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NZTA research

NZ TRANSPORT AGENCY
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SEASONS NOT ACTING ALONE TO AFFECT SKID RESISTANCE

Research into seasonal and short-term variations in the skid resistance of road surfaces shows that the situation is more complex than the industry has previously appreciated, but that awareness of this complexity will help improve the safety of our roads.

The relationship between a road surface's skid resistance and the number of loss-of-control type crashes that can be expected on that road has been well-proven – as skid resistance decreases, so the number of crashes increases, along with the associated levels of injuries and deaths. However, efforts to date to manage the skid resistance of New Zealand roads have been hampered by, often unpredictable, variations in skid-resistance.

One of the most significant factors believed to affect the skid resistance of a pavement is what is known in the industry as the 'seasonal variation effect'. The seasonal variation effect is caused by contaminants building up on the road surface; the aggregate surface becoming polished by the fine contaminant particles and traffic action, mostly during the summer months (decreasing skid resistance); then the contaminants being cleaned away and the aggregate surface rejuvenated by rainfall and traffic. Not surprisingly, this rejuvenation process happens more frequently during winter, giving pavements a different skid resistance profile at this time of year.

Seasonal variations in a pavement's skid resistance usually start to show up after the initial surface polishing of the aggregate has occurred (in what is known as the equilibrium phase). How long this takes depends on the type of aggregate used and external factors such as the amount of heavy commercial vehicles travelling on the road.

Short-term variations in a pavement's skid resistance are caused in much the same way (rainfall and traffic combining to leach contaminants from the road surface), but happen on a shorter cycle (ie after discrete episodes of rain) within the larger cycle set by the seasonal variations. Previous research has shown that the skid resistance properties of a pavement can vary by as much as 25% in a single week in summer, when extended dry periods allow contaminants to build up, making the cleansing effects of a single shower more pronounced.

This research project focused on the seasonal and short-term variations, with field and laboratory testing used to analyse how geological and environmental factors affect the skid resistance of a road surface over time.

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SUBSTANTIAL SHORT-TERM VARIATIONS

Doug Wilson of the University of Auckland's Department of Civil and Environmental Engineering conducted the research.

Doug says, 'The results showed that a pavement's measured skid resistance can vary significantly, often by more than 30%, over short time periods, but that this variation cannot be pinned down to any one factor. Not all of the factors that affect skid resistance have yet been uncovered, and unfortunately it is not as straightforward as knowing when it last rained.

'Rather, a drop in skid resistance is likely to be due to a number of interrelated factors, such as the geological properties of the particular aggregates used in the surface and their propensity to polish or abrade, and the contaminants present on it. Along with rainfall, road geometry, month of the year and the temperature were all also found to be significant.'

What the research clearly showed is that, in New Zealand's climatic conditions, the skid resistance value of pavements varies considerably more over time than was previously allowed for.

This will be of interest to road controlling authorities and road asset managers. Better understanding of the factors that affect skid resistance performance, and how the factors interrelate, will enable them to manage the safety of their road networks more effectively.

Doug says, 'Policies and standards that move towards more effective long-term skid resistance management must recognise that current measurement techniques (as used in this study) have demonstrated an inherent and significant variability, which is more than previously considered. This amount of variability poses significant difficulties for authorities and contractors tasked with managing road networks and their long-term skid resistance performance. It may be that because of its inherent variability, skid resistance can be targeted only as a band or range of values at any location.'

The research also has implications for crash investigators when it comes to analysing causes and contributing factors for crashes. At present, crash investigators use various skid-testing methods to measure a coefficient of friction for the pavement where the crash occurred. This coefficient is then used to calculate the probable operating speeds of the vehicles involved in the crash.

However, the current research has shown that, unless the tests are undertaken almost immediately after the crash occurred and in the same environmental conditions, the measured coefficient of friction could significantly vary from that involved in the crash. This, in turn, means that the estimated speed of the vehicles prior to the crash could also vary significantly. This introduces possible inaccuracy into how inspectors measure and estimate vehicle speeds, posing some significant issues for legal proceedings in crash-reconstruction work.

