Guidance for the use of Audio Tactile Pavement Marking (ATPM)

26 September 2025

Version 2.1

NZ TRANSPORT AGENCY
WAKA KOTAHI

Te Kāwanatanga o Aotearoa
New Zealand Government

More information

NZ Transport Agency Waka Kotahi
Published September 2025

ISBN 978-1-99-106850-7

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Record of Amendments			
Amendment Number	**Status**	**Effective Date**	**Comments**
Version 1.0	Superseded	October 2010	First edition
Version 2.0	Superseded	December 2024	Update including latest research
Version 2.1	Current	June 2025	Update sections 5 and 6.4

Contents

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1. Scope of this document

The objective of this document is to provide best practice guidance on the deployment of Audio Tactile Pavement Marking (ATPM, sometimes referred to as ‘rumble strips’ or ‘audio tactile profiled marking’) on the state highway network. It has been written for state highways, but may be adopted, as appropriate, by other road controlling authorities. Practitioners who wish to depart from the advice in this guide should consider the appropriate process, such as a departure request from the person managing or administering the relevant contract, supported by evidence as to why the departure is appropriate.

This guidance provides up-to-date and objective evidence and information regarding the use of ATPM. It will provide more confidence to designers and network managers considering the installation of ATPM and will provide a more consistent approach to their use throughout New Zealand. This guidance is not intended to replace the information provided in the Traffic Control Devices Manual (TCDM) and the NZ Transport Agency Waka Kotahi specification for audio tactile pavement marking TNZ M/24 and M30 Specification and Guidelines for Road Lighting Design. These specifications give more operational detail on using ATPM and the related high-performance markings. This guidance rather provides a rationale for using ATPM in various circumstances. In addition to the traditional rib-based audio-tactile marking specified in M24 this document also deals separately with profiled high-performance pavement marking, which are covered in the P30 specification.

2. Overarching requirements for ATPM

ATPM is an infrastructural measure aimed at improving road safety. Any activity or infrastructure change on NZ roads should conform with the Safe System approach to road safety and ensure that environmental sustainability is maximised. Contractual arrangements should be set out in order to achieve the above.

2.1. The Safe System Approach to Road Safety

New Zealand's Road to Zero road safety strategy endorses a Safe System approach to road safety. This approach focuses on creating safe roads, safe speeds, safe vehicles, and safe road use. Under the Safe System approach to road safety, we work towards a road system in which serious and fatal injuries do not occur. For this to happen, all necessary measures must be taken to reduce the likelihood of crashes and, if crashes do occur, the people involved should not be subjected to the sort of trauma that would result in fatal or serious injury. This way of thinking also involves realising that road users are human and will make mistakes from time to time. The infrastructure should take this into account and be built to minimise the consequences of such mistakes. Our ability to reach such a point is constrained by the ability to fund such changes, so this progress is bound to happen over time.

2.2. The place of ATPM in the Safe System Approach

ATPM are devices designed to be placed on or beside edgelines or centrelines to provide road users with audible and tactile warning that they are in danger of leaving their lane, thereby alerting them to the injury consequences of such an action. In addition, ATPM improves visibility of line marking. Therefore, ATPM exists to support progress towards a Safe System by reducing the likelihood of a crash, but do not fully reduce the consequence or severity of a crash should one occur. They therefore cannot completely eliminate FSI crashes altogether, but can improve safety nevertheless. They are therefore categorised as Safe System support measures. For more on primary and supporting Safe System interventions refer to the Standard Safety Intervention Toolkit[1].

2.3. Environment and Sustainability

NZTA provides guidance to practitioners on its environment and sustainability expectations[2]. These expectations in addition to enhancing the welfare of the planet also affect the more direct impacts of travel on people including noise, vibration, urban design, and heritage.

2.4. Main Messages

- ATPM is a support for the Safe System approach to road safety and should be used in that context along with other appropriate Safe System measures.
- All work related to ATPM should conform to the NZTA environmental and sustainability requirements.

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[1] Standard safety intervention toolkit | Waka Kotahi NZ Transport Agency (nzta.govt.nz)

[2] https://www.nzta.govt.nz/roads-and-rail/highways-information-portal/technical-disciplines/environment-and-sustainability-in-our-operations/

3. The nature of New Zealand ATPM

In New Zealand, ATPM typically comprise thermoplastic or cold applied plastic lumps (also called blocks or ribs) laid onto the road surface adjacent to a longitudinal line (Figure 3-1, left), or in combination with a longitudinal line. (Figure 3-1, right).

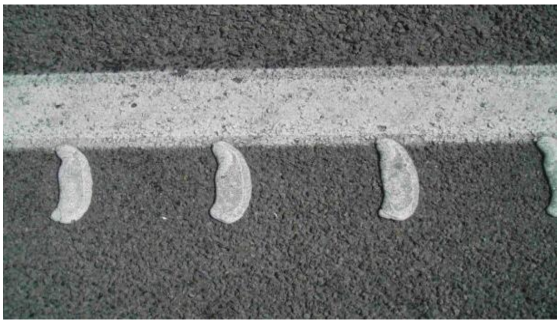


Figure 3-1: Audio tactile pavement marking (ATPM) used in New Zealand (left image: Lester et al, 2017, page 10)

This type of ATPM is also used in Australia and in the UK, while in the US, Canada and continental Europe, wider markings that are milled into the pavement predominate. Milled ATPM is not suitable for our chip seal pavements but have the same safety objectives and can be reasonably expected to have similar safety benefits. However, New Zealand style ATPM are used overseas where chip seal pavements exist - for instance in Texas.

4. The Safety Benefits of ATPM

4.1. The extent of benefits

ATPM are used because of a demonstrated safety benefit. There is a large amount of evidence of this safety benefit (e.g., Mackie and Baas (2007), Hatfield et al (2009), Torbic et al (2009) and Sun et al (2021). ATPM came onto the road safety scene in the 1990s so much of the evidence of their efficacy is now more than a decade old.

Mackie and Baas (2007) found that ATPM provide significant safety benefits that outweigh the installation and maintenance costs even at relatively low traffic volumes.

Hatfield et al. (2009), using Australian ATPM data found that for before/after or treatment/control studies, edgeline ATPM reduced single vehicle run off road crashes by an average of approximately 22% (range 7.3% to 49.8%). Similarly, centreline ATPM reduced opposing direction crashes by an average of 25%. Predictably, as they both had excellent safety benefits the highest safety benefits occurred when they were used together.

Torbic et al (2009) have reviewed USA and Canadian results up to their time of writing and made the crash reduction estimates in Table 4:1. DSI in the table stands for death and serious Injury.

Urban/Rural Freeways	Rural Freeways	Rural Two-Lane Roads
13% in single-vehicle run-off-road DSI crashes	16% in single-vehicle run-off-road fatal crashes	29% in single-vehicle run-off-road DSI crashes
Insufficient data for a useful estimate	*Insufficient data for a useful estimate*	44 percent in DSI head-on and opposite-direction sideswipe crashes

Table 4:1: Crash reduction estimates by road type from Torbic et al (2009)

Sun et al (2021) from the USA found the results for rural two-lane two-way roads:

Edge ATPM
All DSI crashes: -67.2%
Centreline ATPM
All DSI crashes: -35.8%, DSI head-on crashes: -41.8%
Both edge and centreline ATPM
All DSI crashes -22.2%

Table 4:2: Crash reduction estimates by ATPM type from Sun et al(2012)

Their results differ somewhat from those of Torbic et al (2009). However, it must be remembered that Torbic et al (2009) dealt with all crashes on a several different networks and Sun et al (2021) dealt only with two-lane two-way roads. Notwithstanding this difference in the type of data used, Torbic et al (2009)'s results for rural two-lane two-way roads are broadly similar to those of Sun et al (2021).

4.2. Mechanisms of safety benefits

The main source of ATPM safety benefits is the audio-tactile alerting of drivers that they are leaving their lane. ATPM is generally considered most effective against inadvertent excursions out of the travel lane associated with fatigue and/ or distraction. This is because these excursions usually involve crossing the edge line or centreline at a small angle allowing a modicum of time for the driver to take corrective action after receiving the warning.

