Guidelines for using audio tactile profiled (ATP) roadmarkings

NZ TRANSPORT AGENCY
WAKA KOTAHI

New Zealand Government

More information …

Published October 2010

ISBN 978-0-478-37119-2 (print)

ISBN 978-0-478-37118-5 (online)

If you have further queries, call our contact centre on 0800 699 000 or write to us:

NZ Transport Agency
Private Bag 6995
Wellington 6141

This document is available on the NZTA's website at www.nzta.govt.nz.

Contents

Summary of specifications and recommendations for ATP roadmarking use

Key specifications

Please see NZ Transport Agency specifications P30 (www.nzta.govt.nz/resources/high-performance-roadmarking/docs/high-performance-roadmarking.pdf), M24 (+notes) and *Manual of traffic signs and markings* (MOTSAM) for full details.

ATP edgelines

- Edgeline dimensions: 150mm wide profiles. Blocks to be placed on or beside the flat or structured marking, such that a minimum of 3.35 metres of lane width is maintained between centreline and edgeline ATP block edges (ie not centre to centre).
- Inter-block spacing: The pitch of the blocks will be specified by the engineer for each section of the network and the pitch specified will be either 250mm or 500mm.
- Should be installed across minor accessways and on left-hand curves (where a product life of greater than two years is likely).
- Should not be installed across (and approaches to) intersections, major accessways and bridges with insufficient shoulder width or adjacent to turning bays.
- Do not apply ATP edgelines in particularly high wear areas where ATP roadmarkings are likely to be less effective such as winding roads with many tight curves, unless the crash history and lane and shoulder width allow.

ATP centrelines

- No overtaking lines: Superimposed on the no overtaking lines. If the ribs are wider than the no overtaking line then the ribs shall project into the traffic lane maintaining a clear 100mm gap between the double lines.
- White ATP broken centrelines (by NZTA National Office approval only). Inter-block pitch is to be 250mm. 200mm wide ATP block on 100mm paint or long-life centreline.

Product: Thermoplastic or cold applied plastic – must be NZTA approved.

Performance: See P30 for details.

Monitoring and quality assurance: Procedures outlined in contract documents must be followed. Network consultants and mangers should monitor ATP roadmarkings in addition to contractor monitoring.

Maintenance: The NZTA P30 specification states that the maximum permitted block loss is 5% within each km, with no more than 10 missing blocks in sequence.

Key recommendations

ATP should work as a system: ATP roadmarkings should be treated as a system with both edge and centrelines being treated along a continuous route (with only essential breaks in treatment) where there is a minimum lane width of 3.35m between centreline and edgeline ribs.

Shoulder requirements: 1m minimum to accommodate cyclists. Keep shoulder clean to provide 'effective' space for cyclists. Narrower shoulders can be treated to provide a continuous treatment but careful consideration of cyclist requirements (including consultation) must be carried out.

Noise: Evaluate likely noise impacts, do not install ATP roadmarkings where noise disturbance is likely. Following installation remove ATP on a case by case basis if necessary.

Barriers: Use ATP roadmarking next to solid or wire median barriers if favourable benefit cost ratios are achieved by balancing ATP installation costs with the likely reduction in vehicle vs barrier crash costs

Cleaning: ATP roadmarkings should be cleaned at least once, mid-way through their expected life-time using low pressure waterblasting.

Removal, reinstatement and reseals: Ideally, ATP removal should be avoided. For guidance on removal, reseals and reinstatement, please see this section in this report.

Scope of this document

The purpose of these guidelines is to provide up-to-date and objective evidence and information regarding the use of audio tactile profiled (ATP) roadmarkings. This will give more confidence to network managers who are considering the installation of ATP roadmarkings and will help to provide a more consistent approach to their use throughout New Zealand. These guidelines are not intended to replace the information provided in MOTSAM and the NZTA specifications (which give more operational detail on using ATP roadmarkings), but rather to provide a rationale for using ATP roadmarkings in various circumstances. There are some instances where these guidelines suggest practices that are contrary to MOTSAM or the specifications. These instances should be considered as suggestions for future updates to the NZTA documents.

There are three main sections within this document. The first section provides information regarding the safety benefits of ATP roadmarkings and the driver behaviour that might be expected when they are used. The second section provides information mostly related to when and where ATP roadmarkings should be used, as well as information regarding their maintenance and removal. The final section addresses some of the common issues and myths related to the use of ATP roadmarkings.

These guidelines are not intended to provide detailed information about ATP products and installation processes. For this information, please see the NZTA specification M24 and M24 notes, along with information that is provided on the NZ Roadmarkers Federation website.

Background

In New Zealand, ATP roadmarkings are typically plastic lumps (also called blocks or ribs) that are laid onto the road surface (figure 1, left), or as a combined rib/line project (figure 1, right), normally at spacings of 250 or 500mm.

