the operator allows a 50 mm wide overlap to occur. This can be seen as light-coloured longitudinal strips in the photograph in Figure 7.

The diamond blades need water to keep cool, so cold water is used to cool them, forming a slurry behind the grinding drum. The slurry is vacuumed from the surface and temporarily contained in a large trailer tanker. The slurry is then generally disposed of in a temporary sediment pond to allow the excess water to evaporate, and a cementitious soft slurry is left in the pond. The inert dried cementitious slurry may be used in other applications when tested for chemical content, or otherwise, the pond is generally covered with soil.

Typically, the first grinding pass is on the high side of the bridge deck, and the last grinding pass is just past the edge lane line in the shoulder. The final pass is a feathering pass, where the angle of the drum is oriented to match the last pass grinding depth and the grinding depth tapers to zero in the wide shoulder.

On one of the 12 bridges on the Pacific Highway north of Grafton (NSW), the ride quality was measured before and after grinding, and the average lane IRI (International Roughness Index) of three passes of the laser profiler is listed in Table 1. The typical ride quality compliance for concrete pavements in NSW is 1.36 to 1.55 m/km over a 100 m length. The reduction in IRI before and after grinding was between 69% and 91%, with the average IRI on the bridge deck in the slow lane being 0.56 m/km, which is an excellent achievement.

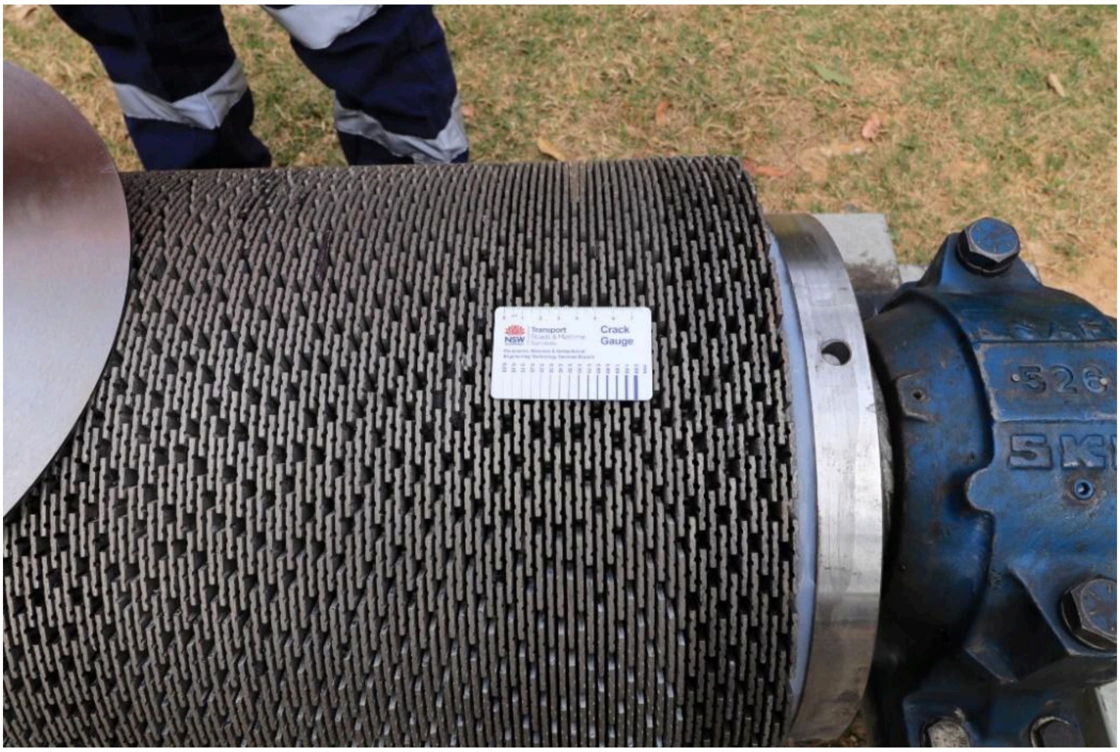

Figure 6: View of the grinding drum with the blades spaced 2.54 mm apart

Figure 7: View of narrow overlapping grinding passes and feathering in the kerbside shoulder

Figure 8: View of the suction devices (to the right of the drum) to collect the slurry from the concrete surface

5. Delivery of deck geometry, texture and safety requirements

Geometry

Road geometric design principles are applied to bridge decks, and the lane and shoulder widths are the same as those of the main carriageway. In addition, the typical 3% crossfall and the location of a crown (where applicable) is to match the pavement either side of the bridge. It is considered that the built-in camber of long-span bridges should not be a problem for the grinding operator (see Figure 4). However, CDG cannot be used to correct undesirable or significant bridge surface geometry noncompliance.

