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CRUMBED TYRE RUBBER OFFERS BENEFITS AT BOTH ENDS OF THE RESOURCE LIFE CYCLE

Research has explored the potential use of recycled rubber from vehicle tyres in road pavements, and recommended an implementation plan to overcome the current barriers that prevent greater use of this sustainable resource.

At present, around five million tyres are imported into New Zealand each year. At the other end of their life cycle, about 62,000 tonnes of waste tyres are generated in New Zealand annually, and around 70% of these (by weight) go into some form of landfill.

Overseas, supportive legislation has led to greater reuse of waste tyres and market demand for crumb rubber modified bitumen and other waste tyre by-products. For example, in Australia, where 16% of the country's waste tyres are recycled each year, many states now have binder specifications that allow crumb rubber seals to be used on state roads; while in the US, 48 states have now implemented legislation to monitor the flow of waste tyres, and many have banned the disposal of tyres through landfill, with various economic schemes and incentives established to encourage reuse.

The effect of these measures is that tyre-derived crumb rubber is now a common additive in bituminous binders in many

countries around the world, and has proved effective for helping tackle pavement performance issues, as well as providing an effective use for end-of-life tyres.

In New Zealand, although some forms of rubber, such as natural latex rubber or styrene-butadiene-styrene block copolymer, have been used for the construction and maintenance of road pavements and surfacing since the 1970s, crumb rubber from recycled tyres has not.

The Opus Research Pavements team at Opus International Consultants conducted this study and reported that at present, there are more than enough end-of-life tyres generated in New Zealand each year to produce sufficient binder modifier to cater for the country's total bitumen market. Yet because there is no strict monitoring of the flow of tyres in the country, either as a product or waste stream, it is difficult to maintain a secure supply of crumb rubber and this undermines the potential market.

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There were early local trials of crumb rubber, in both hot mix asphalt and chipseal pavements, which showed mixed performance, but did not gain any traction in the industry. However, since then, technological advances and ongoing research and practices internationally have demonstrated that crumb rubber can be effectively incorporated into road surfacing.

‘The purpose of our research project was to identify the current barriers that exist in New Zealand to making greater use of tyre-derived crumb rubber in bitumen binders for roads, and explore ways to remove these barriers so that market demand for these products can increase,’ the team reports.

BARRIERS TO CRUMB RUBBER USE IN NEW ZEALAND

The research team used stakeholder consultation and a literature review to identify potential barriers to the use of crumb rubber in bitumen binders.

The high costs of setting up systems and processes to enable the use of ground tyre rubber from end-of-life tyres emerged as one of the major barriers. The New Zealand bitumen market is predominantly unmodified, and the relatively small modified binder market is dominated by styrene-butadiene-styrene polymer. The higher costs associated with crumb rubber flowed from the initial investment in specialised equipment required to use this resource (most of this equipment is not currently available in New Zealand) and the associated training for staff to use the new technologies.

The size of the market was identified as another barrier. Chipseal pavements constructed using polymer modified binders only represent a small percentage (less than 5%) of the pavements constructed in New Zealand, yet these are likely to be the types of applications where crumb rubber binders would be used.

The third major barrier was issues around the security of supply. Despite there being ample end-of-life tyres available to cater for the size of the market, the current lack of regulatory enforcement means that most of these tyres are being either stockpiled or illegally dumped. If left unaddressed, these practices may create supply issues, both for manufacturers and end users of crumb rubber.

The final major barrier identified by the project relates to difficulties in using crumb rubber modified binder as an emulsion in road pavement applications, because when binders are modified with vulcanised tyre rubber, they need to be applied at high temperatures (over 180°C). Yet the New Zealand road industry is currently looking at moving away from using hot cutback bitumen (which is also sprayed at high temperatures) in road construction, and instead making greater use of bitumen emulsions (which are sprayed at heats between 80°C and 90°C). The proposed move is for safety reasons.

CHANGES TO ADDRESS THE IDENTIFIED BARRIERS

The team reports that, despite the identified barriers, none of them were considered insurmountable.

