Transport Roads & Maritime Services

Technical Guide

Grinding Concrete Pavements

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About this release

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1. Introduction

This document contains information for the successful application of diamond grinding of concrete pavements. The requirements for diamond grinding of newer concrete pavements are set out in Roads and Maritime specification R93. The requirements for maintenance diamond grinding of older concrete pavements, particularly in urban areas, are set out in Roads and Maritime specification M229. A list of diamond grinding and associated road specifications is listed in Table 1 (Section 4.4).

Specification R93 has been prepared for projects involving construction of slipformed concrete pavements and where diamond grinding may be required over a significant length of pavement. It may be used for single or multiple lane grinding. Specification R93 is less suitable than M229 for use for diamond grinding of very old jointed reinforced concrete pavements in urban areas.

Specification M229 has been prepared for maintenance diamond grinding of concrete pavements that have been in service for a number of years and which are providing a reduced level of service. These concrete pavements include plain concrete pavement (PCP), discrete reinforced slabs within PCP (PCP-R), jointed reinforced concrete pavement (JRCP), continuously reinforced concrete pavement (CRCP), and steel fibre reinforced concrete pavement (SFCP).

A typical grinding machine used in Australia is shown in Figure 1. The grinding drum is between the front pivoting bogey wheels and rear axles, with the engine and water tank at the rear of the vehicle. In addition, some machines have optional magnetic strip collectors (see Figure 2) in front of the grinding drum to collect metallic debris and prevent damage to the blades. The diamond grinding drum consists of numerous blades clamped together with spacers as shown in Figure 2.

Sections 9 and 10 of this guide provide more information on the application of diamond grinding for reducing surface noise and improving ride quality in tunnels. Roads and Maritime is preparing a specification for producing a low noise diamond grinding surface.

Diamond grinding has been applied on asphalt surfaces and runways have had transverse grooves applied for increasing the surface texture. This guide does not include information on grinding asphalt surfaces.

Figure 1. View of a diamond grind machine with a nominal 1.2 m wide grinding drum used on road pavements in Australia.
(Photo courtesy of Seovic Civil Engineering)

Figure 2. View of a magnetic collector in front of the grinding drum (left), and grinding drum showing numerous blades (right).

2. Purpose of grinding

The main purpose of applying diamond grinding to newly constructed or existing older concrete pavements is to improve ride quality (refer to Section 7). Other benefits of diamond grinding are:

a) Surface profile correction,

b) Restoration of proper surface drainage,

c) Provision of surface texture, and

d) Tyre and road interface noise reduction from joint and crack stepping and coarse surface texture.

Although micro-milling may restore surface texture, the process of micro-milling causes damage to formed and sealed concrete joints. Also, the dust left behind during micro-milling takes about 7 days to be removed from the surface even with constant trafficking of the pavement. Micro-milling is not a replacement for diamond grinding.

Roads and Maritime has adapted the USA experience where diamond grinding technology can be used to further reduce tyre road noise emissions. This next generation grinding technology is discussed briefly in Section 9.

3. Definitions

Definitions of typical terms used to describe the grinding and grooving process are listed below (refer also to Clause 1.3 of specifications R93 and M229). Additional definitions relating to concrete pavements are listed in specification R83.

Approach sections	Pavement which is located within 15 m of bridges (or other structures) where the concrete base is discontinuous, or within 15 m of contract limits.
Dogtails	The portion of the surface which has not been grinded, due to a lack of horizontal overlap between two consecutive passes.