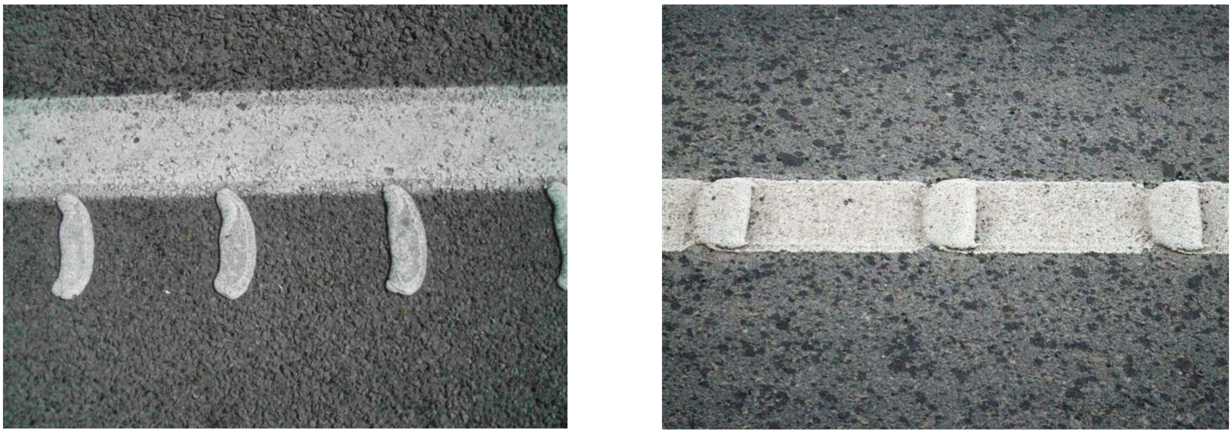

Figure 1: Audio tactile profiled (ATP) roadmarkings used in New Zealand

This type of ATP roadmarking is also used in Australia and in the UK, while in the US and parts of continental Europe, wider markings that are milled into the pavement surface are typically used.

Literature

Safety benefits

ATP road markings are increasingly being used as a road safety countermeasure, in part, as a result of an increasing number of studies that have demonstrated positive safety benefits from their use. In a review of 24 key reports, citing more than 500 source documents (Baas et al. 2004), the effectiveness of ATP roadmarkings have been shown to reduce all types of crashes by 2% to 44% with an average reduction of more than 27%. When considering only 'run off road' (ROR) crashes, shoulder rumble strips were found to reduce crashes by 20% to 80% (an average of 32% for all ROR crashes, 42% for fatal ROR crashes). Similarly, centreline rumble strips were found to produce significant reductions in head-on and sideswipe crashes ranging from 21% to 37% of reported crashes.

Updated estimates for the safety effects of ATP edge and centrelines have recently been published in a large-scale synthesis of North American findings (Torbic et al. 2009). The crash reduction estimates for rural two-lane roads are as follows:

For shoulder rumble strips:

- 15% (std error = 7) reduction in all single vehicle run off road (SVROR) crashes.
- 29% (std error = 9) reduction in SVROR fatal and injury (FI) crashes.

For centreline rumble strips

- 30% (std error = 5) reduction in all target (head-on and opposite direction sideswipe) crashes.
- 44% (std error = 6) reduction in FI target crashes.

Because fatal and injury crashes account for approximately 85% of the social costs associated with all crashes in New Zealand, the SVROR FI (edgeline) and FI target (centreline) crash reduction figures may be the most relevant for New Zealand.

Limited evidence was also reported that shoulder rumble strips are likely to result in a positive safety benefit during low-lighting conditions by providing positive guidance along the travel lanes. This represents the first attempt to understand the safety benefits derived from the visual guidance provided by ATP roadmarkings.

Another recent review (Hatfield et al. 2009), using Australian ATP conditions, found that for before/after or treatment/control studies, edgeline ATP roadmarkings appeared to reduce single vehicle ROR crashes by an average of approximately 22% (range 7.3% to 49.8%). Similarly, centreline ATP roadmarkings appeared to reduce opposing direction crashes by an average of 25%. The greatest benefits to all crashes were shown to occur when ATP edgelines and centrelines were used together.

The limitations of previous studies, including the fact that most analyses have been carried out on North American roads where milled audio tactile lines are used, have also been identified (Hatfield et al. 2009). As a result of the differences between the milled and extruded delineation systems, the findings from North America might be less applicable to countries such as New Zealand, Australia and the UK, where plastic extruded lines are used. Nevertheless, it has been shown that the extruded ATP roadmarking systems produce safety benefits that are comparable to the findings of previous North American studies (Hatfield et al. 2009).

Despite the clear benefits that ATP road markings offer, these markings are expensive and so transport authorities often compare the benefits and costs of their use. Benefit/cost ratios (BCRs) of between approximately 4 and 20 have been estimated using accident prediction models within a delineation cost management tool for a range of typical road environments in New Zealand (Mackie and Baas 2007).