‘We were able to propose two key changes that effectively remove these barriers, namely introducing measures to grow the market for polymer modified bitumen in New Zealand, and investigating ways to use devulcanised tyre rubber, so that it can be used in bitumen emulsions, and applied at lower temperatures.’

Growing the polymer modified bitumen market was largely seen as a matter of demonstrating the widely reported benefits of polymer modified bitumen in chipseals and increasing industry awareness of it (polymer modified bitumen is already extensively used internationally, and recent research has reinforced its benefits in terms of asphalt pavement performance). This should naturally lead to its increased use in chipsealing applications.

Because the properties and performance of crumb rubber modified binders are comparable to those of polymer modified bitumen, if the market for the latter is increased, then the research team surmised there should be opportunities for end-of-life tyre-derived rubber to be used as an alternative to virgin polymer in binder modification.

The research team states ‘End-of-life tyres can be considered a local source of polymer, adding value to the growing waste stream and reducing the local road industry’s exposure to international price fluctuations for imported virgin polymers.’

The second key change – to investigate the use of devulcanised tyre rubber – would address two of the key barriers identified, namely the high costs associated with using tyre-derived crumb rubber, and the emulsification related barriers, which required vulcanised rubber to be sprayed at high temperatures.

The research team proposed that devulcanised rubber modifiers could be incorporated into bitumen binders in the same manner as virgin polymer modified binders with similar properties. The advantages would be the ability to use these binders with established emulsification technologies, already well understood and widely used in New Zealand, and the need for only minimal changes to the plant and procedures currently used for both chipseal and asphalt construction.

RECOMMENDED IMPLEMENTATION PLAN

The research project’s report sets out a three-stage recommended implementation plan that, over time, would see increased uptake of polymer modified binders, better understanding of the scope for devulcanised tyre rubber to be used in emulsification processes, and verification of the field performance of devulcanised rubber modified binders, both with and without emulsification.

The anticipated outcome is that, ‘With a growing market for polymer modified bitumen and crumb rubber modified binders, the expected lower cost of devulcanised tyre rubber would encourage greater use of the technology and increased consumption of waste tyres’, the report concluded.

Removing barriers to the use of crumb rubber in roads,
NZ Transport Agency research report 578

Available online at www.nzta.govt.nz/resources/research/reports/578

ADDITIONAL GUIDANCE FOR INTEGRAL BRIDGE DESIGN

A new research report sets out additional design requirements and considerations that need to be taken into account when designing integral bridges.

The NZ Transport Agency funded report, researched by Opus International Consultants, is intended to support the guidance in the Transport Agency's *Bridge manual*. It incorporates parametric studies and worked examples to provide New Zealand bridge designers with the information they need, and highlight the issues they should consider, in designing integral bridges.

While the report is not intended as a step-by-step guide, it does summarise current best practice with respect to the design and construction of integral and semi-integral bridges in New Zealand, and provides additional research-based information that will help 'ensure excellent performance' of integral bridges in the future.

INTEGRAL BRIDGE DESIGN IN NEW ZEALAND

Integral and semi-integral bridges are a fairly common form of construction for bridges in New Zealand (and internationally).

Essentially, both forms of construction aim to minimise the use of bearings and expansion joints, instead providing a direct connection between the bridge's superstructure (the bridge span and its supporting structures that directly carry the live load on the bridge) and substructure (the abutment, piers and other support structures).

Despite their prevalence, there is still some ambiguity in the design literature and practice about what constitutes an integral bridge, and how this differs from a semi-integral bridge. One of the first tasks of the multi-agency research team for this study was to survey these varying definitions, in order to derive the following definition for use in the research and report (p9):

*An **integral bridge** is a structure where there are no expansion joints in the superstructure between spans and between spans and abutments (but these joints may exist beyond the bridge).*

*An integral bridge where the superstructure and substructure are also designed to move together to accommodate the required translations and rotations (a monolithic structure) is termed **fully integral**.*

*An integral bridge which has bearings at the abutment and/or piers and as a result, the superstructure and substructure do not necessarily have to move together to accommodate the required translations and rotations, is termed **semi-integral**.*

Therefore, an integral bridge can be fully or semi-integral at the abutments and/or at the piers.