Drum hopping	A trough(s) created in the surface by one or more dips of the drum during grinding (see Figure 12).
Feathering	A tapering of the grooves to a nominal zero grinding depth at the nominated boundary to the specified extent of grinding (see Figure 6).
Fin	The raised portion of concrete left behind after grinding (see Figure 4).
Fin width	The width of the raised portion of concrete left behind after grinding.
Grinding depth	The depth of concrete material removed, determined from the difference of height between the concrete surface before grinding and the lowest point in the groove.
Groove	Process used to cut transverse or longitudinal slots into a concrete pavement.
Grooving	Process used to cut transverse or longitudinal slots into a concrete pavement.
Hidden object	Any 'objects' not visible to the naked eye and requiring identification by means of a 'location device' or metal detector.
Holidays	Ungrinded areas resulting from isolated low spots (see Figure 5).
Joint slapping	Noise created from tyre 'slapping' against a stepped concrete transverse joint. Slapping may also be caused by stepped transverse cracks.
Location device	Device capable of identifying 'hidden objects' using a non-destructive technique, specifically a metal detector (or equivalent) for metal objects.
Object	Metal objects, utility service pipes or conduits, old tram tracks, etc.
Slab	A portion of concrete bounded by joints and/or edges.
Slab anchor	A restraining beam cast in the ground, on which a base slab is later cast.
Slab jacking	Raising of a slab, to minimise stepping at joints or cracks.
Slab stabilisation	Restoring support to concrete slabs by filling small voids.
Trafficked slab	A slab bounded by longitudinal joints which lies either totally or in part within the trafficked carriageway as defined by lane lines.

Refer to Figures 4 to 7 for photographs taken from completed diamond grinding work illustrating some of the terms.

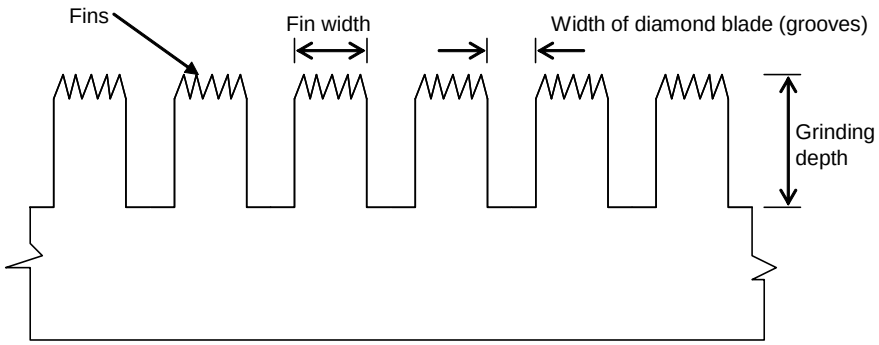

Figure 3. Diagrammatic view of a grinded surface showing the grooves and raised fins at the time of grinding.

Figure 4. Grinded surface showing raised fins.

Figure 5. View of holidays

Figure 6. Edge feathering

Figure 7. View of overlapping of surface after grinding two adjacent runs.

4. Background to specifications

4.1 R93 for new pavements

The first edition of R93 was based on the Georgia Department of Transportation Specification 431 (January 1998) with various changes to reflect Australian experience with diamond grinding applications, and advice from the International Grinding and Grooving Association (IGGA).

Experience on diamond grinding in Georgia has led the Georgia Department of Transportation to specify the following requirements for diamond grinding machines in order to meet the requirements in their specification:

- The grinding machine must have a set of pivoting tandem bogey wheels at the front of the machine, and the rear drive wheels must be positioned to travel in the track of the freshly cut pavement.

- The effective wheel base of the grinding machine, which is the distance from the centre of the front pivoting bogey wheels to the centre of the rear tandem axles, must not be less than 3.6 m.
- The centre of the grinding head must be located no further than 900 mm forward from the centre of the rear tandem axles.
- The minimum power of the equipment must be 522 kW (700 hp).

4.2 M229 for maintenance

Specification M229 is based on Specification R93, but has been amended to deal with conditions that are specific to diamond grinding of older concrete pavements that are typically found in urban areas. Although M229 can be used for diamond grinding of plain concrete pavement (PCP), discrete reinforced slabs within PCP (PCP-R), continuously reinforced concrete pavement (CRCP), and steel fibre reinforced concrete pavement (SFCP), it is particularly aimed at diamond grinding of jointed reinforced concrete pavement (JRCP) which is widely found in urban areas.

4.3 R94 for low noise tyre emissions

Road and Maritime has prepared a draft specification to apply a grooved surface to new concrete pavement that has low tyre noise emissions. This draft specification is based on R93 and includes clauses to construct either one or two passes of diamond grinding. The first pass, when specified is a flush grind and the blade spacing is set at a narrow spacing of 0.9 mm compared to the current blade spacing of 2.5 to 3.0 mm. The goal of this treatment is to not create any fins and to limit the ridge formed between blades during grinding. More information about the grinding process is detailed in Section 9.