Another useful outcome of the research was that it demonstrated large aggregate surfacing samples could be prepared for accelerated polishing tests in the laboratory, for the purposes of predicting an aggregate's in-field performance. A new accelerated polishing device (Auckland accelerated polishing device – refer to figure 1) was developed as an alternative device to the traditionally used polished stone value method, which has been shown to be a poor predictor of in-field performance given current traffic loads. Research is ongoing with the new device, comparing its performance to other methods, but results to date show promise that the method can better simulate in-field stress conditions.

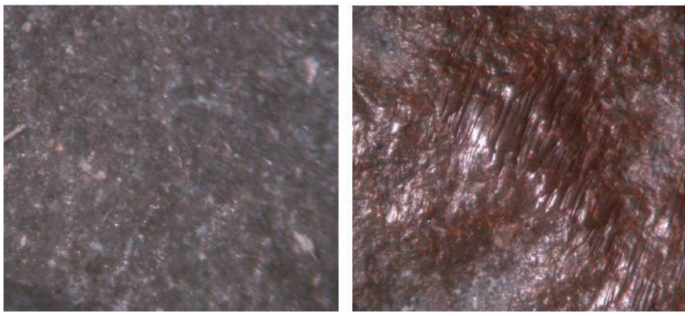
Four different aggregates were tested in this project, with significant variations in their skid resistance achieved by adding different contaminants to the mix. These behavioural differences were related to the geological properties of the aggregates themselves, as well as the nature of the contaminants added.

Figure 1 The Auckland accelerated polishing device developed as part of the research

Doug says this is significant because it shows that 'a geological interpretation of an aggregate's properties and the types of contaminants that end up on the surface will be required before an assessment can be made about the likely performance of the aggregate with regard to trafficking.'

TWO-PHASE TESTING

The research was carried out in two phases between 2003 and 2006. Phase one involved field testing, over 2.5 years, of seven sites in Auckland and Northland. GripTester and Dynamic Friction Tester devices were used to measure how temperature, rainfall, contaminants, new road surfaces, geometric elements and aggregate properties affected the skid resistance of pavement surfaces.



(a) After Leighton Buzzard sand polishing (b) After emery powder polishing

Figure 2 Fine-grained greywacke – after polishing with various contaminants (approximate field of view 3.5mm x 2mm)

In phase two, four different aggregate samples were polished in an accelerated polishing machine to an equilibrium skid resistance level. Contaminants were then added to simulate the seasonal or short-term variations that occur in the field and skid resistance measured again. Figure 2 shows a fine-grained greywacke aggregate that has been abraded with a coarse and hard mineral contaminant (Leighton Buzzard sand that rejuvenates the aggregate surface and increases skid resistance – refer figure 2a) and then subsequently polished with a fine-grained contaminant (emery powder that reduces skid resistance – refer figure 2b).

Doug says that more research using a larger sample of geological and artificial aggregates is required. 'This would enable us to identify aggregate sources and mix designs that are more resistant to polishing and abrasion and that lessen the seasonal and short-term variations in skid resistance that we've observed, and hence improve the safety performance of pavement surfaces in the longer term.'

The effect of rainfall and contaminants on road pavement skid resistance, NZ Transport Agency research report 515

Available online at **www.nzta.govt.nz/resources/research/reports/515**

STUDY FINDS NO EVIDENCE OF RISK FROM ATP ROADMARKINGS

Research into the safety of motorcycles when crossing audio tactile profiled roadmarkings has found no evidence of additional risk.

Since 2008/2009 the use of audio tactile profiled (ATP) roadmarkings in New Zealand has increased markedly, as research has shown the safety benefits of installing these markings on high-risk rural roads. The raised-profile type of ATP roadmarking adopted in New Zealand involves either raised ribs over a base roadmarking line, or a series of raised ribs beside a roadmarking line.

To date, ATP markings do not appear to have caused any negative safety issues. However, the NZ Transport Agency wanted a better understanding of the effect these ATP roadmarkings could have on the stability of two-wheeled vehicles, particularly motorcycles, when they cross the ATP lines. Opus Research, a division of Opus International Consultants, undertook a study of existing international literature, records of local crashes and simulation modelling validated by experimentation.

THE APPROACH

The research focused on the stability of motorcycles travelling at high speeds and encountering ATP roadmarkings.