However, that is not the only way they provide safety benefits. ATPM penetrates films of water, so they have better wet visibility than ordinary painted markings or flat thermoplastic markings. This means that they improve night-time and low-light guidance for drivers, particularly in wet conditions where normal painted lines may be seriously obscured by films of water. Refer also to Section 13 regarding structured markings.

ATPM also provides useful guidance through their audio tactile properties when obscured by snow. A Michigan study of rumble strips (MDOT, 2015) recorded very positive survey participant opinions of the rumble strips from motorists who appreciated the guidance they provided, even when covered in snow.

4.3. Comparing safety benefits with costs

It is a strategic imperative to progress towards a Safe System as expeditiously as possible. Along with less quantifiable influences like material availability and staff availability, the speed of this progress is considered constrained by the financial and delivery resources available. Therefore, given the finite nature of the resources available road safety practitioners have a need to spend these resources so that they get the greatest road safety benefit. This means that when they have choices to make, comparison of the costs and benefits of the various road safety tools at their disposal, including ATPM is required prior to signing off a programme of work.

ATPM is a core support measure in moving towards a Safe System. As such they are considered along with other measures which in combination with ATPM provide progress towards a Safe System. Cost benefit analysis is a tool which may be used in deciding what is the most effective mix of measures to use within a capped amount of road safety funding.

Benefit/cost ratios (BCRs) of between approximately 4 and 20 were estimated by Mackie and Baas (2007} who used accident prediction models and a generalised crash reduction factor of 25% to produce a delineation cost management tool for a range of New Zealand road environments. This provided BCR estimates for ATPM use ranging from around 4 to 20 depending on road characteristics and traffic flow (Figure 4-1). Note that the costs considered are for installation only and do not consider the cost of ongoing maintenance or environmental (eg noise) costs, which can be significant.

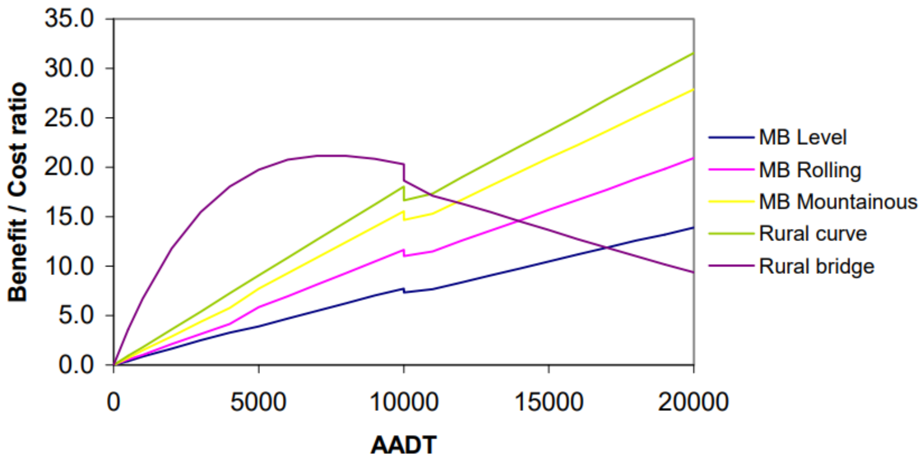

Figure 4-1: Two-way AADT related to benefit /cost ratio of ATPM according to a cost management tool (Mackie and Baas 2007)

When interpreting Figure 4-1 it must be kept in mind that the downward step that exists at 10,000 vehicles per day is due to the increased costs of temporary traffic management. Also, ATPM are not recommended on bridges without sufficient shoulder width for cyclists and ATPM edgelines on mountainous roads may be less effective as drivers tend to be relatively alert in these conditions.

More recent unpublished work carried out within NZTA looked at the benefits and costs of some road markings measures including 150mm wide ATPM on different One Network Road Classification (ONRC) road types. The work indicates that 150mm ATPM could be cost beneficial down to relatively low traffic volumes.

Note that ATPM may have a poor BCR where environmental concerns such as noise dominate.

These results make it clear that ATPM, where used at places where there are lane departure crashes, or the potential for such crashes, reduce such crashes and that the crash benefits are considerably greater than installation costs depending on the local situation. With this in mind, ATPM should be considered as the preferred rural line marking from a safety perspective wherever feasible, especially on lower volume routes where signs and markings are likely to be the only safety tools deployed.

4.4. Main messages

- The main source of ATPM safety benefits is the audio-tactile alerting of drivers that they are leaving their lane.
- ATPM is generally considered most effective against inadvertent excursions out of the travel lane associated with fatigue and/ or distraction.
- Where used appropriately ATPM reduces crashes cost-effectively and can be cost effective at relatively low traffic volumes.
- Appropriate use is as a Safe System support measure in conjunction with other Safe System measures.
- The benefits and costs of road safety measures like ATPM should always be considered in the light of our overarching Safe System approach to road safety.
- Consideration of costs should also include maintenance and environmental effects.

5. Residents and noise

ATPM, by their very nature, generate noise both inside and outside the vehicle and should not be installed where they are likely to cause undue annoyance to residents. Therefore, in general, ATPM is not recommended in urban environments (environments with high residential property density and/or posted speed $\leq$ 70 km/h). Causation of environmental noise can involve costly removal of the ATPM, and this is the only practical treatment.

There is no international consensus as to a minimum distance from residential buildings. Western Australia[3] counsels against their placement nearer than 200m from a residential building. New South Wales[4] has a similar requirement which may be waived if certain crash and consultation requirements are adhered to.

NZ experience is that in some cases ATPM can cause significant noise annoyance many hundreds of metres away, depending on factors such as how often ATPM is struck, topography, prevailing wind, and sensitivity to environmental noise. Of these factors, only how often ATPM is struck can be practicably influenced, by ensuring ATPM is not placed on a frequently traversed part of the carriageway.

It is recommended to omit ATPM where they are likely to be tracked over frequently, such as:

- on the inside of tight corners (note that this may include centrelines)
- where overtaking is frequent
- at intersections.

Where there are nearby dwellings, particularly where they are within 200 m, suitably experienced persons should assess whether gaps should be left in the ATPM, or whether ATPM should be omitted from the site entirely.

5.1. Main messages

- Consider avoiding use of ATPM in urban environments.
- Avoid use of ATPM where frequent tracking over the ATPM is likely to occur, particularly where this may cause environmental noise that will affect residential properties (refer to Section 6 for additional guidance).

6. ATPM installation

6.1. General principles

ATPM is a core measure to support movement towards a Safe System. Under a Safe System approach, a Safe System Assessment according to the Austroads Safe System Assessment Framework[5] should be undertaken when roads are being reassessed from the safety point of view or when a road is being designed according to Safe System principles.

Use of the framework assists in assessing how closely road design and operation align with the Safe System objectives and clarifies what needs to change to achieve closer alignment with Safe System objectives. This assessment will assist in deciding how ATPM fits as part of an appropriate set of road safety measures for a particular stretch of road. The tool enables the assessor to score a stretch of road against its overall Safe System characteristics. The road would be assessed with and without the introduction of ATPM (with or without the introduction of other complementary road safety measures). If their introduction results in a better score, then the piece of road could be considered for ATPM

[3] https://www.tmr.qld.gov.au/-/media/busind/techstdpubs/Traffic-management/Traffic-and-Road-Use-Management-manual-TRUM/Volume-2/Volume2Part5.pdf?la=en
[4] https://roads-waterways.transport.nsw.gov.au/trafficinformation/downloads/ttd_2020-04.pdf
[5] https://austroads.com.au/publications/road-safety/ap-r509-16/media/AP-R509-16_Safe_System_Assessment_Framework.pdf

introduction. The Safe System Assessment Framework is summarised in Figure 6-1 from Austroads (2016).