Specifications R93 and M229 are not applicable for the low noise diamond grinding technology.

4.4 Related specifications

Diamond grind work is typically associated with other maintenance or rehabilitation activities and Table 1 lists those specifications that are commonly used with diamond grinding pavements.

Table 1. Related specifications used with diamond grinding activities.

Number	Title	Comments
R83	Concrete Pavement Base	Application of sealants to joints and rectification for poor ride quality.
R101	Cold Milling of Road Pavement Materials	Removal of an asphalt layer using milling equipment.
R141	Pavement Marking	Application of line marking on bituminous and concrete surfaces
M213	Cross Stitching of Cracks and Joints (Concrete Pavement)	Maintenance of cracked concrete base by cross-stitching
M214	Repair of Joint Seals in Concrete Pavement	Replacement of silicone seals in joints
M215	Repair of Surface Spalls in Concrete Pavement	Repair of sapped cracked and sawn joints
M231	Pressure Grouting for Slab Jacking / Stabilisation	Lifting of concrete slabs using conventional injection grouting
M232	Injected Expanding Foam Slab Jacking / Stabilisation	Lifting of concrete slabs using expanding foam injection

5. Construction practices

5.1 General

This section of the guide outlines current best construction practices for diamond grinding concrete pavements:

- The selection of the number and spacing of diamond blades.
- How to apply grinding runs?
- Overlapping runs.
- When to seal or reseal joints?
- Collection and disposal of slurry residue.
- Texture depth
- Management of hidden objects
- Pavement marking
- Reinforcement steel and traffic
- Proximity to kerbs and F type barriers
- Understanding the impact of climatic conditions

5.2 Number and spacing of diamond blades

The number of diamond blades must be determined by the contractor and detailed in the Project Quality Plan to achieve the requirements in the contract. Diamond grinding blades and spacers are manufactured overseas and are specified in inches. The most common blade width is 3.175 mm (0.125 inches). Spacers vary in width and in NSW, contractors are typically using 2.67 mm (0.105 inches) wide spacers for hard coarse aggregates and it appears that the fins are remaining longer than expected compared to US experience (refer to Figures 8 and 9). Therefore, a blade spacer width of 2.54 mm (0.100 inches) is preferred and this creates a corduroy surface finish as shown in Figure 10. The width of spacers must be such as to minimise tall fins left standing after grinding.

Figure 8. Surface of diamond grinding surface on California highway.

Figure 9. View of fins remaining on the surface of the M1 Motorway after 2 years of trafficking.

Figure 10. Surface of diamond grinding surface with the blade spacing set at 0.1 inches.

Grinding wears out both the blades and spacers. At the end of the blade life both the spacers and blades are replaced along the full width of the drum.

Some blades may wear unevenly or some may become damaged from impacting hidden objects, such as steel reinforcement just below the surface. The end result is that some blades may become considerably shorter than the rest. In general, if a blade is more than about 2 mm diameter smaller than the adjacent blades, remedial action is required. This remedial action may be in the form of stopping grinding and replacing the offending blade(s) or restacking the grinding head so there is no visible step.

The diamond grinding process leaves fins as the depth of grinding increases and these normally become dislodged after trafficking of the pavement. The fins may remain for a considerable time after trafficking before they break off, due to the hardness of the coarse

aggregates in the concrete or wide blade spacing, as shown in Figure 9. The specifications limit the fin thickness to 2 to 3 mm to ensure that contractors do not unfavourably reduce the number of blades on the drum.

Continuous tall fins may occur when grinding, which is undesirable. It may only be a single line or a few lines of fins. This is caused by debris being wedged between the blades. Remedial action is required which may take the form of stop grinding, lifting up the grinding drum, and plucking out the debris from between the blades.

5.3 Grinding runs

The number of runs required to cover the specified area may be detailed in the specification Annexures or determined by the contractor.