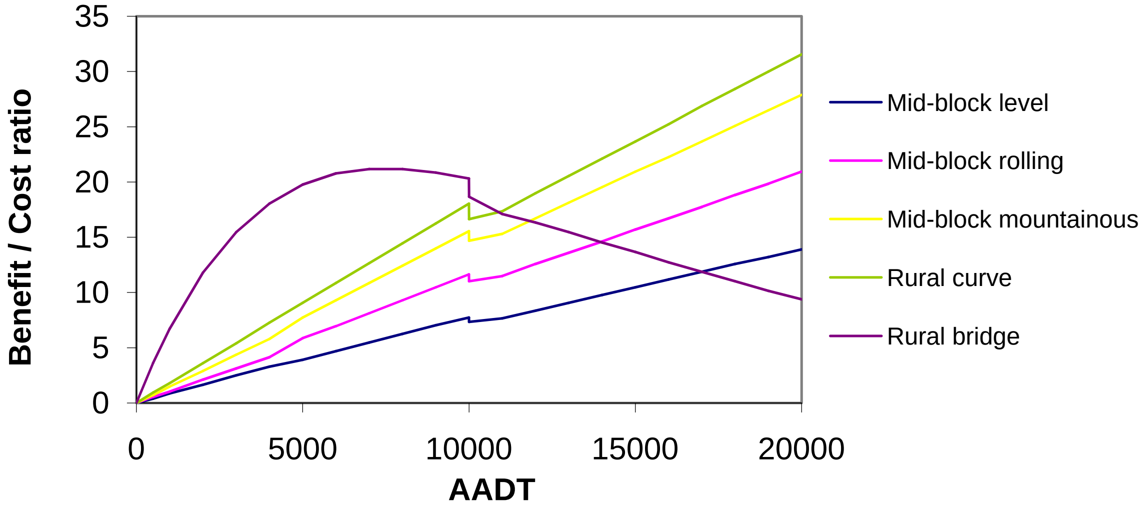

Figure 2: The relationship between two-way annual average daily traffic (AADT) (vehicles per day) and benefit/cost ratio using the cost management tool (Mackie and Baas 2007). The delineation upgrade is from 100mm waterborne painted edge and no overtaking centrelines to 150mm profiled CAP (at $7,500 per km laid and including traffic management) with ATP ribs (250mm centres) on or outside existing painted edgeline, and ATP ribs on double yellow centreline.

Notes:

1. A generalised crash reduction factor of 25% has been used.
2. The downward step that exists at 10,000 vehicles per day is due to the added costs of temporary traffic management.

3. In reality, ATP roadmarkings are not recommended on bridges without sufficient shoulder width and ATP edgelines on mountainous roads may be less effective.

Analyses of early actual ATP installations in New Zealand (Otago and Canterbury) have provided some validation of the BCRs of ATP installations estimated by Mackie and Baas (2007), as have some independent BCR evaluations for specific installations since this report was published.

Clearly these numbers are estimates, but the graphs shows that for a typical state highway with an AADT of approximately 10,000 VPD, a BCR in the range of 7–10 is to be expected. It should be noted that since this report was published, more consideration has been given to maintenance and removal costs (discussed later), and therefore the overall costs of ATP might in reality be higher. However, this may be offset by decreases in ATP costs through competition between suppliers and roadmarkers, along with larger contracts.

Driver behaviour and ATP roadmarkings

In parallel with studies of the safety benefits of ATP roadmarkings, some studies have focused on the behaviour of drivers on roads with ATP roadmarkings (Anund et al. 2008, Finley et al. 2009, Miles et al. 2006, Porter et al. 2004 and Noyce and Elango 2007). In general, it appears that ATP roadmarkings promote better lane keeping (Charlton 2006, Finley et al. 2009, Mackie 2009, Porter et al. 2004), with drivers tending to position themselves further from lines that have been treated with ATP roadmarkings. It has also been shown that drivers react very quickly to ATP markings, their approach angle to the markings is usually very shallow (typically less than two degrees) and drivers typically travel laterally by approximately one foot (approximately 0.3 m) after driving on ATP lines before moving back towards the centre of the lane (Finley et al. 2009). There is no evidence that drivers react suddenly to ATP roadmarkings or that ATP roadmarkings cause potentially unsafe lane placement (Mackie 2009, Miles et al. 2006, Noyce and Elango 2007 and Porter et al. 2004) which is consistent with the evidence of their overall safety benefits. Mackie (2009) found that ATP roadmarkings on white dashed centrelines did not prevent deliberate overtaking and ATP edgelines did not prevent (but did reduce) edgeline crossing. Given that lane keeping in general was improved, this suggests that ATP roadmarkings discourage inadvertent, but do not prevent deliberate, lane departures. This reinforces the belief that ATP roadmarkings are 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.

Public perceptions of ATP roadmarkings

The motoring public's perception of ATP roadmarkings are important because negative perceptions could lead to an undermining of support for their use. Ideally, public perceptions and objective evidence should be aligned.

Research suggests that the clear majority of motorists believe that ATP centrelines have safety benefits (Hatfield et al. 2008, Tuovinen et al. 2005 (in Hatfield et al. 2008), Mackie et al. 2009), with only few motorists believing that these roadmarkings have no safety benefits or are dangerous.

A survey of 775 drivers was conducted in Australia to explore drivers' beliefs and behaviours relevant to the road safety effects of ATP roadmarkings (Hatfield et al. 2008). While the overall benefits were demonstrated by the survey findings, motorists felt that ATP roadmarkings were more helpful at night than during the day and more helpful in wet rather than dry conditions. This indicates that the visual benefits of ATP roadmarkings are appreciated by motorists as well as their audio and tactile effects.

Effects on motorcyclists and cyclists

There is limited information regarding the risks (or benefits) that ATP roadmarkings pose to cyclists and motorcyclists, although a study of motorcycle behaviour on roads with centreline rumble strips in the US (Miller 2008) provides some guidance. The findings of this study, along with anecdotal evidence in New Zealand suggest that ATP roadmarkings do not pose a specific risk for motorcyclists. Some motorcyclists have indicated that as long as they can see them, they can take reasonable steps to avoid them. For this reason, ATP roadmarkings where the rib is outside or wider than the base line are beneficial.

For pedal cyclists, current research by OPUS Central Labs suggests that a clear path ahead is one of the most important considerations for cyclists. As well as sufficient shoulder width, debris and other obstacles like parked vehicles and edge-break need to be considered for cyclist safety. See the sections ‘Shoulder requirements’ and ‘Issues and myths’ later in this document for more discussion of cyclist considerations.