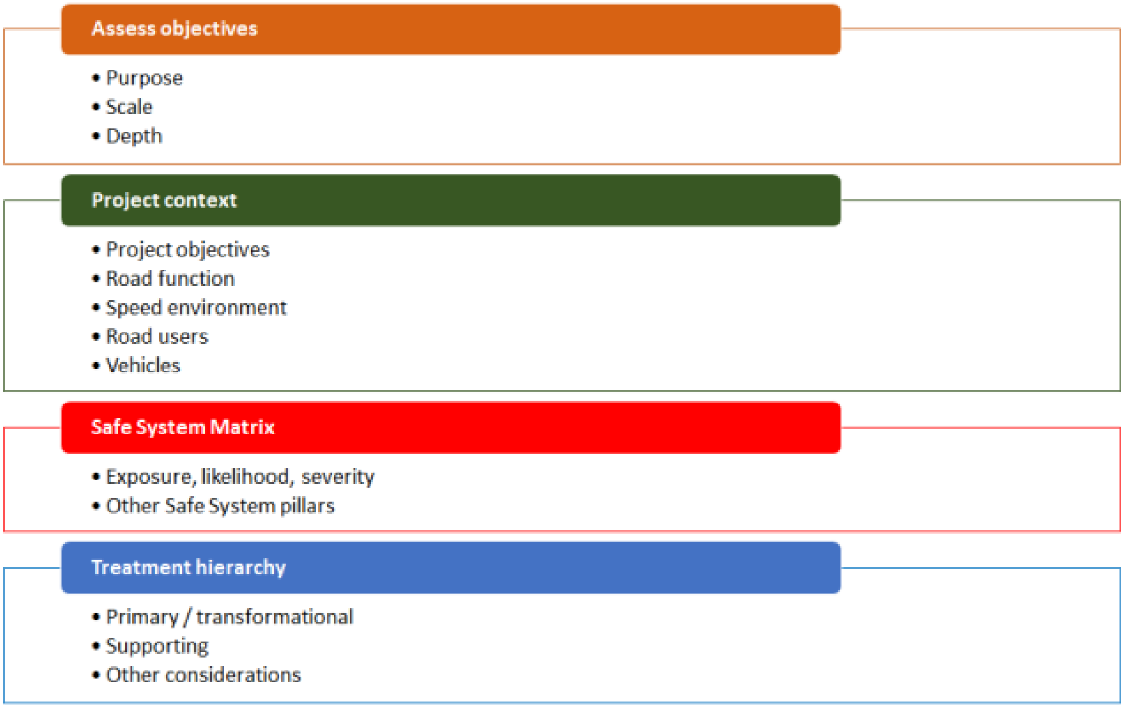

Figure 6-1: Summary of Safe System Framework

The framework which uses historical information from many sources to inform risk appraisal should be used in conjunction with historical crash analysis from the road in question to provide an overall view of the situation.

ATPM is effective against single vehicle crashes and as such will have impact at traffic volumes where multivehicle crashes are rare as vehicles are well-spaced. Therefore, they may be considered as a preferred treatment in non-urban areas subject to the following conditions:

- Consistency with the Safe System Assessment
- Environmental suitability (potential noise effects and width requirements, refer to Section 0)
- Confirmation of funding

The framework specifies no explicit volume constraints and subject to available funding Road Controlling Authorities should be consider ATPM as a safety measure across all networks irrespective of volume.

The Standard Safety Intervention Toolkit (SSIT) lists a minimum daily traffic for installations of ATPM as 1000 vehicles per day if they are part of a project utilising the NZTA streamlined investment pathway described in the SSIT.

The NZTA Traffic Control Devices Manual Part 5 also states a minimum volume of 1000 vehicles per day as a cut-off point in the absence of specific safety related issues. However, given the excellent benefit to cost ratio that can be achieved by installing ATPM it should be considered on roads with lower traffic volume where the funding to install and maintain the ATPM is available.

6.1.1. Main message

- ATPM should be installed as Safe System support measures in conjunction, where required, with other complementary Safe System measures. They can be considered preferred options for non-urban use subject to confirmation of funding and environmental suitability. The volume cut-off of the SSIT and the TCDM should be considered, but not be a barrier to installation.

6.2. Length of installations

The present consensus is that ATPM should be used in long lengths rather than as a treatment for specific locations with specific crash problems. ATPM may be interrupted for various reasons. These include exposure of nearby houses to noise, proximity to intersections or very tight curves or places where shoulder width is insufficient for cyclists (including bridges where this is the case). Interruption may also be used to provide gaps for cyclists to cross markings. However, efficacy of treatment will be degraded if frequent breaks are present.

6.2.1. Main messages

- ATPM should be used in long lengths rather than as a treatment for specific locations with specific crash problems.
- ATPM may be interrupted for reasons such as exposure of nearby houses to noise, and proximity of intersections, very tight curves, or low shoulder width for cyclists (including bridges where this is the case). Interruption may also be used to provide gaps for cyclists to cross markings.

6.3. ATPM on and adjacent to edgelines

Where ATPM installation is appropriate it should be applied to all edgelines except those where frequent crossing may cause problems with noise or wear (refer Section 5) or where shoulder width is insufficient (refer Section 7.3).

6.4. ATPM on and adjacent to centrelines

Compared to edgelines there are more cases where centreline ATPM will not be appropriate as explained further in the following subsections of this guide. Where ATPM installation is appropriate it should be applied to all centrelines, except those where frequent crossing may cause problems with noise or wear, (refer Sections 5 and 6.6).

Sample layouts for ATPM on centrelines are provided in TCDM Part 5.

6.4.1. White centrelines

White centre lines are to delineate the centre of the road rather than prevent crossing of the line. A solid rather than dotted white centreline denotes a need for extra caution if considering a manoeuvre involving crossing the line. The object of ATPM is to prevent involuntary crossing of the ATPM line while not preventing deliberate but legal crossing such as when a driver crosses a dashed or solid white centreline to make a passing manoeuvre. Mackie (2009) showed on some SH27 right-hand curves that vehicles shied away from ATPM on dashed or solid white centrelines. Therefore, ATPM will in these situations assist in keeping vehicles in their lanes unless deliberately crossing the line to overtake.

6.4.2. Solid yellow centrelines

ATPM may be used on these whether they are in single or double configurations.

6.4.3. Single dashed yellow centrelines

ATPM improves lane keeping but do not prevent deliberate lane departures, say, for the purpose of overtaking. This implies that ATPM on single dashed yellow centrelines benefit safety without increasing risk to those crossing them for a legal passing opportunity.

6.4.4. Wide centrelines

ATPM is an appropriate treatment on wide centrelines both white and yellow.

6.4.5. Flush medians

Flush medians are generally used in urban areas where noise from ATPM is likely to cause issues, therefore ATPM is unlikely to be an appropriate treatment. However, for where noise is unlikely to be an issue and ATPM may mitigate safety issues they may be considered.

6.4.6. ATPM on both centrelines and edgelines

Where criteria for both edgeline ATPM and centreline ATPM exist simultaneously both may be considered. Hatfield et al. 2009. indicated there are synergies when both edgeline and centreline ATPM are used together. Ideally a clear lane width of 3.5m should be available between ATPM central and edgeline roadmarkings, however research indicates that the safety benefits are from the overall carriageway width. As the shoulder width is also important, a sensible allocation of road width between lane and shoulder may indicate a slightly lower clear lane width in some circumstances (refer TCDM Part 5 ATPM configuration and dimensions). Lane width should not be reduced lightly as ATPM is for higher risk locations where lane width is important. As much shoulder as possible should be provided as long as lane widths are within the acceptable range.

6.4.7. Main messages

- ATPM is recommended on white centrelines and yellow centrelines as they assist in keeping non-overtaking vehicles in their lanes and do not increase risk to those crossing them for a legal passing opportunity.
- ATPM is an appropriate treatment on wide centrelines both white and yellow.
- There are synergies in safety benefits when both edgeline and centreline ATPM is used together.
- Safety benefits are from the overall carriageway width contingent upon a sensible allocation of road width between lane and shoulder.

6.5. ATPM on lane lines

Discontinuous lane lines can be crossed by drivers as appropriate and this could occur frequently, therefore ATPM should not be installed on lane lines. Currently the preferred rural lane line marking is long life marking with four even-spaced raise reflective pavement markers. Additional guidance for lane lines is provided in TCDM Part 10, however note that at the time of publication this is due for revision.