Although specification M229 specifies that grinding must be square across the entire lane at the start and end of the work completed during each shift, there is scope to vary this requirement to allow grinding in long continuous passes by completing Annexure A for a particular work site.

Careful planning of runs is required to ensure feathering of the grinding at the edges of the pavement, to prevent the development of longitudinal steps in the concrete surface after grinding.

For concrete pavements that have designated road shoulders, transverse feathering is not permitted in the traffic lanes. Where feathering is required, it must be carried out in the road shoulders. However some older concrete pavements may have shoulders constructed with asphalt or sprayed seal surfaces. While older asphalt surfaces may be grinded successfully for the purpose of feathering, sprayed seal shoulders should not be grinded.

5.4 Overlaps

Clause 3.1.4 of specification R93 and Clause 4.1.9 of specification M229 state that overlapping runs must not be carried out over longitudinal joints (see Figure 9). This is to avoid the potential spalling of joints or the formation of steps at the joint that may impact on resealing the joint reservoir or damage the seal in the existing joint.

The edge of the overlap may occur adjacent to the edge of the longitudinal joint, or as shown in Figure 11, such that the overlap is near or in the same area as the lane markings. In some instances, where permitted by the Principal, some overlap may occur over the joint to accommodate the situation where the longitudinal joint does not run parallel to the lane markings, or where a narrow overlap width would be less beneficial than an overlap on the joint.

In some instances the Principal may allow a wider overlap for a specific road site, and this will be indicated in Table R93.A2 of Annexure R93/A or Table M229.A2 of Annexure M229/A.

At tapers or merging lanes, the overlap is increased to allow for the grinding equipment to gradually steer in these regions and minimise stepping.

When determining the area for feathering of grinding, the width will include up to the edge of the feathering (which will have zero grinding depth).

It is thus best to locate the feathering run in the shoulder, or within existing pavement, and this will require the reinstatement of pavement marking.

Figure 11. Overlapping run adjacent to the longitudinal joint on PCP.

Particular consideration of the longitudinal edge when grinding on ramps is needed to prevent the development of stepping at 'high spots' in the concrete.

Modern grinding machines only permit grinding to within approximately 600 mm to the edge of the kerb or raised median (see Figure 12). Areas adjacent to any medians or lips of gutters and areas which are inaccessible to grinding by the contractor's primary equipment, must be grinded using a secondary process. The secondary process must also use diamond grinding equipment to achieve surface characteristics identical to that achieved with the primary equipment. Impact methods such as milling or profiling are not permitted as a secondary process because these methods cause damage to the concrete.

Figure 12. Conventional grinding equipment can only get to 600 mm to the edge of the kerb.

One Australian contractor has manufactured a device as a special attachment to the conventional diamond grinding machine to allow grinding to within 100 mm of the edge of the kerb, as shown in Figure 13.

In some instances the steering of the grinding around terminating raised medians is acceptable as shown in Figure 14.

Figure 13. Grinding can be carried out close to the edge of the kerb with an attachment to the equipment.

Figure 14. The grinding patch curves to match the raised median.

5.5 When to seal or reseal joints?

Specifications R93 and M229 do not include the permanent sealing of joints as this may be covered under a different specifications, such as R83 or M214. However diamond grinding may damage existing seals and the extent is difficult to estimate before the start of grinding operations. Therefore, sealing is carried out after grinding.

Temporary sealing is required in R93 to limit the amount of residue that may flow into the joint leading to possible lockup of the contraction joint. In some cases bitumen emulsion is used for joint resealing and crack sealing older concrete pavements after grinding, and the poor application of the sealant could leave the sealant proud of the grinding as shown in Figure 15, and cause a joint slapping noise.

Figure 15. A bitumen emulsion seal poorly applied after grinding.

The limited experience with low noise diamond ground indicates that sealing should take place prior to grinding and grooving. If sealing is carried out after grooving it is difficult to shape the silicone in the reservoir resulting in poor application.

5.6 Collection and disposal of slurry residue

Specifications R93 and M229 require the contractor to collect the slurry residue after grinding.