Wairua River Bridge, is an example of an integral bridge discussed in the research report

ISSUES ASSOCIATED WITH INTEGRAL BRIDGES

New Zealand bridge designers tend to favour integral and semi-integral bridges, because they offer a number of major advantages over other conventional simply supported forms of bridge construction.

These advantages include ease of construction, lower construction costs, lower maintenance costs and requirements, improved durability and improved vehicle ride quality.

However, despite these advantages, there are currently a number of unresolved issues relating to their design and construction in New Zealand.

The research report identifies, investigates and expands upon these issues, categorising them for the purposes of the discussion into three topics:

- static design
- seismic design
- geotechnical considerations.

A separate section of the report is dedicated to each topic.

Issues that were identified during the research as of particular significance, and which are addressed in some detail in the report, are:

- the structural form adopted at supports, and in particular the connection details between superstructure and substructure
- the considerable actions imposed through secondary static effects, including creep, shrinkage and temperature – the report provides guidance for formulations to be used during design, as well as a detailed example and parametric analyses (in its appendices)
- preferred structural forms for integral bridges in regions of moderate-to-high seismicity
- analysis methods for seismic design, with an emphasis on displacement-based design – the modelling of integral abutments and the soil-structure interface was of particular interest to the researchers, due to the considerable influence of soil response on overall integral bridge response during seismic motions
- geotechnical analysis and design for integral bridges – the effect of abutment form selection on horizontal earth pressures and overall soil response is addressed in great detail in the report, with guidance provided on preferred forms for bridge approach systems and abutments.

Overall, the report's main purpose is to provide guidance to New Zealand bridge designers on best practice for addressing these issues, and where guidance is limited, to identify areas for future research.

Criteria and guidance for the design of integral bridges in New Zealand, NZ Transport Agency research report 577

Available online at www.nzta.govt.nz/resources/research/reports/577



BETTER TOOLS NEEDED TO TACKLE CRACKING

Building understanding about chipseal cracking, and how to model, prevent and repair it, was the focus of a recent NZ Transport Agency funded project.

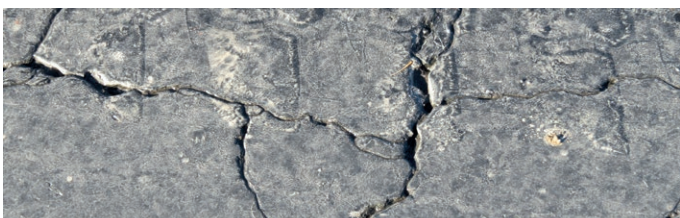
A multi-agency team, comprising researchers from Opus Research, R&D Consultants and the University of Auckland, investigated various aspects of chipseal cracking throughout 2014 and 2015.

Phil Herrington of Opus says, 'The study was needed because, although cracking is one of the major failure modes for chipseal pavements in New Zealand, there has been relatively little research into why it occurs, or what to do about it, either here or overseas.'

Approximately 20% of seals on the New Zealand state highway network currently fail due to cracking; cracking ranks second only to flushing as the reason why a pavement is likely to require resealing.

Cracking in chipseals can have serious consequences, such as allowing water to enter and damage the underlying pavement. Aspects of the phenomenon investigated by the research included:

- causes – how and why cracks form in the seal and whether pavement deflection is a dominant factor
- mitigation and repair – cost-effective methods for sealing individual cracks and preventing the need for broader repair works
- modelling – analysis of crack initiation and growth rates and the potential for using this data to prevent or defer the need for repairs or resealing.



WHY CHIPSEALS CRACK

The research investigated the hypothesis that chipseals fatigue crack in the same way as asphalt mixes, but with abnormal pavement deflection being the main factor affecting whether cracks form and grow. (This is opposed to the cracking being due solely to excessive hardening of bitumen in the seal.)

Phil says, 'By understanding the key factors involved in cracking, we aimed to be able to better identify and focus on the construction and maintenance practices that will help to minimise it.'