6.6. ATPM and intersections

TCDM cites a greater need of motorcyclists and cyclists to cross ATPM at intersections, which is considered undesirable. Motorists will also cross them more placing them at risk of greater wear. Where there are known high volumes of right turns by cyclists and motorcyclists the centreline ATPM should terminate 3 m from the right turn bay limit line. Sample layouts for ATPM in the vicinity of T intersections and right turn bays are provided in the TCDM Part 5.

6.6.1. Main message

- ATPM at intersections should be clear of line marking that is frequently intentionally tracked over.

6.7. ATPM on curves

ATPM are an effective road safety measure on and in the vicinity of rural curves but are not recommended for very tight curves or curves where frequent tracking over the ATPM may cause environmental noise. Environmental noise is more likely especially on the inside of curves and excessive wear by motorists may also occur, especially from heavy commercial vehicle drivers (HCVs) cutting across the ATPM in order to follow a driving line they may perceive as more comfortable.

It is acceptable practice to interrupt an ATPM installation along a route to accommodate tight curves. Therefore, stretches of very windy roads with frequent tight radius curves are not recommended for ATPM as continuity could only be achieved on the infrequent short straights. Exceptions might be considered on a case-by-case basis where run off road crash rates are high; shoulder width is acceptable and other safety treatments are unsuitable.

On roads with lane widening to accommodate the tracking of HCVs it is recommended to consider omitting ATPM on the inside of curves with horizontal radius < 300 m. On roads without lane widening for HCVs consider omitting ATPM below a curve radius of 400 m. This restriction primarily applies to the marking on the edgeline. Where risk of environmental noise due to tracking over ATPM on the centreline is high this must be weighed against the safety risk from vehicles crossing the centreline without the warning that would be provided by ATPM.

6.7.1. Main messages

- ATPM is an effective road safety measure on and in the vicinity of rural curves.
- ATPM is not recommended for tight curves or for road stretches with frequent tight curves.
- Exceptions with high run off road crash rates may be considered on a case-by-case basis.

6.8. ATPM on bridges, bridge approaches and accesses

To accommodate cyclists, ATPM should not be used on bridges or their approaches, unless at least 1 m shoulder width is maintained (refer also to Section 7.4.1). ATPM should continue across minor or residential property accesses unless it is likely that noise will be a problem for residents (Figure 6-2) (refer also to Section 0).

Sample layouts for ATPM on bridge approaches and passing lane terminations are provided in TCDM Part 5: Audio tactile profiled roadmarking.

6.8.1. Main messages

- Should not be used on bridges or their approaches, unless at least 1m shoulder width is maintained.
- ATPM should continue across minor or residential property accesses unless noise is likely to be a problem.

Figure 6-2: Continuity of edgeline ATPM broken at an access point

6.9. ATPM in snow/ice conditions

Anecdotally, ATPM has been successfully used on South Island roads subject to snow, but only with a rib height (5mm) half that specified in the NZTA M24 specification. This was apparently enough to protect them from snow ploughing operations. Lester et al (2017) found that ATPM on some snow ploughed surfaces produced acceptable sound/vibration levels despite loss of rib width from the ploughing (see Figure 6). It was not known how many times ploughing had happened so resistance to long term ploughing is unknown and information on the effective life of 5mm ribs is not available. ATPM which have partially lost ribs could be assessed using the Subjective Rating System from Lester et al (2017) described in Appendix 2: Subjective assessment procedure adapted from Lester et al (2017). Audio tactile impact is of course not the only function of ATPM and the adequacy of retroreflectivity and daytime luminance should also be checked where ribs are damaged.

Figure 6-3: ATPM loss due to snow ploughing (from Lester et al (2017))

The Minnesota Department of Transport[6] minimises ploughing of edgelines and centrelines with a process called "Bare Lane" illustrated in Figure 6-4. Ninety-five percent of wheel tracks and everything in between must be ice and snow free with centre and edgelines having less than 1 inch (25.4 mm) of snow and ice on them.

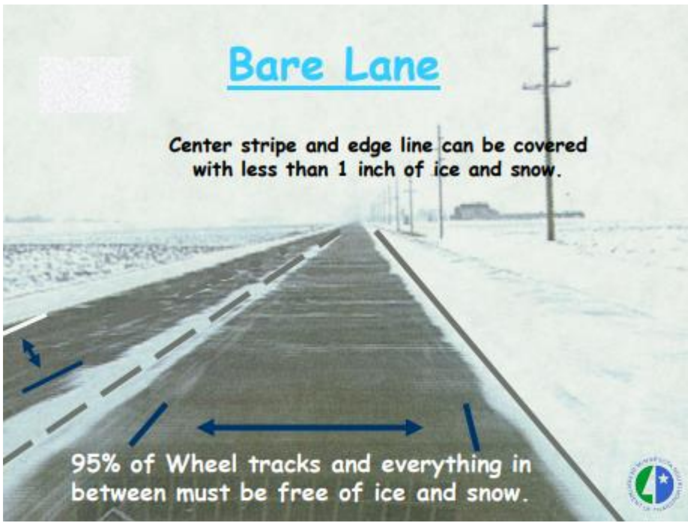

Figure 6-4: Example of Bare Lane Roadway Condition from the Minnesota Department of Transport

This is a similar concept to in-lane sealing and is worth consideration by practitioners. It is also worth noting that even when covered with thin layers of snow ATPM retain their audio tactile properties and provide valuable guidance, however their visual guidance is reduced.

The above refers to areas with frequent snow. Where snow is infrequent, ATPM should be considered along with the use of rotary broom equipment to remove the snow without damaging the ATPM.

6.9.1. Main messages

- Anecdotally, ATPM have been successfully used in snow, but only with a 5mm rib height to protect them from snow ploughing operations.
- Where snow is infrequent, ATPM should be considered along with the use of rotary broom equipment to remove the snow without damaging the ATPM.
- Minnesota minimises ploughing of edgelines and centrelines by ploughing 95% of wheel tracks and everything in between to an ice and snow free condition with centre and edgelines allowed less than 1 inch of snow and ice.

[6] https://www.dot.state.mn.us/maintenance/hsop/pdf/report.pdf accessed 28/6/2021

- Even when covered with thin layers of snow ATPM retain their audio tactile properties and provide valuable guidance.

6.10. ATPM with road safety barriers

A significant proportion of vehicles driving onto ATPM require a relatively low width of pavement to recover. Therefore, ATPM placed along linemarking adjacent to safety barriers will reduce the numbers and/or severity of hits on the barriers thus reducing damage repair costs including temporary traffic management costs. There will also be savings related to lower traffic delays and greater resilience resulting from the lower traffic delays.

Smith et al (2016) found that ATPM adjacent to both left side and median side wire rope barriers can reduce barrier strikes considerably thus reducing both crashes and barrier repair costs. Where injury from the barrier is unlikely the ATPM are not primarily crash injury avoidance mechanisms but rather infrastructure damage avoidance mechanisms and their economic justification should be treated accordingly. If the barriers are unforgiving and more likely to inflict injury on vehicle occupants any economic analysis should account for this. Smith et al (2016) includes a spreadsheet tool which may be used to assist decision-making related to the maintenance cost savings of installing ATPM in conjunction with existing or new flexible barrier installations. With more rigid barriers like W-beam or concrete, crash savings will accrue but not the same level of maintenance cost savings.

6.10.1. Main messages

- ATPM should be installed on/or next to the line adjacent to the barrier unless there are practical reasons they cannot be installed. On the line is preferred for median barriers and immediately to the left for edge barriers. In the case of edge barriers if shoulder space is substandard they should be placed on the edgeline.
- ATPM adjacent to safety barriers can reduce barrier strikes considerably thus reducing both crashes and barrier repair costs. There will also be savings related to lower traffic delays and greater resilience resulting from the lower traffic delays.

7. Road user and vehicle issues

7.1. Driver behaviour

The target group for ATPM is inattentive and fatigued drivers who may also be impaired by alcohol or drugs and consequently may have longer than normal reaction times.

ATPM have an impact on the lateral position of drivers who do not stray from their lanes as well as the drivers who stray from their lanes and receive audio-tactile feedback from the ATPM. Research by Rosey et al (2008) and Mackie (2009) suggested that drivers tend to shy away from centreline ATPM. Where there are both centreline and edge line ATPM shying away from the centreline still occurs.