On a skewed bridge, the transverse joints will be skewed. The greater the skew, the more noticeable the staggered ends of the grinding pass will be, due to the width of the grinding drum containing the blades, as shown in Figure 6. A follow-up transverse pass parallel to the skewed joint is considered inappropriate as this may generate a bump for vehicles.

Table 1: Average ride quality measurements in the slow lane before and after grinding at 10 m intervals (Heathwood, 2020)

Chainage (m)	IRI before (m/km)	IRI after (m/km)	Reduction in IRI
0 -10	2.89	0.69	76%
10 – 20	2.55	0.80	69%

Chainage (m)	IRI before (m/km)	IRI after (m/km)	Reduction in IRI
20 – 30	2.57	0.31	88%
30 – 40	2.49	0.28	89%
40 – 50	2.91	0.25	91%
50 – 60	5.53	1.04	81%
Total average	3.16	0.56	82%

Texture

CDG produces a uniform texture (see Figure 7) along the grinding pass except at these locations:

- The concrete finishing is set lower than the surrounding area, resulting in a holiday or unground surface.
- The outside feathering pass (i.e. in the shoulder) where the surface has the grinding depth set from normal to zero.
- A small, staggered area of no grinding occurs on either side of a skewed transverse joint, as shown in Figure 9.

The area of holidays in the trafficable lane should be limited to 10% of the total area of grinding (excluding the feathering pass).

USA practices note that the spacing between blades is a function of the hardness of the coarse aggregates, with softer aggregates requiring a wider spacing of blades. The initial NSW experience was that the gap between the blades was set at between 2.79 mm (0.110”) and 2.92 mm (0.115”), and it was found that the fins of hard aggregates remained for many years, as shown in Figure 10.

Figure 9: A view of the CDG surface on a new bridge deck in Minneapolis, Minnesota

Figure 10: View of the coarse aggregate fins 10 years after grinding, when the gap between the blades was set too wide

For the last decade, the blade spacers have been set at 2.54 mm, which has resulted in a satisfactory surface texture for the typical use of hard aggregates in concrete decks and pavements in NSW. If soft, coarse aggregates are used in the concrete bridge decks, the concrete should be tested before proceeding with the CDG treatment.

Three key properties of surface texture are texture depth, skid resistance and ride quality. For CDG in the early days in NSW, single-point lasers were found to give unreliable readings for texture depth as the laser beam wandered from the bottom of the groove to the tops of the thins or the beam remained in the bottom of the groove, showing no texture depth. The alternative is a 100 mm wide beam that provides an average texture depth reading. In NSW, the typical texture depth of a CDG with a blade spacing of 2.54 mm is in the range of 0.5 to 1.2 mm.

The USA has established significant measurements of texture depth, and Figure 11 shows the mean texture depth of various concrete surface finishes for highways (Roberts, 2011). The typical texture depth for CDG is about 1 mm.

Skid resistance on NSW road surfaces is measured using the SCRIM (Sideways force Coefficient Routine Investigation Machine) vehicles of the same device installed on the Traffic Speed Deflectorgraph (TLD). The skid resistance from the TLD is reported as Side Force Coefficient (SFC) in the outer wheel path (OWP), inner wheel path (IWP) and the difference in the SFC between IWP and OWP values. The Somersby to Kariong project was completed in 2020 and most of the concrete pavement was a diamond grind to achieve smoothness. The 2023 NSW Network data indicated appropriate levels of skid resistance on this concrete surface, as listed in Table 2, and shows that CDG is effective in providing high values of skid resistance. These high levels have also been observed in the USA (Roberts, 2011).