Effects of ATP roadmarkings on heavy vehicles

There is anecdotal evidence of some annoyance caused by ATP roadmarkings on truck drivers. However, the change in noise levels and vibration levels when traversing ATP markings compared to being on unmarked roads are significantly less for trucks than for cars (Dravitzki 2009). It may be that the wider and longer heavy vehicles are more likely to run over ATP roadmarkings, causing a degree of annoyance over the course of a journey. There have also been reports of ATP roadmarkings causing damage to hubometers and that they may cause steering problems in some types of truck. However, there is no objective evidence that ATP roadmarkings adversely affect truck travel and based on this lack of evidence, there should be no special provision for heavy vehicles. As for light vehicles, placing ATP ribs on the outside of the line on left-hand curves and omitting them completely from edgelines at highly used entranceways might assist if there is a perceived truck driver annoyance issue.

Best practice

This section provides specific guidance on various aspects of ATP roadmarking use. The guidance is based on current knowledge and evidence and reference to other sources is provided where appropriate. Previous guidance material for the use of ATP roadmarkings include:

- *Review of best practice for rumble strips in New Zealand*, by DEC Munster and VK Dravitzki (1998).
- *Memorandum: audio tactile line markings*, by C Brodie, Transit NZ, (2007).

This material has been considered in the development of present guidelines.

Key documents

In addition to the material provided in this guide, familiarisation with key NZTA reports and specifications is essential if ATP roadmarkings are to be used appropriately and consistently.

NZTA specifications P30 and M24

Use this link to access these specifications: www.nzta.govt.nz/resources/results.html?catid=257.

P30

This specification sets out the requirements for high performance roadmarkings for road safety. This specification applies to specialised pavement markings installed on roads with a traffic volume of > 5000 vehicles per day and where a traffic safety strategy has identified the need for improved delineation. Work carried out under this specification comprises the supply and placement of a system, which may include one or a combination of:

- traditional (flat) roadmarkings delivering high performance in wet and dry
- night-time conditions
- structured roadmarkings
- discontinuous ATP roadmarkings
- pre-form materials and tapes for roadmarking
- profiled roadmarkings
- markings designed for visibility in falling rain.

M24

This specification applies only to audio tactile profiled (ATP) roadmarkings that provide all three of audio, tactile (vibratory) and visual information to road users. This specification applies only to longitudinal ATP roadmarkings applied alongside the traffic lane and excludes transverse ATP roadmarkings applied across the traffic lane.

Manual of traffic signs and markings (MOTSAM)

Part 2 of MOTSAM provides policy and location requirements for roadmarkings, delineators and hazard markers. Its use is mandatory on state highways and it is recommended that other road controlling authorities also use it on their roads, to ensure consistent roadmarking and delineation nationally.

Use this link to access the relevant section of MOTSAM: www.nzta.govt.nz/resources/motsam/part-2/docs/motsam-2-section-4.pdf.

Local and recent research reports

There are a large number of research reports regarding ATP roadmarkings. The following reports provide local and recent information that is directly applicable to ATP roadmarking practice in New Zealand.

South Waikato and Taupo target 2010 remediation treatments monitoring. Prepared for SWATT 2010 Corridor Study Team by TERNZ Ltd and TARS (Waikato University), 2006.
This report describes three phases of data collection undertaken to assess the effects of several delineation treatments, including ATP edge and centrelines, designed to affect driver behaviour.

The usability and safety of audio tactile profiled roadmarkings. NZTA research report 365, February, 2009.
The purpose of this project was to support the development of best practice guidelines for the safe and effective use of audio tactile profiled (ATP) roadmarkings, also known as rumble strips, in New Zealand to help facilitate their wider use. Use this link to access this specification:
www.nzta.govt.nz/resources/research/reports/365/index.html.

The cost effectiveness of delineation improvements for safety. NZTA research report 322, 2007.
The purpose of this research was to develop a cost management tool that would assist road controlling authorities and their consultants to prioritise delineation treatments that have added safety benefits compared with standard roadmarkings. The spreadsheet based tool is also available, but as this was published in 2007, costs and benefits are subject to change over time. Use this link to access this specification:
www.nzta.govt.nz/resources/research/reports/322/index.html.

The effect of dashed and solid white audio tactile centrelines on driver behaviour and public acceptance. Prepared for the NZTA by TERNZ Ltd, April, 2009. The NZTA commissioned a trial on SH27 to evaluate the effects of white dashed and white continuous ATP centrelines (with and without ATP edgelines) on driver behaviour and public acceptance. This report describes the trial that was conducted.

Investigation of audio tactile roadmarking performance in the upper North Island. Prepared for the NZTA by TERNZ Ltd, September, 2009.
The purpose of this investigation was to give a better understanding of the performance of different ATP roadmarking products and layouts through time and under different conditions. By learning from this investigation, practices that lead to more effective, durable and ultimately more affordable ATP roadmarkings may be adopted for future ATP roadmarking contracts.

Evaluation of the contract process for 2009 audio tactile roadmarking projects. Prepared for the NZTA by TERNZ Ltd, December, 2009.
The objective of this project was to evaluate the contracting procedures used in eight recent (subsequent to the NZTA P30 specification) audio tactile profiled roadmarking (ATP) contracts and therefore identify procurement practices that could be improved.

General considerations

ATP roadmarkings should be used as a continuous treatment system rather than as a series of 'spot' treatments at high crash risk locations. ATP contracts are now being let for extended lengths of road, but care needs to be given to the number of breaks that might occur over the treatment length. Noise complaints, bridges and intersections and road maintenance can all result in breaks in ATP lines, usually for good reason. However, these breaks must continually be balanced with the general need to provide a continuous treatment. MOTSAM states that on rural roads, the desirable minimum length of profiled line marking is 1km. However, increasingly longer sections of ATP roadmarking are being installed to treat entire routes.