Rosey et al (2008) carried out a simulator study. They found that with ATPM on both sides of the centreline and beside a sealed shoulder, drivers drive nearer the centre of their lane, away from the centreline (by about one tyre width) than with just painted edge and centrelines. The ATPM simulated resembled those used in New Zealand.

Mackie (2009) found that ATPM on white dashed centrelines did not prevent deliberate overtaking and ATPM edgelines did not prevent (but did reduce) edgeline crossing. Given that lane keeping in general was improved, this suggests that ATPM discourages inadvertent, but does not prevent deliberate, lane departures. This reinforces the belief that ATPM is most effective as a fatigue or distraction countermeasure and may be less effective in situations where deliberate line crossing is common, such as on roads with significant curvature.

Vehicles typically impact upon ATPM edge or centrelines at small angles, typically around 3 degrees, and seldom more than 5 degrees (Hoschopf and Tomasch (2008)). The impact angle, speed, surface friction and driver's reaction time determines the shoulder width required to react in time to avoid running off the road. As the reaction times of target group drivers may be higher than the norm this is reflected in the shoulder width necessary for recovery to take place.

7.1.1. Main messages

- The target group for ATPM is inattentive and fatigued drivers who may also be impaired by alcohol or drugs and consequently may have higher than normal reaction times.
- Drivers do not need to stray from their lanes to be affected by ATPM. Drivers tend to shy away from ATPM with their presence on both sides producing a move towards the centre of the travel lane, away from the centre of the road.
- ATPM do not prevent deliberate line crossing.

7.2. Road user perceptions of ATPM

There is a dearth of recent sampling of road users' opinions of ATPM. However, the evidence which is available (Hatfield et al. (2008), Mackie (2009)) suggests that road users generally perceive ATPM positively. As an example, Mackie (2009) features Figure 7-1 which describes the opinions of a sample of drivers on the safety of white centreline ATPM, with a large majority viewing them positively.

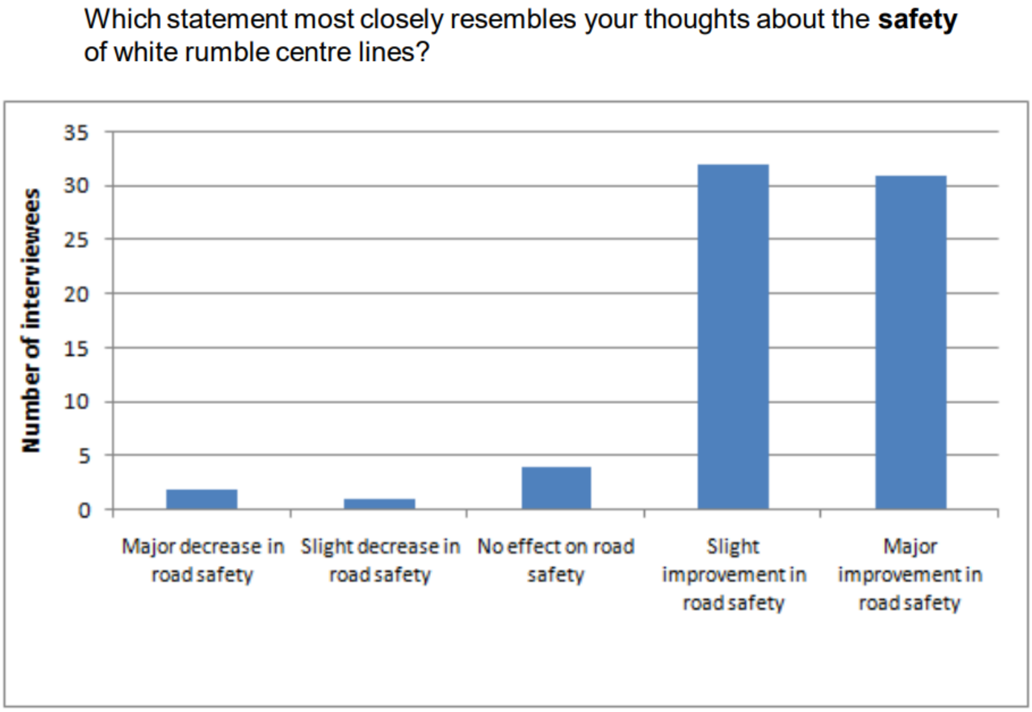

Figure 7-1: Opinions of a sample of drivers to the safety of white centreline ATPM (Mackie, 2009)

Australian Drivers surveyed by Hatfield et al. 2008 were positive towards ATPM while believing they were most useful at night and in wet conditions This indicates that their visual aspects are valued. Michigan motorists valued the guidance afforded by "rumble strips" even when covered with snow (MDOT, 2015).

7.2.1. Main message

- Most road users view ATPM positively.

7.3. Shoulder width requirements

Shoulder width is a concern both for cyclists who require it to ride on and drivers who require it to recover from incursions onto or over the ATPM.

Shoulders should be as wide as possible to maximise recovery area consistent with the cross-section width available and the necessity to have acceptable lane width. In some cases, such as at accessways and rockfall or slip catch areas the shoulder may be widened for these purposes rather than for general traffic.

Where the shoulder has a gravel component outside the paved component the gravel may act as part of the recovery zone. However, if the gravel is loose, soft, non-level, eroded, or there is an "edge-drop" from the pavement to the gravel, then the gravel shoulder portion is considered ineffective for recovery, especially at highway speeds. TAC[7] (2001) recommends at least 200mm between the marking and the edge of the seal in the absence of cyclists and 1m where cyclists are present.

According to the US Federal Highway Administration (FHWA)[8] incremental benefits from ATPM exist even when the shoulder has negligible recovery area. Therefore, lengths of ATPM where the shoulder is very small or non-existent, connecting other lengths with acceptable shoulders do have some direct benefits.

Tomasch et al (2016) compared the reduction of run-off-road crashes by hard shoulder width and reaction time, for rumble strips 0.5 meters from the driving lane by reaction time. They found the necessary width to achieve a significant crash reduction percentage increases markedly as reaction time increases.

All things being equal, the New Zealand practice of placing the edgeline and the ATPM in the same position or overlapping or very close to each other is preferred as it provides the greatest amount of recovery space for a given shoulder width. If the edgeline and the ATPM are close by, coincide or overlap this has wet weather visibility benefits as the ATPM ribs project above moisture films making the line of ATPM more visible forming a surrogate edgeline. The TCDM Part 5 has standard layouts for differing shoulder widths.

7.3.1. Main messages

- Placing the edgeline and the ATPM in the same position, overlapping or very close to each other is preferred as it provides the greatest amount of recovery space for a given shoulder width along with wet weather visibility benefits. Shoulders should be as wide as practical to maximise recovery area consistent with the cross-section width available and the necessity to have acceptable lane width.
- According to FHWA incremental benefits from ATPM exist even when the shoulder has negligible recovery area. Therefore, lengths of ATPM where the shoulder is very small or non-existent, connecting other lengths with acceptable shoulders do have some direct benefits (but note potential negative effects for cyclists as per Section 7.4.1).

7.4. Two wheeled vehicles

7.4.1. Cyclists

ATPM can affect cyclists and it is important to carefully consider the amount and type of cyclists on a road and the useable shoulder width before decisions are made. and documented consultation with local cycle groups may be required. Advice is presented in TCDM Part 5 regarding ATPM and cyclists, including the decision-making flow-chart of Figure 7-2.

The decision-making flow chart is accompanied by notes indicating in summary that:

- Cyclist safety should always be considered when installing ATPM.
- Cyclists will generally avoid riding over ATPM if they can.
- The minimum desirable shoulder width for cyclists is 1m but a 0.6m width will accommodate most cyclists and should not preclude ATPM installation.
- ATPM should not be installed on shoulders less than 0.6m as cyclists are likely to use both the shoulder and the traffic lane, possibly crossing the edgeline frequently.
- Gaps should be left in ATPM wherever cyclists are expected to cross the edgeline.