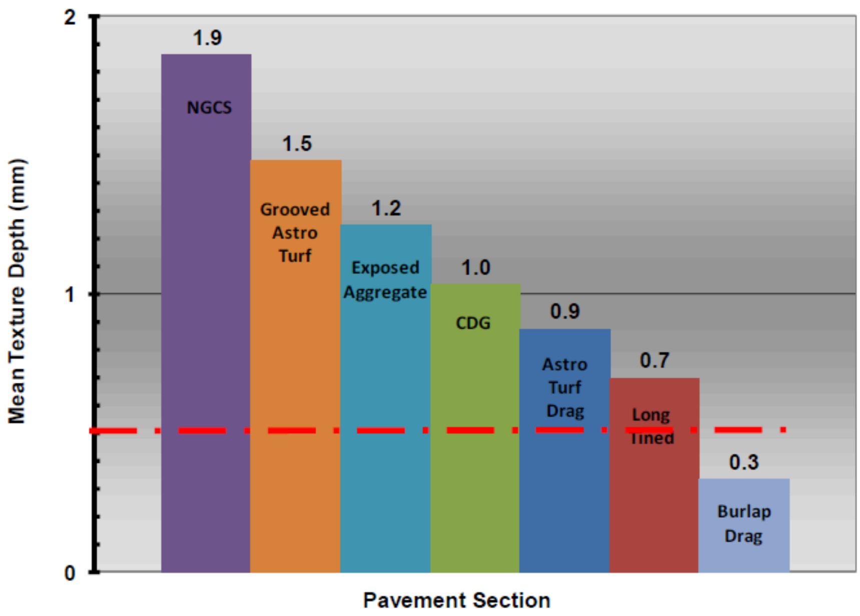

Figure 11: Mean texture depth for various concrete surface finishes (Roberts, 2015)

Safety

One of the critical safety requirements is for the crossfall to drain the water into small drainage pits to minimise the potential aquaplaning. However, if these pits are not maintained and free of debris, water ponding on the carriageway is likely to occur.

Uniform skid resistance is an important safety feature of CDG surfaces. For example, tolerances to the surface levels of the bridge deck should be achieved so that the area of holidays is minimal.

The USA research and results show that traffic accidents are lowered by the use of diamond grinding (Rao, et al 2001).

Table 2: SFC for OWP and IWP for the slow lane for the NB carriageway of the Pacific Highway, Kariong

	SFC OWP	SFC IWP	SFC Differential
Number of 100m segments	139	139	139
Lowest	24	36	2
Highest	80	78	22
Average	59.0	59.7	8.5
Standard Deviation (SD)	15.2	11.3	4.4
Average - 1SD	43.8	48.4	4.1

A smooth ride for road users on the main carriageway should also be attainable for bridge decks. A high IRI (i.e. greater than 1.55 m/km) for ride quality of a new bridge deck with a posted speed limit of 80 km/h or greater is considered nonconforming, and two thin layers of asphalt are not going to significantly reduce the IRI of a 'rough' bridge deck ride. The application of CDG by a competent contractor may be the IRI as low as 0.4 m/km. The ride quality test results at one of the bridges on the W2B project are detailed in Table 1.

Line Marking

The white dashed lane line marking may be hard to distinguish under some lighting conditions, and this issue was overcome some 15 years ago in NSW by placing two narrow black lines and then placing the white line between the black lines to give it contrast, as shown in Figure 12. In addition, a raised pavement marker is used between the dashed lines.

Figure 12: A view of the white dashed line over two black lines

6. Sustainable practices using diamond grinding

Concrete is sometimes, unfortunately, observed as an intensive greenhouse gas emission product due to the use of Ordinary Portland Cement (OPC). In Australia, that misunderstanding still needs to be corrected as a minimum of 25% fly ash is used in concrete bridge decks. Granulated blast furnace slag can also be used as a replacement for OPC without effecting durability and strength.

The obvious benefits of a concrete-wearing course are:

- the concrete-coloured surface reflects more light, a reduction in energy costs for nighttime lighting,
- the exposed concrete surface absorbs carbon,
- eliminate the use of a waterproof membrane, and
- the minor reduction in dead load without asphalt slightly reduces member sizes for small-span bridges.

The Portland Cement Association (USA) published a Roadmap indicating that the industry has a role to play in addressing climate change (PCA, 2021). Within the Roadmap, stakeholders are to work together to ensure that users of cement and concrete create a built environment that is actually sustainable. Table 3 lists the various objectives that could be embraced by road agencies and bridge designers that would apply to concrete bridge decks, with carbonation being specific to CDG.