For diamond grinding carried out in rural areas, if sufficient space is available, and if agreed to by the Principal, the contractor may construct temporary ponds at its own cost for the short-term storage of the residue on site. If the Contractor proposes to use this approach, it is important that this is raised at the pretender meeting, so that an appropriate cost allocation can be determined.

Figure 16. The construction of slurry settling ponds used on the M1 project in 2010.

Alternatively, settling ponds at the mobile batch plant on the construction site may be used for this purpose.

For diamond grinding carried out in urban areas, the slurry is collected and removed from site as the work progresses.

The wet slurry residue, either directly from the tanker or from the temporary ponds, must be disposed of in a manner that meets the site requirements, and NSW Environmental legislation.

It is accepted that some traces of residue may remain within the grooves in the pavement even after suction.

Currently a review of the reuse or application of the slurry is being considered by Roads and Maritime.

5.7 Texture depth

Measurement of texture depth is included in the specifications to ensure that large areas of the pavement (not including holidays and feathering) are not simply lightly skimmed by the diamond grinding blades. The texture depth that is achieved is a function of the depth of grinding and width of diamond grinding blades and spacers.

The minimum nominal depth of grinding is 3 mm, as grinding at a lesser target depth is likely to create a large percentage of holidays. If the extent of holidays is unacceptable during the evaluation of the trial, increase the nominal grinding depth by 1 to 2 mm. In the case of maintenance diamond grinding using specification M229, any increase in nominal grinding depth is subject to the maximum total depth of grinding not being exceeded.

The theoretical texture depth of the specified grinding pattern varies between approximately 0.45 to 1.45 mm.

The forward speed of the grinding machine is a balance between maintaining a suitable production rate and eliminating ‘drum hopping’ as shown in Figure 17. If the grinding results in over grinding (including ‘drum hopping’), this area cannot be included in the texture depth measurements and is nonconforming if the depth in the trough is greater than specified.

Figure 17. Nonconforming troughs in the surface caused by 'drum hopping.

5.8 Hidden objects

It is important that all users of specifications R93 and M229 have a clear understanding of the risk allocation in relation to 'hidden objects'. It is envisaged that:

a) the Principal will provide details of 'hidden objects' in Annexure R93/A or Annexure M229/A (as applicable to the contract) based on enquiries to Public Utility Authorities, examination of Work-as-Executed drawings and any other reasonable enquiries which the Principal has undertaken before tenders are invited.

b) The contractor has undertaken a metal detector survey, or equivalent, to locate the positions of the items nominated in Annexure R93/A or Annexure M229/A (as applicable to the contract) as well as any other items which have not been nominated (e.g. old tram tracks) but which should have been detected by a well executed survey.

c) If hidden objects which have not been disclosed by reasonable enquiries and detection surveys are nevertheless encountered, the contractor is entitled to submit a claim for time and costs.

5.9 Pavement marking

Specifications R93 and M229 specify that the over lapping of grinding runs is kept to a width of 50 mm to ensure uniform texture is maintained across the pavement. Where possible, grinding overlaps should be at lane line locations as these overlaps may appear as lane marks on wet days, particularly if there are no raised lane markers and only water borne paint is used.

In the US black paint has been used to increase the contrast between the concrete surface and new lane marking as shown in Figure 18. In some instance raised pavement markers have been used in NSW to assist with the lane delineation after diamond grinding (refer to Figure 19).

Figure 18. View of black paint applied to the concrete surface before white line marking paint is applied.

Figure 19. View of raised pavement marker with white line marking paint to enhance lane delineation.

Very small amounts of surface residue may exist after grinding which may hinder the application of pavement marking. Specification R141 provides requirements for surface preparation before pavement marking.

5.10 Reinforcement steel and traffic

Diamond grinding blades may be damaged when cutting against existing reinforcement located near the surface (eg as a result of insufficient concrete cover) or prefabricated steel used for construction joints.

Depending on the depth of grinding, traffic loops may be damaged if grinding is too deep. While reinstating traffic loops is not part of the scope of specifications R93 or M229, the maintenance contract should allow for the repair of these devices if damaged during grinding operations.