[7] TAC is the Transport Accident Commission of Victoria, a no-fault insurer for Transport Accidents
[8] https://safety.fhwa.dot.gov/roadway_dept/pavement/rumble_strips/faqs.cfm

7.4.2. Motorcyclists

Jamieson et al (2013) studied the impact of New Zealand ATPM on motorcycle stability, which of course impacts upon the ability to recover. They found no evidence of any safety problems related to motorcycles crossing ATPM. This is corroborated by overseas evidence from Vadeby and Anund (2016) and Miller (2008).

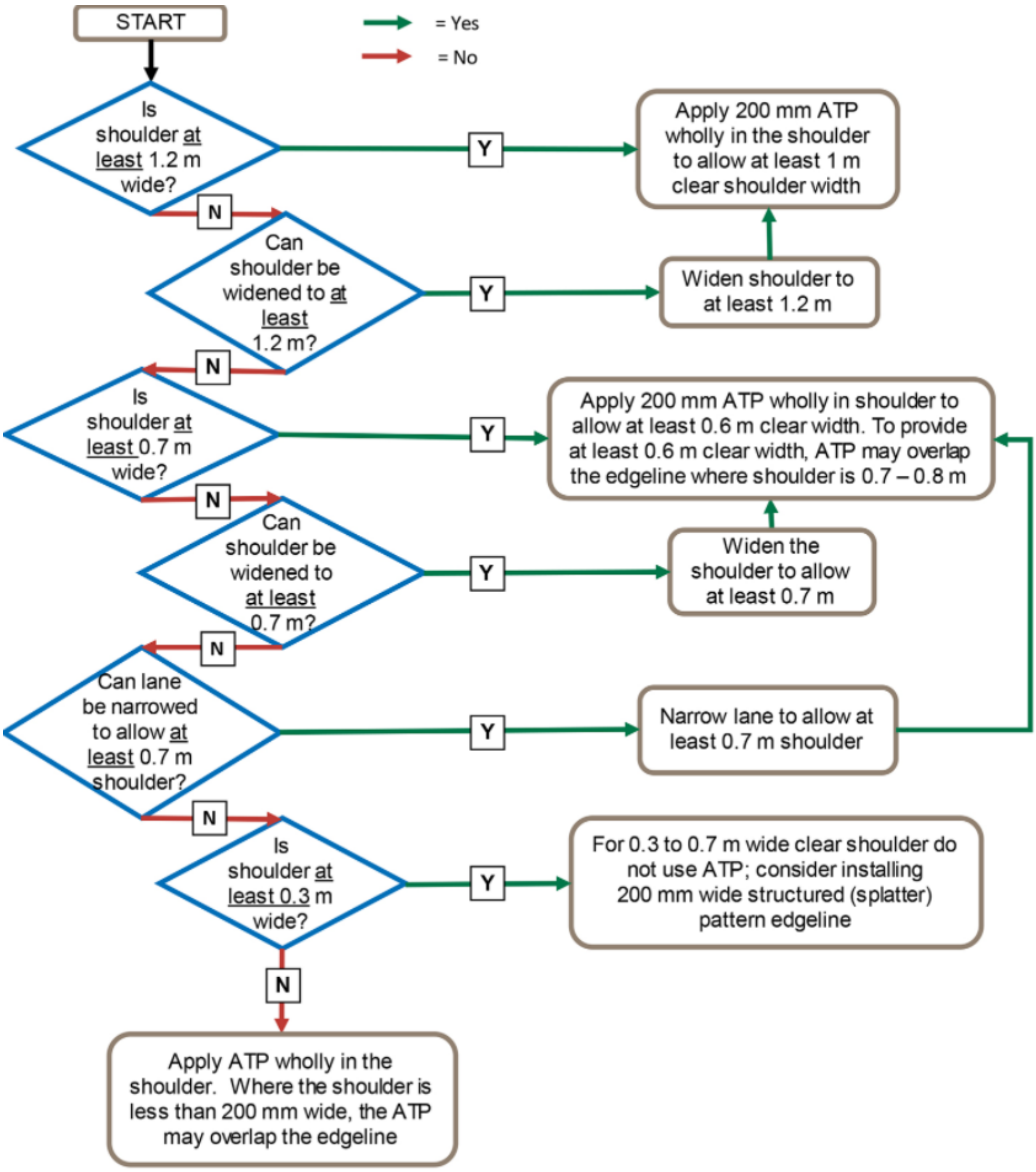

Figure 7-2: TCDM Part 5 decision flow chart for considering cyclists in relation to ATPM

7.4.3. Main messages

- Remember that two wheeled vehicles deserve the same priority under a Safe System approach as four wheeled vehicles.
- It is important to carefully consider the amount and type of cycle use on a road before decisions are made, and documented consultation with local cycle groups is required. Sensible advice is presented in the NZTA Traffic Control Devices Manual part 5.
- No evidence of any safety problems related to motorcycles crossing ATPM has yet been found either here or overseas.

7.5. Heavy vehicles

Heavy vehicle drivers are less affected by ATPM than the rest of the driving population (Edgar et al, 2009) and there is no evidence of any adverse impact other than environmental noise. Heavy vehicles need more space than light vehicles to manoeuvre so it is important that acceptable lane widths and overall carriageway widths are adhered to. There is anecdotal evidence that on tight left-hand curves and wide shoulder areas used as informal passing areas heavy vehicles may cross ATPM excessively, causing too much wear. This can be mitigated by omitting short lengths of ATPM. These situations are best avoided up front in the designs of new roads.

7.5.1. Main messages

- No evidence of heavy vehicle drivers being adversely impacted by ATPM.
- it is important that acceptable lane widths and overall carriageway widths for manoeuvrability are adhered to on heavy vehicle routes.
- Anecdotal evidence exists that heavy vehicles may cross ATPM excessively on tight left-hand curves.
- Best to avoid up-front at design stage or omit ATPM for short lengths on such curves.

7.6. Visibility

It must be remembered that ATPM have a visibility function as well as an audiotactile function. It is important that this function be maintained through the life of the ATPM. Cleanliness is of prime importance, meaning regular cleaning is essential (See section.8.3). Night-time visibility relates primarily to retroreflectivity and daytime visibility to luminance.

7.6.1. Night-time retroreflectivity

The retroreflectivity of ATPM has an important road safety function especially in wet, dark conditions where the reflective ATPM ribs can rise above water layers and improve visibility considerably. This is illustrated in Figure 7-3 from Thomas et al (2017) showing the wet weather impact of installing 150mm wide ATPM on edgelines and centrelines.

Retroreflectivity is to be measured according to Austroads Test Method AG:AM/T017 (Austroads, 2018). The method involves night use of a low angle retroreflectometer. From AG:AM/T017 the following requirements apply:

- For dry retroreflectivity (dry - R): The minimum retroreflectivity of the audio tactile ribs shall not be less than 150 mcd/m²/lux for the life of the rib.
- The wet retroreflectivity (condition of wetness - RW): of any pavement marking shall be a minimum of 80 mcd/lx/m^2 at any time after application.

Before treatment

After treatment

Figure 7-3: Wet weather visibility improvements following installation of 150mm wide ATPM on centre and edgelines (Thomas et al (2017, page 27))

7.6.2. Daytime luminance

The NZTA P30 Specification requires that markings be readily visible when viewed dry or wet in daytime for a forward distance of at least 150m or a Qd of 100 mcd/m²/lux. In order to achieve the above, it is important that ATPM show up clearly against the background of the pavements upon which they are laid during daylight hours. The extent to which this is achieved is measured by the Luminance Factor which is an indicator of the visual contrast between the marking and pavement surface during daylight hours. Luminance factor requirements for roadmarkings are found in Austroads (2018).

7.6.3. Main messages

- The retroreflectivity of ATPM has an important road safety function especially in wet, dark conditions where the reflective ATPM ribs can rise above water layers and improve visibility considerably.
- Marking should also be readily visible when viewed dry or wet in daytime.
- ATPM must be kept clean in order to provide maximum visibility.