Table 3: Goals to reduce greenhouse gas emissions for concrete bridge decks (Partial extract PCA, 2021)

Objective	Description of task
Optimise concrete mixes	Considering the specific needs of the construction project and using only the materials necessary, avoiding excess emissions.
Avoid overdesign and leverage construction technologies	Designing for the specific needs of the construction project reduces unnecessary overproduction and emissions; incorporating just-in-time deliveries.
Decreased maintenance	Due to their durability, concrete structures (buildings, pavements, bridges, dams, etc.) last longer and require less frequent maintenance.
Recycling	Concrete in place can be 100% recycled, limiting the use of raw materials and production emissions.
Carbonation	Every exposed concrete surface absorbs CO_2 and over the course of its service life, a building can reabsorb 10% of cement and concrete production emissions.
Educate design and construction community	Improve design and specifications to be more performance oriented which will permit innovation in cement and concrete manufacturing. Encourage the use of advanced technologies to improve structural performance, energy efficiency, resiliency, and carbon sequestration.

7. Lessons learned from projects

The USA has had decades of experience with the application of CDG on concrete bridge decks with the International Grinding and Grooving Association (IGGA) producing the following tips for CDG bridge decks (IGGA, 2022):

- Ensure tight line and grade controls when placing the concrete.
- Add additional concrete thickness to account for the sacrificial concrete removal during the grinding process.
- Reinforcing steel set improperly or at the incorrect elevation will cause problems during the grinding process.
- Inconsistent supply of uniform concrete (i.e. variable slump) during the placing of concrete process can result in low spots on the deck surface, making it difficult for the grinder operator to meet specifications.

Seovic also found the following improvements helped to achieve the desired outcomes (Seovic, 2021):

- Conduct ride quality testing before and after, as a guide for conformance.
- Conduct a surface survey before and after grinding on a 1.0 m grid pattern to establish the average thickness of concrete removed from the deck for the as-built drawings, and not for conformance.
- Place the surface of the concrete deck 10 mm higher than the surface of the (metallic) expansion joint to allow the grinding process to be continuous over joints.
- Grind to approximately 650 ± 25 mm of the concrete safety barriers or where practicable, feather in the shoulders.

General discussion amongst professional engineers about how much information should be included on the drawings or specifications continues. One view is to keep it simple to prevent any ambiguity for the contractor in the delivery of the works. As new Austroads specifications are produced to cover a broad scope of their use in the construction of roads, drainage and bridges; the specifications will rely on the design and delivery team to complete the project-specific requirements for the project.

As there are no Austroads specifications for diamond grinding, the current TfNSW specification R93 (TfNSW, 2020) should be used as an interim approach. However, the following details are required as notes on the pavement profile drawings or pavement notes sheet:

- Finish the wet concrete deck and approach slab surfaces with a coarse broom finish.
- Remove all debris from the concrete surface before the commencement of grinding.
- Conduct longitudinal diamond grinding 28 days after concrete placement or as specified by the Principal.

- The diamond grinding machine is to have a drum located between the front and rear axles and have sufficient mass to apply continuous and uniform pressure onto the minimum 900 mm wide drum. Due to the hardness of the coarse aggregates used in concrete pavement and bridges in NSW, the diamond tip blades are to be 3.2 mm wide and spaced 2.54 mm apart.
- The grinding equipment is to be equipped with a slurry capture device that is wider than the drum width. All slurry is to be collected and disposed of according to the contractor's Environment Management Plan.
- The first grinding pass is to be on the high side where there is a one-way crossfall or at the crown where a two-way crossfall exists.
- The full width of the lane plus an additional 200 mm past the outer edge of the lane line is to be diamond grind. Where the width of the shoulder is greater than 1.0 m wide, the shoulder grinding pass is a feathering pass.
- Where there is a transverse step along any edge of a grinding pass that exceeds 5 mm, the vertical edge is to be chamfered at 40^{0} to 55^{0} by a hand grinding unit.
- Milling or impact equipment is not permitted for use as it damages the concrete surface and joints.
- One or more broken blades are to be removed at the end of a grinding run.
- Where practical, place a 5 to 7 mm thick aluminium cover plate over the set-down expansion joint plates. The minimum length of this plate is the drum width plus 500 mm.

Similar to pavement construction practices, most modern specifications require the contractor to deliver thickness, levels and ride quality within the specified tolerance. Given that ride quality and minimum thickness are essential for bridges and pavements, where the contractor cannot meet levels in some areas of the bridge deck, the Principal may consider only relaxing the surface level requirements.

Rather than modifying an existing Austroads specification for CDG for concrete pavements, a dedicated specification should be prepared along with pay items and project-specific information for the contractor to deliver the design intent. In addition to the bridge deck specification, road agencies should prepare a set of standard drawings of acceptable CDG practices.