Edgelines/centreline combinations

Given the predominance of SVROR crashes in New Zealand, edgeline ATP roadmarkings provide a greater overall road safety benefit than centreline ATP roadmarkings. However, recent research has found that the benefits of ATP roadmarkings are maximised when they are applied to edge and centrelines together (Hatfield et al. 2009). This way they can help to prevent all types of lane departure crashes. For this reason, ATP roadmarkings should be considered on both edge and centrelines wherever possible, particularly on higher volume, higher risk highways where cross centreline crashes are a concern.

There is a misconception that edgeline ATP roadmarkings cause dangerous driver behaviour by forcing motorists towards the centreline. There is no evidence to support this and conversely the safety benefits of ATP edgelines are well documented. See the 'Issues and myths' section for further discussion on this.

It is desirable that a clear lane width of 3.5m should be available between ATP roadmarkings. However, a minimum distance between ATP markings of 3.4m was trialled in a road safety campaign in the South Waikato without adverse effects. As a guide, a minimum of 3.35 between ribs has now been adopted.

Figure 3: ATP white dashed centrelines

ATP roadmarking on white dashed centrelines

A recent evaluation of ATP white dashed centrelines on SH27 (Mackie 2009) showed that on right-hand curves, ATP ribs on dashed or solid white centrelines resulted in vehicles tracking further away from the centreline. On straights, where passing opportunities existed, ATP ribs on the white dashed centrelines did not restrict overtaking. Although MOTSAM states that ATP centrelines should only be used in 'no-overtaking' situations, recent findings suggest that they may improve safety and that there is a case for their increased use where 'crossing the centreline' crashes are a problem. So that they are clearly visible to motorcyclists, 200mm wide ribs should be used on a 100mm centreline. They should be also placed at 250mm intervals so that they produce a sufficient audio tactile effect to be effective.

ATP roadmarking on single dashed yellow centrelines

Research to date has shown that ATP roadmarkings improve lane keeping but do not appear to prevent deliberate lane departures, nor do they appear to cause confusion for motorists. Given these findings, it would seem logical that ATP roadmarkings on single dashed yellow centrelines would offer safety benefits and would not pose a risk to those who might travel over them (as there is potentially a passing opportunity in the opposite direction).

Shoulder requirements

Research suggests that drivers may only need approximately 0.3m of shoulder to respond to ATP roadmarkings (Finley et al. 2009), therefore cyclists are the main concern when considering shoulder width. Current OPUS research has found that cyclists generally need a minimum of 0.7m, but this does not consider a desirable separation between vehicles or avoiding detritus or other obstacles that may exist in the shoulder. In order to accommodate cyclists, ideally 1.5m (MOTSAM) but a

Figure 4. Sufficient shoulder width is needed to accommodate cyclists where ATP roadmarkings are used

minimum shoulder width of 1m should be present before ATP roadmarkings are used. However, a balance between accommodating cyclists and providing a continuous safety countermeasure for motorists needs to be reached and ATP roadmarkings may be used with narrower shoulder widths in special circumstances. It is important that engineers and consultants carefully consider cycling use on a road before decisions are made, and documented consultation with local cycle advocacy groups is required.

Where not to apply ATP roadmarkings

MOTSAM states that ATP roadmarkings must not be used in the vicinity of intersections and major accesses because cyclists and motorcyclists are likely to need to cross them. ATP roadmarkings applied across these areas may also wear excessively, which may not be cost-effective. The gap in ATP roadmarkings may also help to provide a more intuitive delineated intersection.

ATP edgelines may not be as effective, and may wear excessively on winding roads with many tight curves. Lane departures are less likely to be inadvertent as motorists are more likely to intentionally cut curves in an attempt to straighten them and provide a more comfortable journey. Unless there is a particularly high crash rate and lane and shoulder width are sufficient, another long-life product might be a better option.

To accommodate cyclists, ATP roadmarkings should not be used on bridges or their approaches, unless the full shoulder width is maintained (minimum 1m). ATP roadmarkings should be maintained across minor or residential properties unless it is likely that noise will be a problem for residents. See MOTSAM for more detail on the installation of ATP roadmarkings at intersections and entrances.

In general, ATP roadmarkings are not used in urban environments due to noise issues. However, they may be effective in some circumstances where residents are less likely to be annoyed by noise from vehicles tracking over the ATP roadmarkings.

Figure 5. ATP roadmarkings should be omitted from major accessways and intersections but continuous across minor entrances unless noise is a problem for residents

Residents and noise

The Mainroads (Queensland) *Guidelines for audio tactile line marking* states the following:

> 'Do not install ATLM within 500 metres of a residential building unless appropriate noise barriers are installed, or unless the frequency and severity of fatigue related crashes in the area are such that a continuous treatment is considered essential on safety grounds. In such cases, a distance of 200 metres may be acceptable subject to consultation with the property owner.'

While it is attractive to have tangible guidelines regarding noise and the use of ATP roadmarkings, in many instances the regular frequency of dwellings would create a very discontinuous and less effective treatment if such guidelines were strictly adhered to. Also, levels of noise disturbance can be affected by much more than distance alone, including individuals' sensitivity to noise. In order to deal with the tension between reducing noise impacts and providing a continuous safety treatment for road-users, it is suggested that the following approach be adopted:

1. Before a decision to install ATP roadmarkings is made, an evaluation of the likely noise impacts along the route should be carried out. If the route treatment is likely to be severely compromised by the omission of

significant ATP roadmarkings along the route, then ATP roadmarkings may not be appropriate for the route.