8. Keeping existing ATPM effective

8.1. Overall maintenance and monitoring

The M24 specification covers only the maintenance period for which the contractor is responsible, post installation, which is a minimum of 12 months. ATPM may last up to 8 years or more. Maintenance, and monitoring to know when and where to maintain is required throughout this life. The process is described in the P30 specification. Network managers and their maintenance contractors should work together to achieve this systematically and effectively Also, network managers should be aware of future maintenance costs and make appropriate allowance in their financial planning. Lack of maintenance will compromise the safety benefits of the ATPM by eroding all their functions.

ATPM is generally placed in situations where they are seldom traversed. Occasionally they may be placed in more frequently traversed situations, in which case they should be more frequently inspected.

Maintenance of ATPM amounts basically to replacing lost or damaged ribs and cleaning. The P30 Specification allows an acceptable rib loss of 5% per kilometre, with a maximum of 10 missing blocks in sequence. Contractors' obligations and remuneration must be clearly set out in maintenance contracts. The condition of ATPM which have partially lost ribs can be assessed using the Subjective Rating System from Lester et al (2017). This system is described in Appendix 2: Subjective assessment procedure adapted from Lester et al (2017)

8.2. Snow plough damage

Lester et al (2017) measured sound and vibration from snow plough damaged ATPM (Figure 8-1). Very few ribs were missing, and some had become shortened.

Figure 8-1: ATPM damaged by snow plough (Lester et al, 2017, page 34)

The measurements indicated that audio tactile performance was still acceptable, meaning that shortened ribs do not necessarily indicate a need for replacement. Replacement decisions should be made on a case-by case basis using the Subjective Rating System.

8.3. Cleaning

ATPM need to be clean to preserve their retroreflectivity and daytime luminance. Figure 8-2 illustrates the deleterious impact of dirt on the visibility of ATPM. Cleaning is relatively inexpensive, increases the effective life of the ATPM and should be an integral part of maintenance contracts.

Mackie (2009a) mentioned successful cleaning of ATPM reported by contractors and network managers using low-pressure water blasting. The cleaning resulted in substantial improvements in retro-reflectivity. Mackie (2009a) also found that retroreflectivity was sometimes poor when the ribs of ATPM were still within specification and that visibly dirty ATPM (Figure 8-2) were common. Road Controlling Authorities may consider including in maintenance contracts a provision for contractors to wash ATPM every second year throughout the life of the installation. With climate change weather events may result in unexpected muddying of ATPM. This contingency should be allowed for in maintenance contracts.

Another option is to paint over the ATPM with reflectorised paint and anecdotal evidence suggests this lasts longer than the effects of water blasting. Where the ATPM is on top of the linemarking this may automatically occur due to programmed remarking.

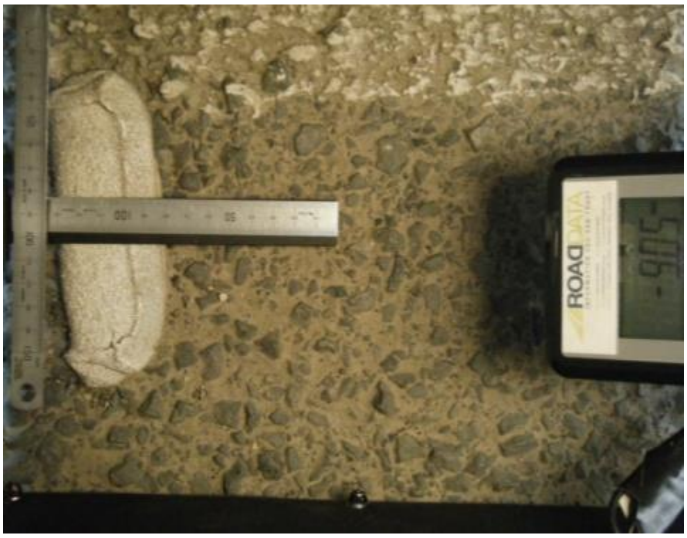

Figure 8-2: ATPM ribs, with good rib height, in need of cleaning (Mackie, 2009a, page 15)

8.4. Budgetary considerations

The processes involved in keeping ATPM effective are not without cost. Road Controlling Authorities should be mindful of this when negotiating their maintenance contracts, in order to ensure that their networks continue to benefit from the safety and traffic flow resilience impacts of ATPM.

8.5. Main messages

- Maintenance of ATPM amounts basically to replacing lost or damaged ribs and cleaning.
- Contractors' obligations and remuneration must be clearly set out in maintenance contracts.
- Snow plough damage does not necessarily indicate a need for replacement. Replacement decisions should be made on a case-by case basis.
- Cleaning or repainting the ATPM is relatively inexpensive, increases the effective life of the ATPM and should be an integral part of maintenance contracts.

9. Removal of ATPM for reasons other than resealing

ATPM should only be removed when absolutely necessary. It is much better to get their installation right in the first place. Removal might be necessary where residents have noise issues, however this should be rare due to appropriate care during site selection, or in the case of lane realignment such as when widening and/or barriers are constructed. In these cases, the removal needs to also remove the visible line. A grader blade has anecdotally been found effective on thermoplastic ATPM. High pressure water blasting is effective but very costly and risks damage of the surfacing. Austroads (2018) reports that Hong Kong considers grinding to be the "most effective method" due to its "simple and quick operation". Victorian Department of Transport (2020) recommends grinding followed by suction sweeping to clear any resultant debris. Note that the grinder must use a planer mill head. Any removal must follow the principles laid down in the NZRF Line Removal Guide, (https://nzrf.co.nz/techdocs/Line-Removal-Guide.pdf) which is endorsed by NZTA.

9.1. Main messages

- ATPM should only be removed when absolutely necessary. It is much better to get their installation right in the first place.
- Any removal must follow the principles laid down in the NZRF Line Removal Guide.

10. Life of ATPM

Austroads (2018) estimates the lifetime of ATPM to be 6-8 years - similar to the life of road surfaces. The life of any installation will depend on the road environment. Under-performance may come from reduced reflectivity or from reduced audio tactile response. Installations may last considerably longer under certain circumstances. Keisel (2007) found after testing some ATPM sites in Australia, that for some of the sites the ATPM is still effective approaching 10 years. This means that ATPM should not be automatically replaced at an assumed life but rather inspected and kept if in acceptable condition. A minimum height of 5 mm is needed to achieve acceptable driver warning. This can be taken as one indicator of acceptable condition.

10.1. Main messages

- ATPM should last as long as a seal-6-8years and may last longer.
- ATPM should not be automatically replaced at an assumed life but rather inspected and kept if in acceptable condition.
- Acceptable condition can be taken as a rib height of 5mm or more.

11. Reseals

11.1. In lane resealing

A reseal may be required when ATPM is still working effectively, such as when the ATPM has been installed sometime after the last seal. Where reseals are required in situations where ATPM is still working effectively their effectiveness can best be retained by in-lane resealing. This is where the trafficked lane adjacent to the ATPM is resealed but the non-trafficked shoulder and the ATPM is not resealed (Lester et al, 2017). Good sealing practice (described in Lester et al, 2017) is essential to ensure cycle and motorcycle safety are maintained. A well carried out in-lane reseal is illustrated in Figure 11-1 from Lester et al (2017).

Figure 11-1: A well carried out in-lane reseal (Lester et al 2017, page 14)

11.2. Avoid resealing over ATPM where possible

Resealing over ATPM is associated with the following problems (from the Line removal guide):

- Inhibiting of drainage from the road surface.
- Breakdown of some seal types (debonding) due to the extra stresses imposed on them by the nature of the profiles.
- Adverse impact on the reinstatement of markings following the reseal.

- If the ATPM needs to be moved in the future due to changes in road alignment sealing over the ATPM will add extra cost to their removal.
- Bitumen stuck to existing ribs following resealing, may pose a hazard to cyclists and motorcyclists as they may not detect the ribs.
- There may be difficulty in painting a new line to acceptable tolerances over ATPM which have been sealed over.
- If the shoulder is in bad condition, full resealing is appropriate whatever the condition of the ATPM and the ATPM should be replaced.

In lane resealing is likely to be possible for up to 2 reseals. Where it is not possible the ATPM should be inspected for audio-tactile properties post seal. If the audio-tactile properties are found not to be adequate, the ATPM should be removed and reinstated.