5.11 Proximity to kerbs and F type barriers

Conventional diamond grinding machines typically permit grinding only as close as 600 mm to kerbs and F type barriers. Although smaller machines are now available overseas which allow grinding closer to these facilities, none are currently available in Australia. As noted in Section 9, an Australian company has adapted a conventional grinding machine with an attachment to allow grinding to take place to within 100 mm of kerbs and F type barriers.

5.12 Climatic conditions

Similar to specification R101 'Cold Milling of Road Pavement Materials', restrictions due to climatic conditions, such as rain or specific low or high ambient temperatures, have not been stated in R93 and M229. However conditions that may impact on the safety of workers or road users must be considered when preparing the Safe Work Method Statement for the grinding project.

6. Using diamond grinding specifications

6.1 Completion of Annexures R93/A and M229/A

When the Principal completes Annexures R93/A and M229/A, the following information in Tables R93/A.2 and M229/A.2 is optional:

- Type and source of coarse aggregates
- Number of blades per metre
- Nominated grinding depth

The Principal may alter the default values for minimum texture depth and percentage of holidays to provide for project specific conditions.

Refer to Section 13 regarding decisions to be made when completing Annexures in specification M229.

6.2 Disposition of nonconformities

Specification R93 allows conditional nonconforming work but additional diamond grinding in some instances may reduce the pavement thickness resulting in a reduction in the remaining pavement life. When preparing the disposition, the Contractor must carry out a rigid pavement analysis to estimate the reduction in pavement life from a lesser pavement thickness for the area in question. The proposed disposition may be slab replacements followed by diamond grinding.

6.3 Use of laser based measurement equipment

Where a specification requires the contractor to measure ride quality or texture depth using vehicle driven laser based equipment, it is noted that some laser readings may not provide reliable results by a single pass over a conventional diamond ground surface. It is recommended that two passes are completed to minimise discrepancies between the laser bouncing off the fin or bottom of the trough.

For low noise diamond grinding it is possible ride quality may be inaccurate due to the potential for the laser beam to jump between measurement on the top surface and bottom of groove. Further research work is required to provide better guidance in the measurement of ride quality using laser based equipment.

7. Grinding new pavements

Slurry produced during diamond grinding of a new concrete pavement should be prevented from entering into unsealed transverse contraction and longitudinal joints as it may enter the newly formed cracks and lead to 'locking up' the contraction joints. If the seal has not been installed before grinding, ensure the backing rod does not protrude above the concrete surface and use a sealant to fill the small gaps at the ends of backing rods.

Similar to grinding existing pavements, holidays may appear at the transition zone at the start of a paving run where the concrete slipform paver tends to start low before reaching a target base thickness. Figure 20 shows a typical holiday at the start of slipform paving. This holiday can only be overcome by additional grinding depth either over the whole length of the works or a localised increase in grinding depth which may compromise ride quality. The latter approach may be necessary should the start of paving occur where the crossfall is less than 3% or in a superelevation.

Figure 20. View of holiday (far view) commonly found at the start of slipform paving.

Specification R83 allows the contractor to present a disposition of nonconformity by diamond grinding a new concrete pavement that does not meet the specification requirements.

Specification R93 may be used to restore ride quality to a NAASRA roughness count of 40 counts/km (or its IRI equivalent) when measured with Test Method T182. The conversion equation from IRI to NAASRA roughness count is -1.27 + (26.49 x IRI).

The requirements for using grinding as a disposition to rectify surface nonconformity are detailed in Clause 5.7 of specification R83. There is no Pay Item for this work as rectification of nonconforming work would be paid by the Contractor. If specification R93 is used in conjunction with the requirements of R83, the minimum requirements in Annexure R83 Clause A5.7 apply.

When ride quality is sought as an end product requirement, it is recommended that the Contractor determines the ride quality value before and after grinding. If the first grinding run is used to match adjacent runs, ride quality measurements should be obtained on the first run to correct any potential errors that may accumulate across all lanes of work.

In some cases, ride quality may compromise the 3 mm transverse step at the edge lane where feathering is sought on the outside grinding run. The Principal must assess this on the basis of the longitudinal extent of the step and the crossfall.