Vince Dravitzki of Opus Research says, 'At the time we carried out the research, the most common place for ATP markings to be used was on open highways, so this was a natural place to focus our enquiry. Although there was no evidence that these markings caused stability risks for motorcycles, there was a possibility that, if there were issues, they were being masked by the overall drop in crash statistics that followed the widespread installation of the markings. Nationwide, previous studies have associated ATP roadmarkings with a 15% to 20% reduction in crashes, but these statistics, and the studies behind them, were not looking specifically at the effects on motorcycles.'

Bicycles, the other two-wheeled vehicle most likely to encounter ATP roadmarkings, were not included in the study, as there is already extensive research into the risks associated with ATP roadmarkings for cyclists, which has already been incorporated into existing standards and guidelines.

EXISTING EVIDENCE

A preliminary survey of records for crashes involving motorcycles and mopeds, and of the international literature, indicated that, to date, no specific issues had been identified for motorcycles from ATP roadmarkings. This was further borne out by the international literature of both crash data and trials where there was no evidence from other countries of additional risk from ATP markings.

FURTHER EVIDENCE

Example of computer simulation programme

To obtain further evidence, the research team followed up with computer simulations of interactions between motorcycles with ATP roadmarkings to identify any potentially destabilising effects. An internationally recognised three-dimensional vehicle crash and trajectory simulation modelling program – PC-Crash (3D Version 9) – was used for the simulations.

Vince says, 'We validated the computer simulations using physical tests with an instrumented motorcycle, which was driven over a range of ATP roadmarkings at a range of speeds. There was reasonable agreement between the data from the physical tests and that from the simulations, which verified the PC-Crash model was suitable.'

The team used PC-Crash to simulate model-runs for three different motorcycles (considered representative of motorcycles commonly driven in New Zealand):

- at two speeds (100km/h and 140km/h)
- with different braking scenarios (no braking, 50% braking and full braking)
- in wet conditions
- for an alignment of poor riding-line entry into a tight corner
- in situations with no ATP roadmarkings, and ones with ATP roadmarking ribs at 3mm, 6mm and 12mm heights, and 250mm and 500mm spacing.

All of the PC-Crash simulations (and the physical testing simulation used to validate them) showed no significant stability or loss-of-control differences between the simulations with no ATP roadmarkings and the simulations with ATP roadmarkings.

Some simulations included conditions that led to motorcycle instability or loss of control. However, this instability occurred in both simulations with no ATP roadmarkings and simulations with ATP roadmarkings, ie the presence of ATP markings had no significant impact on motorcycle stability.

When trying to maintain the same vehicle path, the PC-Crash simulations showed that contacting ATP roadmarkings did cause small differences in the steering angles of the motorcycles, and consequently their heading angles, but these differences were small compared with simulations where there was no contact with roadmarkings.

One possibility not tested by the simulations was that drivers could react abruptly when their motorcycles first contacted a roadmarking rib, and that this might create a safety risk. Although there was no evidence from the crash records or the literature that this was happening, the report flags motorcycle rider behaviour as an area for monitoring in the future.

Vince says, 'From all of our research – the existing crash records, the literature and the validated computer simulation modelling – we found no evidence that ATP roadmarkings, as they are currently used in New Zealand, create any significant instability issues for motorcycles.

'So at this stage, there doesn't appear to be any need to change current practice in this area. However, if the Transport Agency does change its practices with respect to ATP roadmarking dimensions or other properties of ATP roadmarkings in the future, then computer simulation can be used to help test the modifications before they are trialled on the road.'

Stability of motorcycles on audio tactile profiled (ATP) roadmarkings, NZ Transport Agency research report 526

Available online at **www.nzta.govt.nz/resources/research/reports/526**

NEW FRAMEWORK ESTABLISHES BEST PRACTICE FOR NEW ZEALAND TRANSPORT INDICATORS

A newly developed indicator framework for land transport takes the wellbeing of New Zealanders as its starting point.

The framework, developed by Covec during a research project funded by the NZ Transport Agency, identifies a suite of best-practice indicators that can be used to measure the contribution that land transport (road and rail) makes to New Zealanders' wellbeing.

Based on principles of welfare economics, the framework takes wellbeing, and the contribution that transport makes to it, as its starting point.