The team's hypothesis was tested in the laboratory using a four-point beam bending test method. Both laboratory-prepared and field-cut chipseal sample beams were tested.

The tests showed the chipseal samples failed through fatigue cracking at 5°C. The samples were not able to be tested at higher temperatures due to deformation over the period of the test.

The sample beams' fatigue lives were then compared with existing data for typical New Zealand asphalt surfacing. Major findings were:

- chipseal fatigue lives at 5°C were up to eight times greater than those estimated for asphalt surfaces under the same loading conditions – this finding needs to be confirmed through more extensive testing
- higher fatigue lives are consistent with the high binder content in multi-layer chipseals, compared with asphalt, and the lower initial moduli
- the potential for chipseal to self-heal is expected to be significant, due to the thick binder films present, which would tend to further increase the relative fatigue life of chipseals compared with asphalt. Self-healing was not investigated in the project, and needs to be confirmed through testing, but detailed site investigations have shown that visible cracks do reduce over the summer period
- bitumen with an equivalent field age of approximately four to five years resulted in a slight improvement in chipseal fatigue life at 5°C.

These findings, together with previous work on binder hardening in New Zealand seals, enabled the research team to reach several conclusions.

Phil explains, 'Our observations suggest that oxidation is not the dominant factor in chipseal cracking, and that in fact, cracking is likely to occur as a result of very high, localised deformations. Such deformations may be due to weak patches in the basecourse formed during construction, or to water damage as a result of leaking seals. In multi-layer seals, water ingress can also weaken the seal structure by stripping the bitumen from the aggregate at the base of the layer. This makes it likely that, in many cases, seal cracking and flushing are directly related.'

Part of the team's investigations involved analysing and modelling crack initiation and progression rates on both state highways and local authority roads. This strand of the research used the Transport Agency's long-term pavement performance monitoring site data to show that, overall, the average number of cracks per site tended to increase linearly from the time the cracking started. In addition, the average annual increase in crack length is approximately half the crack length, so as the crack grows, the rate of crack growth (expressed in millimetres

per year) also increases. This was the same for all three of the different types of cracks looked at (transverse, longitudinal and alligator).

The team also detected a time-based relationship between crack initiation and when potholes began to form, although more analysis was needed to confirm this.

BEST PRACTICE FOR REPAIRS AND MAINTENANCE

Based on their findings, the research team prepared suggested guidelines and performance-based specifications for repairing cracks in chipseals. These are set out in the report.

The suggested specifications set a minimum performance level that repairs should meet during their defects liability period (generally two to three years). Performance would be assessed in terms of a number of factors, including bleeding, bitumen pick up and tracking; pothole formation (on the repaired area); and repair failures (including reopening, spalling, widening, loss of adhesive and other failures of the repaired crack).

In addition, suggested physical tests in the guidelines will serve to exclude unsuitable repair materials.

In terms of maintenance, the research reinforced existing industry knowledge and practice about the importance of watertight surfaces and good drainage in maintaining pavement integrity.

Local authority field and optimal programmes were looked at, with a view to shaping practical guidance for better decision making when considering defects such as cracking and rutting.

The research team recommended that field inspections should consider combinations of defects when deciding on the appropriate treatment for a particular site, rather than looking at isolated defects individually. Practitioners should also pay more attention to the underlying reasons for cracking, rather than just observing, and reacting to, cracking that had occurred.

The authors believe that, 'Cracking is an excellent flag that something is amiss with regards to the pavement or upper layer performance. The only way to make an informed decision on the maintenance needs of a cracked pavement, is to investigate additional condition and strength data that helps explain the underlying mechanism of the failure.'

However, the team noted that current New Zealand pavement design and rehabilitation guidelines are light on diagnostic processes and tools that practitioners can use to decide which resurfacing or rehabilitation strategy is best for a particular site. This gap would benefit from being addressed.

'The research highlighted the need for more diagnostic tools that take account of multiple data inputs in order to decide or eliminate certain treatment types for the combination of certain defects or pavement characteristics,' the full report concludes (p84).