2. If it is decided to install ATP roadmarkings along a route, then the markings should initially be planned on a continuous basis with breaks only for intersections, bridges and major accessways.
3. A detailed examination of the route along the planned ATP installation should then be carried out to determine the likely effects of ATP noise on nearby residents. Where residents are likely to be affected, ATP roadmarkings should be omitted within 100m of the dwelling. In order to evaluate the likely effects of ATP noise, the following should be considered:
   - Distance of the dwelling from the road.
   - Existing barriers between the dwelling and the road (eg solid fence, earth cutting, other buildings).
   - The expected frequency in which ATP roadmarkings are likely to be driven over (especially during night-time).
   - Predominant wind direction.
   - Existing levels of noise from the road.
4. Following the installation of the ATP roadmarkings, it is possible that despite best efforts to mitigate potential noise problems, residents still find ATP generated noise annoying. In these instances ATP should be removed on a case-by-case basis, with due consideration of the road safety benefits that would be lost through their removal. Over time, the situations where ATP roadmarkings are likely to be annoying for residents should become clearer and these guidelines can be up-dated accordingly.

Use with barriers and physical medians

Research has shown that motorists need relatively little shoulder recovery space when ATP roadmarkings are used and anecdotally, highway engineers have found less damage occurs to wire-rope barriers when ATP roadmarkings are placed on the inside edgeline, very close to the barrier. For these reasons, ATP roadmarking on right-hand edgelines adjacent to barriers and physical medians are recommended, although further consideration of the costs and benefits needs to be carried out. Because the barrier is preventing right-hand lane departures, the ATP is no longer providing this safety benefit. However, the ATP is helping to prevent damage to the barrier. Therefore, when considering benefits and costs, rather than considering the social costs of opposite direction crashes, the total costs of vehicle vs barrier incidents (barrier and vehicle damage plus, any crash social costs) need to be compared with the costs of installing the ATP roadmarkings.

Signposting

If ATP roadmarkings are installed along a route where people may be unfamiliar with them, then signposting should be erected for a three-month period and then removed. If the installation is within an area of road network where ATP roadmarkings are commonplace then they are not required. As ATP roadmarkings become more prevalent, and motorists become familiar with them, this requirement will no longer apply.

Maintenance of ATP roadmarkings

Over time, ATP blocks (ribs) can be lost or removed for a number of reasons including road damage, residents' noise complaints or surface reseals. The NZTA's P30 specification states that the maximum permitted block loss is 5% within each kilometre, with no more than 10 missing blocks in sequence. In exceptional circumstances ATP ribs may fall below specification before their expected life-end. As a general principle, gaps in ATP installations should only occur at specified locations. See 'Where not to apply ATP roadmarkings' earlier in this document.

It is important that the respective responsibilities of contractors who install and maintain ATP roadmarkings are well understood and clearly defined in contractual agreements. Active monitoring by contractors and network managers (as per P30 and M24) will also ensure that adequate maintenance of ATP roadmarkings is carried out.

P30 states that the contractor shall not be held responsible for roadmarking defects where it can be shown that the defect can be directly attributed to:

- on-road-operations such as gritting or snow-ploughing, or
- road/pavement-behaviour such as bleeding, cracking or rutting, or
- pavement surface or substrate failure such that ATP markings are punched into the pavement surface, or
- tampering by a third party or unreasonable and unexpected trafficking, or
- abnormal conditions.

Cleaning ATP roadmarkings

A number of contractors and network managers have reported success in cleaning ATP roadmarkings, with significantly renewed retro-reflectivity following low-pressure water blasting. In a recent investigation of ATP performance in the upper North Island (Mackie 2009a) it was found that often retro-reflectivity was poor when ATP ribs were still within spec and also visibly dirty ATP roadmarkings were common. It is recommended that maintenance contractors wash ATP roadmarkings at least once, preferably mid-way through the expected life-time of the ATP. This relatively inexpensive procedure will, in most cases, significantly increase the effective life of the markings, and provision for this should be built into maintenance contracts.

Figure 6. New ATP ribs, with good rib height, in need of cleaning (along with the road surface in this case)

Removal, reinstatement and reseals

The removal of ATP ribs should ideally be avoided but is sometimes necessary, particularly when a nearby resident has issues with noise. Recent New Zealand trials suggest that a grader blade (if the ribs are big enough) or grinding are effective options. High pressure waterblasting appears to be most effective but is also very costly.

In Australia, evaluations of ATP roadmarkings that have been sealed over have been carried out (Kiesel 2007). It was found that a 7mm reseal over existing ATP markings resulted in a ‘reasonable’ audio tactile response when driven over whereas a 10mm seal resulted in a medium to poor response and 14mm seal resulted in a poor response. Obviously, variation will occur depending on the condition of the ATP ribs. In New Zealand there are examples of ATP roadmarking being resealed over. Where the ribs were relatively new (SH1 South of Whangarei), a clear audio tactile response was provided, and where the ribs were worn (SH27 North of Matamata) there was little or no ATP effect.