If the Contractor has proposed diamond grinding as a disposition of surface nonconformity to restore surface texture from concrete surface delamination or to resolve plastic hardening cracking, it is recommended that advice be sought from the Road and Maritime Services' Rigid Pavement Group.

8. Concrete pavement maintenance

For Roads and Maritime maintenance work, diamond grinding is considered to be essentially a surface finishing operation which can be used to correct or improve some types of surface defects. This means that all maintenance work required to improve the overall condition of the concrete pavement and to properly prepare the concrete pavement must be carried out before the start of the diamond grinding operation.

In cases of concrete pavements that have stepping greater than 5 mm at joints or cracks, this stepping must be corrected before the diamond grinding operation. Failure to correct the excessive stepping may lead to too much of the existing slab being removed during diamond grinding in order to achieve the specified ride quality. An excessive reduction in the slab thickness may lead to reduced service life of the slab. The risk of a reduced service life of the slab is greater in older concrete pavements in which slabs are substantially thinner than is the case with newer concrete pavements. In order to reduce the risk of a reduced service life of the slab, specification M229 imposes a default upper limit on maximum total depth of grinding of 10 mm. This upper limit may be changed depending on the existing conditions for a particular concrete pavement. Diamond grinding is not recommended for concrete pavement slabs that are less than about 180 mm thick because of the risk of reduced service life of the slab.

The purpose of the Hold Point on additional diamond grinding in Clause 5.3 of M229 is to prevent excessive reduction in the slab thickness. The Hold Point allows an assessment of ride quality and maximum depth of grinding to be made in the case in which the specified ride quality has not been achieved and the maximum total depth of grinding is likely to be exceeded.

When completing the Annexures of M229, a compromise may be required between the specification of final ride quality to be achieved, maximum total depth of grinding, and the allowable percentage of holidays. For example, it may be necessary to specify a higher NAASRA roughness count and higher percentage of holidays in order not to increase the maximum total depth of grinding.

Depending on the type and condition of the concrete pavement, it may not be possible to achieve desirable improvements with diamond grinding. In this case, alternative maintenance options may need to be considered.

Specification M229 is used for maintenance of older concrete pavements, particularly those in urban areas. The recommended sequence of work is as follows:

Before grinding, carry out (as required):

- Slab replacement (Roads and Maritime specification M258)
- Cross-stitching (Roads and Maritime specification M213)
- Slab jacking (Roads and Maritime specification M231 or M232)
- Temporary or final sealing of joints (Roads and Maritime specification M214)

After grinding (as required):

- Reseal joints (Roads and Maritime specification M214).
- Repair joint and crack spalling (Roads and Maritime specification M215)

When tining the surface of a concrete slab replacement section, the Contractor should orientate the tines in the longitudinal rather than transverse direction in case a holiday occurs and a cross groove pattern develops on the surface. On high speed roads, this cross pattern may increase the tyre road noise emissions due to different surface texture.

The specifications allow for the diamond grinding process to exclude defined areas of pavement in the vicinity of utility service covers, drainage grates, access hole covers, etc. The exclusion of these defined areas of pavement may lead to the formation of local high spots on the pavement. These local high spots may have adverse impacts on post-grinding ride quality and surface drainage. Adjustment of the surface level of these items should be considered as part of the planning and execution of the maintenance work.

9. Low noise diamond grinding

Conventional diamond grinding (CDG) has been widely employed in NSW in recent years. Low noise diamond grinding (LNDG) is a new surface treatment for new and existing concrete pavements and uses similar equipment to achieve a different finish. Originating from the USA, their testing shows the finished surface has good skid resistance and noise reduction properties equivalent to asphalt surfacing. Figure 21 shows the visual difference between the surface texture of CDG and LNDG.

Figure 21. View of conventional (left) and low noise diamond grinding surfaces.

Whilst the LNDG process has been used for about a decade in the USA, it was first trailed in early 2012 on the Hunter Expressway. The initial trial was constructed on an old section of the New England Highway and followed the USA approach where the LNDG process is a two step process. The first pass grinds the surface with the grinding blades (ie 3.2 mm wide) and separated with 0.9 mm spacers. The second pass grooves the surface and as before the grooving blades are 3.2 mm thick but in this pass are typically separated by 12.5 to 16.0 mm spacers and set to cut 3 to 5 mm deep (as shown in Figures 22 and 23). Also, two drums are required by the contractor to allow for the two different blade spacing's.