Chipseal cracking, NZ Transport Agency research report 579

Available online at www.nzta.govt.nz/resources/research/reports/579

INNER CITY PARKING MISCONCEPTIONS TACKLED

Research has contributed to local understanding of the costs and benefits of inner city kerbside parking, and how these compare with the 'opportunity cost' of this road space being reallocated to other uses.

The project, undertaken by Opus Research, aimed to address the NZ Transport Agency identified knowledge gap – What are the costs and benefits of inner city kerbside parking?

Traditionally, most inner city roads in New Zealand have incorporated kerbside parking. However, increasing competition for road space, and evidence from overseas that there are substantial benefits to be gained from reallocating kerbside road space to other uses, has led to demand for this practice to be revisited. Potential benefits from reallocations can include improved safety, more efficient pedestrian and freight movements, and better street amenity values, to name just a few.

Despite this, there is generally resistance when projects propose to remove or reduce roadside parking, due to the assumption that this will have a negative impact on local businesses. However, previous research, here and overseas, suggests this could be a misconception. Not only does the negative economic impact tend not to materialise, but the new uses that the parking road space is given over to can bring additional benefits, such as more pleasant and usable street environments, and better functioning urban transport networks, which encourage, rather than deter trade.

At present, most of the research pointing to these additional benefits has been conducted overseas, and it can be hard for New Zealand businesses to accept and apply the findings in a local context. Transport Agency research report 530 (2013) investigated the economic impact of road space reallocation in shopping areas, finding that retailers generally overestimate the importance of kerbside parking outside shops. The potential costs and benefits of kerbside parking reallocation are much wider than just impacts on adjacent businesses. However, these effects are not routinely assessed before and after the implementation of projects in New Zealand.

To this end, the research project used a four-stage process to investigate the monetary and non-monetary costs and benefits associated with reallocating inner city kerbside parking to new uses in New Zealand. Case studies, industry feedback and a literature review were used to develop a proposed framework for capturing the costs and benefits of inner city kerbside parking reallocation in the context of particular local projects.

THE FRAMEWORK

The proposed framework includes a wide range of costs and benefits that should be included as part of pre- and post-project evaluations of projects that reallocate parking space.

The range of costs and benefits incorporated in the framework is broader than is currently included in the Transport Agency's project evaluation tools. For example, the framework takes into account several non-monetary, contextual and wider economic factors – such as the presence or absence of other parking options in the area, parking turnover and occupancy, and traveller satisfaction – which do not currently feature in the Transport Agency's *Economic evaluation manual* processes.

The table below summarises the factors taken into account in the framework, as well as the types of scenarios where they should be assessed. Some cost-benefit factors are recommended for all parking space reallocation projects, while others relate to projects where specific alternative uses (such as extra road lanes, or pedestrianised zones) are proposed.

Proposed kerbside parking reallocation evaluation framework, costs and benefits presented by relevance to project type

COST-BENEFIT	PEDESTRIANISED SHARED SPACES AND QUALITY URBAN REALMS	CYCLE INFRASTRUCTURE	PUBLIC TRANSPORT SERVICES	EXTRA VEHICLE LANES
Travel time	●	●	●	●
Mode share	●	●	●	●
Journey satisfaction	●	●	●	●
Existing parking supply	●	●	●	●
Occupancy of existing parking	●	●	●	●
Use of existing parking	●	●	●	●
Capital and operating expenditure	●	●	●	●
Public transport patronage	●	●	●	●
Business income	●	●	●	●
Adjacent land use	●	●	●	●
Crashes and perceptions of safety	●	●	●	●
Pedestrian usage	●	●	●	●
Visitor satisfaction	●	●	●	●

● Recommended ● Not recommended

The research team also identifies in their report a range of methods that could be used to measure the factors in the proposed evaluation framework.

However, the report also recognises the difficulties that local authorities face in effectively assessing the full range of costs and benefits of reallocation projects. These include prohibitive assessment costs (especially for smaller projects); data availability and timeliness; the difficulties of attributing particular improvements, such as network travel time savings, to singular causes or projects; and the problems associated with measuring some impacts, such as those on population health and the environment.