Figure 7. ATP rib removal via grader blade

Given the information that exists, the following is recommended for ATP removal or reseals:

- For reseals, if the ATP ribs are significantly worn or have been punched into the seal, then resealing and reinstating the ATP roadmarking should proceed as usual with no ATP removal or pre-treatment.
- If resealing is to occur over relatively new ribs (and this should be avoided as much as possible by careful network management) and a fine grade chip is to be use for the reseal, then the ATP should be resealed over and a continuous line should be marked either immediately next to or over the existing ribs. When the ribs fall below specification, then the ATP roadmarking will need to be reinstated
- If a course grade chip is to be used over fresh ATP ribs and residual ATP response is non-existent or very faint, then reinstatement of ATP roadmarking can proceed as usual, otherwise the ribs must be mechanically removed prior to the reseal.

Note: Figure shows that the bitumen has stuck to the existing ribs following resealing. This potentially poses a hazard to cyclists and motorcyclists as they may not detect the ribs. Until the bitumen has worn off through trafficking, a temporary ‘rumble edgeline’ warning sign should be placed at the beginning of the resealed section.

Figure 8. A reseal using a fine grade chip over relatively new ATP ribs. Note the new line has been incorrectly placed and should be immediately adjacent to the ATP ribs

Renewal

Recent research (Mackie 2009a) has shown that, to date, ATP roadmarkings typically have a life of approximately 3–4 years, depending on the road environment. Given that a road’s seal life can typically be approximately eight years, ATP will need to be renewed within the life of the seal. Under-performance may come from reduced reflectivity or from reduced audio tactile response (typically when rib height is worn to 3–4mm, as shown by Mackie (2009a). Recent trials by OPUS Central Labs have also shown that simulated ATP ribs start becoming detectable when they reach a height of approximately 3mm.

Figure 9. Old ATP that is due for reinstatement

Where ATP roadmarkings have reached their effective life-end and a reseal is not due for some time, the ATP roadmarking will need to be reinstated. In this situation, if there are still clearly detectable ribs, then they will need to be ground down so that they are effectively flush with the surrounding surface. Alternatively, if the contractor is confident that they can match the spacing of the old and new ribs, then this approach is also acceptable. Careful monitoring needs to be carried out to ensure sufficient adhesion and alignment of the new markings over the old ones.

In many cases ATP roadmarkings will still be economically viable with a life of as little as two years. If a reseal is scheduled within two-years of the ATP roadmarking’s effective life, then ATP renewal should not proceed until the re-seal has been completed.

Please refer to the NZ Roadmarkers Federation for ongoing guidance regarding the process for removal, reinstatement and reseals.

Monitoring and quality assurance for ATP roadmarkings

The NZTA specifications P30 and M24 have guidance on monitoring and quality assurance for ATP roadmarkings. A recent NZTA report (Mackie 2009b) found that, in practice, monitoring and quality assurance tend to happen informally, and generally not to the level of thoroughness described in the specifications. It is essential that both contractors and network managers have a good understanding of the state of ATP roadmarkings within their contracts and take action to maintain the roadmarkings to specification when necessary. The increasing use of ATP roadmarkings is mostly a result of proven safety benefits. If these benefits are compromised through sub-standard roadmarkings, then the attractiveness of ATP roadmarkings as a cost-effective road safety countermeasure will diminish.

Product

Thermoplastic and cold applied plastic (CAP) each have their advantages and disadvantages. The recent report of ATP performance in the upper North Island Mackie (2009a) found that CAP ribs might be more wear resistant (but may be more likely to be punched into the seal), but thermoplastic might have better retroreflectivity properties over its lifetime. However, these findings are still speculative as they were not statistically significant.

Recent examples suggest that there might be larger differences in performance between variations of the same product than between thermoplastic and CAP. For this reason, rather that favouring the use of one of these products over the other, there should be an emphasis on using the best quality thermoplastic or CAP. Also, consideration of whole-of-life costs including maintenance reseals and renewal should be given higher weighting in contracts.

In any case ATP products need to be approved by the NZTA. Please refer to the NZTA specifications M24 for details.

Issues and myths

There are some negative perceptions of ATP roadmarkings based on a range of beliefs. The following section addresses some of these beliefs based on the information that is known to date.

ATP roadmarkings on left-hand curve edgelines are dangerous because they cause motorists to drive close to the centreline or because motorists may react sharply to the ATP and overcorrect across the centreline

There is strong evidence that ATP roadmarkings improve lane keeping through avoidance of the ATP roadmarkings by motorists. However, rather than driving dangerously close to the centreline when ATP roadmarkings are present on edgelines on left-hand curves, motorists will tend to either travel with their left wheels close to the edgeline or in the shoulder – in both cases leaving plenty of room between the vehicle and the centreline. Research to date suggests that ATP discourages inadvertent lane departures but does not prevent deliberate lane departures.

A North American study (Finley et al. 2009) showed that motorists tend not to react suddenly to ATP roadmarkings and that they do not cause potentially unsafe lane placement, which is consistent with the evidence of their overall safety benefits. Nevertheless, a very small minority of people do believe ATP roadmarkings can cause dangerous driver behaviour and so this risk will continually be assessed based on the information available.

Vehicles need 1.5m of shoulder to respond to ATP roadmarkings

Recent research by Findley et al. (2009) found that in North American conditions, motorists continued to move laterally (away from the centreline) by approximately 0.3m after running over ATP edgelines before changing direction back towards the centreline. Although caution is needed in using North American conditions where wider milled rumble lines are used, there is at least anecdotal New Zealand evidence that supports this. Highway engineers have found less damage occurs to wire rope barriers when ATP roadmarkings are placed on the inside edgeline very close to the barrier. However, a suitably wide shoulder is desirable when ATP roadmarkings are used, but this is so cyclists have sufficient room to manoeuvre safely and comfortably.