It is also noted that a recently restored concrete bridge deck in Minnesota (crossing the Mississippi River) had CDG, rather than asphalt, applied to the surface. As the bridge had a longitudinal curve, some of the expansion joints were skewed to the road alignment, resulting in staggered ends to the grinding passes (see Figure 9). The photograph shown in Figure 9 also shows the typical line marking arrangement in the USA for lane delineation, that is a white line painted over two narrow black lines (see Figure 12). This line marking feature enhances the contrast between the grey concrete colour and the white pavement marking.

8. Conclusions

The use of a waterproofing membrane for concrete bridge decks appears to be a default treatment in NSW, as designers have low confidence that the contractor can place the hardened concrete without plastic shrinkage cracking occurring. The use of exposed concrete bridge decks in rural NSW is prevalent where asphalt is not practical, and the same design of bridge life is required. In addition, there is no mandatory requirement in AS 5100 for waterproofing membranes for concrete bridge decks.

A concrete surface with conventional diamond grinding provides skid resistance and surface texture depth. The light surface appearance also reduces road lighting requirements, plus a concrete surface reflects heat, unlike an asphalt surface.

Where the bridge deck becomes a rough surface after construction, a thin layer of asphalt is unlikely to achieve ride quality improvements, whereas diamond grinding allows a smoother road surface to be achieved. Low IRI values (i.e. 1.0 m/km) on bridge decks translate into lower dynamic axle loads from heavy vehicles.

The delineation of dashed white lines on the light coloured concrete surface can be resolved with the use of black lines under the white lines and the use of raised pavement markings.

Diamond grinding can be expected to last as a durable surface for over 20 years, is more environmentally friendly and provides a safe driving surface. In the opinion of the author, the bridges that have been subject to diamond grinding and discussed in this paper, demonstrate that waterproofing using a membrane and asphalt is no longer a default treatment for bridge decks.

9. References

AS 5100.1 (2017), *Part 1: Scope and general principles*, Australian Standards, Sydney, NSW.

Austroads (2023), *Waterproofing of Concrete Bridge Decks*, Austroads Technical Specification ATS 5350, Sydney, NSW.

CPTECH (2022), *Evaluation of Penetrating Sealers for Concrete*, IHRB Project TR-765, National Concrete Pavement Technology Center, Iowa State University, Ames, Iowa, USA.

Heathwood, M (2021), *W2B in the rear-view mirror*, ASCP Conference Proceedings, xxx.

IGGA (2020), *Comparison Between Diamond Grinding vs. Carbide Milling for Surface Restoration*, International Grooving & Grinding Association, West Coxsackie, NY, USA.

IGGA (2021), *Bridge rideability*, International Grooving & Grinding Association, West Coxsackie, NY, USA.

IGGA (2022), *Tips for diamond grinding bridge decks*, International Grooving & Grinding Association, West Coxsackie, NY, USA.

PCA (2021), *Roadmap to Carbon Neutrality*, Portland Cement Association, Washington, DC, USA.

Rao, S, Yu, H.T and Darter, M.I (2000), *The Longevity and Performance of Diamond-Ground Pavements*, Research & Development Bulletin RD118, Portland Cement Association, Skokie, Illinois, USA.

Roberts, J (2011), *The Next Generation Concrete Surface*, Roads & Traffic Authority (RTA) Pavements Conference, Sydney, NSW

Seovic, J (2021), Private meeting notes with George Vorobieff, Sydney, NSW.

TfNSW (2016), *Pavement Standards Drawings 0-981-RV-01*, Woolgoolga to Ballina Upgrade, Pacific Highway, Transport for NSW, Grafton, NSW.

TfNSW (2020), *Diamond Grinding of Concrete Pavement*, R93 Specification, Transport for NSW, Sydney, NSW.

Acknowledgments

In preparing this paper, I would like to thank John Roberts (IGGA) for his review of the paper. I would also like to thank Jason Seovic for doing an excellent job diamond grinding the 12 bridges on the Pacific Motorway project north of Grafton, NSW and Michael Heathwood (Laing and O'Rourke) for his professionalism in making CDG a reality on the Pacific Motorway bridges.

Author contacts

George Vorobieff, Head to Head International, Subject Matter Expert on Concrete Pavements

vorobieff@headtohead.com.au, LinkedIn https://www.linkedin.com/in/george-vorobieff-aa6231120/

FIEAust CPEng NER APEC Engineer IntPE (Aus)

PO Box 6001, Narraweena NSW 2099