To help address these difficulties, the team suggests building up a wider New Zealand evidence base of the impacts of parking reallocation projects. Authorities can then draw on this broader experience where appropriate, and will not be required to assess every factor in every situation. To this end, the report recommends the framework should be put into practice for upcoming kerbside parking reallocation projects; and in the longer term, encourages local authorities to make note of the local effects of their reallocation projects.

If the framework is adopted, the research team suggests there may be scope for it to be included in the Transport Agency's *Business case assessment strategic options toolkit*. While many of the factors in the framework are excluded from the Economic evaluation manual processes, this is not true for businesses cases. Business cases are typically developed to support proposed reallocation (and other transport) projects. The toolkit helps facilitate their development by suggesting the type of outcomes being sought, potential strategic options that may be explored, and strategic interventions that could be implemented.

Despite the recognised implementation difficulties, the proposed evaluation framework attracted very positive feedback from industry experts and stakeholders, who were consulted as part of the project. This led the research team to conclude in its report that:

Consistently evaluating kerbside parking reallocation against the same set of costs and benefits, and contextual elements, across New Zealand is expected to reduce misconceptions about negative impacts on businesses, provide a robust evidence base for the net benefits of reallocation, reduce reliance on overseas and anecdotal evidence and contribute to best practice decision making for future reallocation projects. (p9).



Permanent and temporary reallocation of kerbside parking on Papanui Road in Christchurch has improved the safety and efficiency of travel for public transport and people on bikes (Source <http://viastrada.nz/project/2010/christchurch-city-goes-green>)

The costs and benefits of inner city parking vis-à-vis network optimisation, NZ Transport Agency research report 575

Available online at www.nzta.govt.nz/resources/research/reports/575

NEW RESEARCH REPORTS

The role public transport can play in Safer Journeys and, in particular, to advance the Safe System approach

NZ Transport Agency research report 581

Available online at www.nzta.govt.nz/resources/research/reports/581

The key objectives of this research, undertaken by Opus Research, were to identify the contribution that urban public transport (PT), which is generally considered safer than travel by light motor vehicles, can make to the Safe System approach, and to develop an implementation plan for the insertion of PT as a safe mode into the Safer Journeys framework and action plans. The work indicated that, as in New Zealand, the practice overseas was for road safety strategists not to attempt to influence modal split in the direction of safer PT modes, but rather to accept the levels of modal split resulting from government PT policies and then to ensure that the system which results is managed according to Safe System principles. This would mean including in Safer Journeys PT-related injuries not at present covered in Safer Journeys actions. This would require no structural change, just a restatement of the reach of the strategy and the inclusion of some new areas of interest and action plans. To achieve this, the whole journey rather than just the road phase needs consideration. Data on injury related to all aspects of the journey should be gathered and analysed; safety expertise can be positioned in organisational structures to influence how PT is operated; and tools to better monitor PT safety can be made available and used.

OBTAINING TRANSPORT AGENCY RESEARCH REPORTS

All research reports published since 2005 are available free of cost for downloading from the Transport Agency's website www.nzta.govt.nz/planning/programming/research PDF scans of research reports published prior to 2005 are available by emailing research@nzta.govt.nz

A NOTE FOR READERS

NZTA research newsletter

The *NZTA research* newsletter is published quarterly by the NZ Transport Agency. Its purpose is to profile research funded through the Transport Agency's Research Programme, to act as a forum for passing on national and international information, and to aid collaboration between all those involved. For information about the Transport Agency's Research Programme, see www.nzta.govt.nz/planning/programming/research.html.

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DID YOU KNOW...

That there is a spreadsheet on the Transport Agency website listing all published Transport Agency research reports?

The spreadsheet is searchable by several criteria and can be found at www.nzta.govt.nz/planning/programming/research.html.

The spreadsheet has two worksheets; the first worksheet lists research reports with associated key words and the second lists research reports with the report abstracts.



Road space in Auckland's Fort Street area has been reallocated to prioritise pedestrians and created a socially vibrant inner city area (Source <http://transportblog.co.nz/tag/fort-street/>)