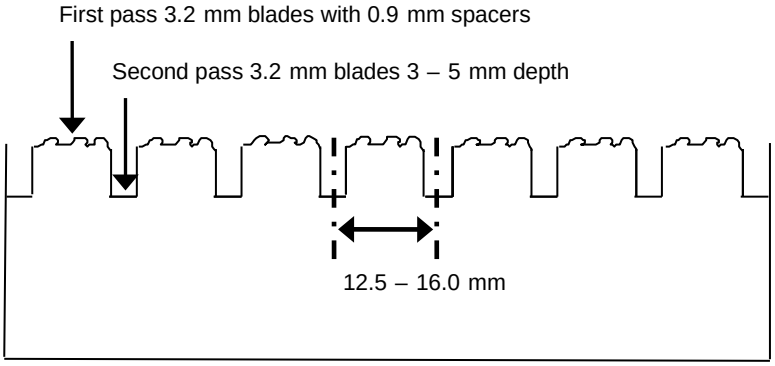

Figure 22. Simplified view of blade settings to achieve the LNDG surface.

Figure 23. Close up view of the finished surface from next generation diamond grinding technology used by USA.
(Photo source is Izevbekhai, 2007)

The current practice in NSW is for the blades to be separated by 14.25 mm spacers until further date can be collected to refine the spacing to optimise tyre noise reduction and durability of the surface. In addition, after a review of the initial LNDG trial on the New England Highway, the flush grind stage was not used on the Hunter Expressway due to the reduction on skid resistance, and the hessian drag surface remain effective at this stage (see Figure 24).

Figures 24 to 26 shows the following features of application of LNDG applied on the plain concrete pavement on some sections of t the Hunter Expressway:

- The LNDG is applied from the edge of the longitudinal joint at the shoulder to the outside edge of the lane marking in the median (see Figure 25)
- Initially sealing of the joints was completed after grinding and experienced had shown that it was difficult to form a neat finish to the joint as shown in Figure 26. Sealing of all joints is completed prior to grinding.
- Unlike conventional grinding no overlap occurs and the longitudinal grooving pattern should be uniform across the pavement.

Limited road side noise measurements have been undertaken and it appears that road tyre noise emission levels are equal to or lesser than dense graded asphalt, and it is expected with further noise measurements and refinements to the process, the LNDG technique could achieve noise emission levels similar to SMA surfaces.

A draft specification has been developed for use by project managers and contractors to conduct trials and is available from the Pavements Unit.

Figure 24. View of the finished surface on the Hunter Expressway.

Figure 25. View of the finished LNDG surface from the longitudinal shoulder joint (left) to the outside edge of the lane marking in the median.

Figure 26. View of the transverse contraction joint finished with the sealant applied after grinding (left) compared with the cleaner surface appearance with sealant applied before grinding.

10. Grinding concrete pavements in tunnels

Diamond grinding has been successfully used to improve ride quality for manually placed concrete pavements in tunnels. Figure 27 shows the grinding machine used to improve the ride quality in the Clem 7 Tunnel in Brisbane.

Figure 27. The diamond grinding technology has been used in the Clen7 tunnel.
(Photo courtesy of Seovic Civil Engineering)

11. References

Roads and Maritime (2011) *Diamond Grinding of Concrete Pavement* Specification R93, Ed.1 Rev 0, Roads and Maritime Services, North Sydney, NSW.

Roads and Maritime (2013) *Low Noise Diamond Grinding of Concrete Pavement* Specification R94, Not published, Roads and Maritime Services, North Sydney, NSW.

Roads and Maritime (2015) *Maintenance Diamond Grinding of Concrete Pavement* Specification M229, Ed.1 Rev 0, Roads and Maritime Services, North Sydney, NSW.

Roberts J H & Scofield, L (2011) *The Next Generation Concrete Surface* Roads and Maritime Services Pavement Conference 2011, Sydney, NSW.

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