11.3. Remarking of associated lines

Whatever the mode of sealing, if existing ATPM is retained then the associated lines should be remarked as retroreflectivity declines faster than audio-tactile performance.

11.4. Synchronisation of ATPM renewal and sealing

ATPM renewal should be synchronised with seal renewal and new installations should not generally proceed within 2 years before a seal renewal as the pre seal life of the ATPM is likely to be uneconomic. This is important as experience in the industry suggests that in some cases the cost of the ATPM may rival the cost of the seal. However, this period may be varied downwards if indicated by a risk assessment. An exception is where in lane resealing can be positively identified as viable at the installation of the ATPM thus extending its life into the period of the new seal.

11.5. Main messages

- Avoid resealing over ATPM where possible
- Where avoidance is not possible the ATPM should be inspected for audio-tactile properties post seal. If the audio-tactile properties are found not to be adequate, the ATPM should be removed and reinstated.
- In lane resealing is recommended when reseals are required in situations where ATPM is still working effectively.
- If existing ATPM is retained, then the associated lines should be remarked as retroreflectivity declines faster than audio-tactile performance.
- ATPM renewal should be synchronised with seal renewal.

12. Topics related to ATPM ribs

12.1. Rib material

ATPM installers have the choice of thermoplastic or cold applied plastic (CAP) as the materials for the ribs. These products have advantages and disadvantages in different installation contexts. Austroads (2018) suggests that the variation between different batches and brands of either material may be more than the differences between the two materials. This is corroborated by Mackie (2009a) who found Thermoplastic and CAP to behave very similarly in an upper North Island trial. Therefore, practitioners should make their choice based on local conditions, product availability and product price rather than favouring either of the materials. Suppliers of materials must go through an approval process outlined in NZTA specification M24. Only products approved by NZTA may be used.

12.1.1. Main messages

- Thermoplastic and CAP to behave very similarly.
- Therefore, practitioners should make their choice based on local conditions, product availability and product price rather than favouring either of the materials.
- Only products accepted by NZTA may be used.

12.2. Spacing of ribs

NZTA specifies either 250mm or 500mm for edgeline ATPM and 250mm for white centreline ATPM. Rib spacing for yellow no-passing line ATPM is not specified. Lester et al (2017) carried out field measurements on a private road and recordings of in-car noise emanating from simulated ATPM with spacing of 250mm and 500mm. There was no appreciable difference in noticeability found between 500m and 250mm using this measure at the between 4 mm and 9 mm rib heights used. This could mean cost savings without safety penalty by using the larger pitch. Therefore, it is recommended that 500mm become the default option for all circumstances with the exception of locations such as tight curves where rib loss may be excessive. Such situations should be dealt with on a case by case basis. This should be accompanied by contractual arrangements to mitigate rib loss as this would be more problematic with a larger spacing.

12.2.1. Main messages

- It is recommended that 500mm rib spacing becomes the default option except at locations where rib loss may be excessive.
- Contractual arrangements to mitigate rib loss should be in place.

12.3. Height of ribs for replacement

The prescribed height for New Zealand ribs is 9mm but they are generally installed at a slightly higher level than that. According to Lester et al (2017) they appear to provide acceptable performance down to a level of 5mm. Therefore, 5mm should be the level below which replacement is required. This provision should be built into contractual arrangements.

12.3.1. Main message

- 5mm should be the height below which rib replacement is required.

12.4. Rib width

Research involving increasing rib width (Dravitzki et al (2012)) indicated that increased width did not impact markedly on the audiotactile performance of the ATPM. However increased width would be accompanied with road safety benefits from increased visibility. Therefore, ATPM on top of edge lines and centre lines should be at least 50 mm wider than one side of the underlying line width. ATPM beside line marking should be at least 150 mm wide and may be wider than the line marking.

Refer to TCDM Part 5 for layout diagrams.

12.4.1. Main message

- ATPM should be at least 150mm wide.
- ATPM on top of line marking should overlap the line marking.

13. Profiled high performance marking

These are specialised pavement markings generally installed on roads with a traffic volume of greater than 5000 vehicles per day and where a traffic safety strategy has identified the need for improved delineation. The conditions for their use lie in NZTA P/30 specification for high performance markings. Some profiled longitudinal line markings in use in New Zealand, which do not directly comply with the M24 specification have some audio tactile properties. Such profiles may be submitted to NZTA for approval and if approved for use as ATPM could be listed in M24. In this context they may be used in the same way as the familiar ribbed ATPM. The process involved is described in Appendix B of M24.

These profiled markings may be referred to by more than one name but are mostly consistently called “structured markings”. Depending on their particular characteristics they may be referred to more specifically as “splatter” (or random) pattern or “dot matrix”. A splatter/random structured marking is illustrated in Figure 13-1and a dot matrix structured marking is illustrated in Figure 13-2.

Figure 13-1: Structured ("splatter/random pattern") markings

Figure 13-2: Structured dot matrix marking

Structured markings are designed for enhanced visibility including during wet weather, rather than audio tactile effects. The enhanced wet weather visibility, compared to ordinary paint, is achieved by the markings being proud of the road surface, placing them above the road surface water.

Structured markings should be considered for use where ATPM cannot be installed in order to provide the next best safety performance. In such cases the sections of structured markings used as infill between gaps in ATPM should achieve consistency of appearance of line width, where this is practical.

13.1. Main messages

- Some high-performance profiled markings have audio tactile properties without directly complying with the M24 specification.
- Such profiles may be submitted to NZTA for approval for use as ATPM and if approved would be listed in M24. The relative efficacy of such markings should be derived to assist designers.
- Structured marking should be considered where ATPM cannot be installed.

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[9] AP-R578-18 | Austroads

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Appendix 1: Key documents

NZTA Specification P30

This specification sets out the requirements for high performance roadmarkings for road safety. This specification applies to specialised pavement markings which are usually installed on roads with a relatively high traffic volume or where a traffic safety strategy has identified the need for improved delineation. Such markings may also be submitted to NZTA for approval to be used as ATPM.

NZTA Specification M24 and associated notes[10]

This specification applies to longitudinal ATPM roadmarkings applied alongside the traffic lane.

NZTA Traffic Control Devices Manual Part 5: Traffic Control Devices for general use-between intersections

This includes typical layouts for ATPM.

Austroads (2018) Harmonisation of Pavement Markings and National Pavement Marking Specification Austroads Publication No. AP-R578-18[11]

This report documents a project undertaken to achieve harmonisation of roadmarking between Jurisdictions. It contains a wealth of valuable ATPM information.

Austroads (2018) Safe System Assessment Framework Austroads Publication No. AP-R509-16

This report proposes an assessment framework designed to help road agencies methodically consider Safe System objectives in road infrastructure projects.

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[10] Audio tactile profiled road markings | Waka Kotahi NZ Transport Agency (nzta.govt.nz)
[11] AP-R578-18 | Austroads

Appendix 2: Subjective assessment procedure adapted from Lester et al (2017)

The rating system uses a regular car and at least two assessors in the car, without significant eyesight or hearing impairment (using corrective lenses or devices if necessary). The driver must have a current driving licence and must drive with due care and attention at a time when traffic volumes are low. The assessors drive over the subject site at least twice (but more if required to obtain agreement between their ratings). Each drive includes periods of:

- Driving with the vehicle completely within the traffic lane, as per regular travel, making no contact with the ATPM.
- Steering smoothly but to make brief or 'glancing' contact with the ATPM as if accidentally or inadvertently drifting while driving.
- Steering to make sustained (0.5 to 1.0 second) contact with the ATPM.

The assessors jointly assign ratings according to the extent to which they notice:

- The audio effects relative to travel on the adjacent road, scored from 0 to 4.
- The tactile effects relative to travel on the adjacent road, scored from 0 to 4.
- The visibility of the ATPM, scored from 0 to 2.

The total score from the subjective rating system is summed:

- If the summed score is less than 5, the ATPM effects are deemed deficient and new ATPM should be instated.
- If the summed score is S or greater, the ATPM is considered effective and can be retained.

Appropriate health and safety management is required.