ATP roadmarkings are dangerous for cyclists

ATP roadmarkings help to protect cyclists by improving motorist lane keeping. On rural roads, rear-end and overtaking crashes are the most common fatal and injury crash type respectively for vehicle vs cyclist crashes. Therefore ATP roadmarkings clearly have a role to play in protecting cyclists. The sound of a vehicle's wheel travelling over ATP roadmarkings may provide a life-saving and last-second warning to cyclists who might take evasive action to prevent a collision from behind.

However, ATP roadmarkings may also pose a risk to cyclists. Sufficient clear shoulder width (free of detritus and edge-break) is needed so that cyclists can avoid running on ATP edgelines. While there is no evidence to suggest that ATP roadmarkings would cause cyclists to lose control or crash, cyclists would prefer to avoid them and they may pose a danger to cyclists if they are encountered unexpectedly or if the cyclist is already not in full control of their bike.

The pavement in the traffic lane will wear faster when ATP roadmarkings are present

Improved lane keeping may mean a higher concentration of vehicle passes over the most trafficked parts of a lane. However, in New Zealand, cost allocation models for traffic related road damage attribute all of the damage to heavy vehicles. Because of their width and because truck drivers are more likely to be professional drivers, the variability of lane keeping in trucks is less than cars, and so the effects of ATP roadmarkings in reducing variability is likely to be less for trucks than for cars (this was demonstrated by Mackie 2009). Although there is no evidence to date that ATP roadmarkings cause accelerated pavement wear, this could be something to monitor in the future.

ATP roadmarkings cause damage to truck hubometers

There have been reports from some transport operators that their hubometers have been damaged by the vibration caused by running on ATP roadmarkings. Conversely, other truck operators have stated that they believe this is not the case and that hubometers are often prone to failure anyway. In any case, electronic hubometers' that do not have mechanical devices within wheel hubs are likely to be standard in the near to medium term and so even if this was a real problem, it is likely to diminish over time.

References

Anund, A., Kecklund, G., Vadeby, A., Hjälmdahl, M and Åkerstedt, T. (2008). *The alerting effect of hitting a rumble strip: a simulator study with sleepy drivers.* Accident Analysis and Prevention 40(6), 1970-1976.

Baas, P. H., Charlton, S. and de Jong, D. (2004). *Review of lane delineation*. A report prepared by TERNZ for Transit New Zealand.

Charlton, S. (2006). *South Waikato and Taupo target 2010 remediation treatments monitoring*. Prepared for SWATT 2010 Corridor Study Team by TERNZ Ltd and TARS (Waikato University).

Dravitzki, V. (2009). *Measuring the effect of audio tactile profiled roadmarkings*. Paper presented at the NZ Roadmarkers conference, Nelson, 2009.

Finley, M.D., Funkhouser, D.S. and Brewer, M.A. (2009). *Studies to determine the operational effects of shoulder and centerline rumble strips on two lane undivided roadways*. Report 0-5577-1, Texas Transportation Institute, 2009.

Hatfield, J., Murphy, S. and Soames Job, R.F. (2008). *Beliefs and behaviours relevant to the road safety effects of profile lane-marking*. Accident Analysis and Prevention 40, 1872-1879.

Hatfield, J., Murphy, S., Soames Job, R.F. and Du, W. (2009). *The effectiveness of audio-tactile lane-marking in reducing various types of crash: A review of evidence, template for evaluation, and preliminary findings from Australia*. Accident Analysis and Prevention 41, 365-379.

Kiesel, K. (2007). *Management of Audio tactile edge line markings*. A Research and Development Report (Project No. 952) prepared by GeoPave for VicRoads, 2007.

Mackie, H.W. (2009). *The effect of dashed and solid white audio-tactile centre lines on driver behaviour and public acceptance*. A report prepared by TERNZ Ltd for the NZ Transport Agency, April 2009.

Mackie, H.W.(2009). Investigation of audio- tactile road marking performance in the upper North Island. A report prepared by TERNZ Ltd for the NZ Transport Agency, September, 2009a.

Mackie, H.W. (2009). *Evaluation of the contract process for 2009 audio tactile roadmarking projects*. A report prepared by TERNZ Ltd for the NZ Transport Agency, December, 2009b.

Mackie, H.W., Baas, P.H. (2007). *The cost effectiveness of delineation for safety.* A report prepared for Land Transport New Zealand (Land Transport Research Report 322) by TERNZ Limited.

Miles, J.D. (2005). *An investigation of passing operations on a rural, two-lane, two-way highway with centreline rumble strips*. Thesis, Texas A&M University.

Miller, K.W. (2008). *Effects of center-line rumble strips on non-conventional vehicles*. Minnesota Department of Transportation, January 2008.

Noyce, D.A., and Elango, V.V. (2004). *Safety evaluation of centreline rumble strips: crash and driver behaviour analysis*. Transportation Research Board, 1862, 2004.

Porter, R.J., Donnell, E.T. and Mahoney, K.M. (2004). *Evaluation of effects of centreline rumble strips on lateral vehicle placement and speed*. Transportation Research Record: Journal of the Transportation Research Board, 1862, 10-16.

Torbic, D. J. et al., (2009). NCHRP report 641*: Guidance for the design and application of shoulder and centerline rumble strips*. TRB National Research Council, Washington D.C. 2009.