This is in contrast to existing transport indicators used in New Zealand, which tend to focus on either the long-term impact of transport policies and initiatives, or whether they are achieving the government's strategic priorities.

Aaron Schiff of Covec says, 'The problem with such indicators is that they tend to change, alongside changing government policies and objectives, over time. By focusing instead on the concept of wellbeing, and transport's contribution to it, we can provide a more consistent and enduring indicator framework that measures the overall contribution and effectiveness of land transport.'

The framework does this by viewing transport as an input into generating wellbeing, reflecting transport's role in enabling human interaction, trade and other activities. Transport improves wellbeing if it better facilitates these activities or imposes lower costs.

The approach is innovative; while indicator frameworks used in other countries may be implicitly based on wellbeing, it is not common for the links between transport and wellbeing to be so clearly established or explicitly drawn, or for those links to then be translated into a coherent set of indicators.

HOW THE INDICATORS ARE ORGANISED

The research team's task was to build a framework of indicators that together measure the contribution that transport makes to New Zealanders' wellbeing. This involved identifying categories of indicators based on the characteristics of the transport system that affect the contribution of transport to people's wellbeing.

Four categories were developed:

- network performance and capabilities
- safety
- health and environmental effects
- cost.

A set of indicators was chosen within each category; the indicators measure the characteristics of the transport system most closely related to that category. So, for example, for:

- network performance and capability – indicators were selected that measure the ability and performance of the transport system to move people and freight when and where demanded
- safety – indicators were selected that measure the extent that individuals suffer physical injury and property damage from transport services or activities
- health and environmental effects – indicators were selected that measure the impact of transport activity on the natural environment, where those impacts have direct effects on human health or on wellbeing derived from the environment
- cost – indicators were selected that measure the financial cost to users of the transport system.

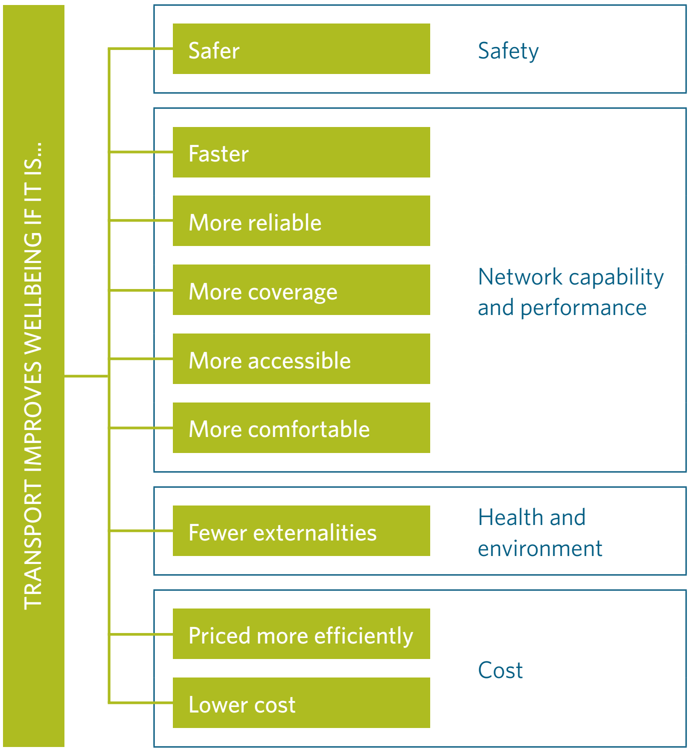


Figure 1 Conditions where wellbeing from transport is improved, everything else equal

Having identified the indicator categories (and the indicators within them), the research team then used the Organisation for Economic Cooperation and Development's (OECD) pressure-state-response framework to add another dimension to how the indicators were classified. The pressure-state-response framework separates indicators into those that reflect:

- external forces (pressures)
- the current state of the transport system
- policy responses over time.

Aaron says, 'Overlaying the OECD's framework on our own, enabled us to develop a two-dimensional system for organising the indicators, and to easily identify how external pressures affect the indicators, and what impact policy approaches have on them over time.'

Figure 2 shows how the indicator framework looks once the OECD framework has been overlaid.

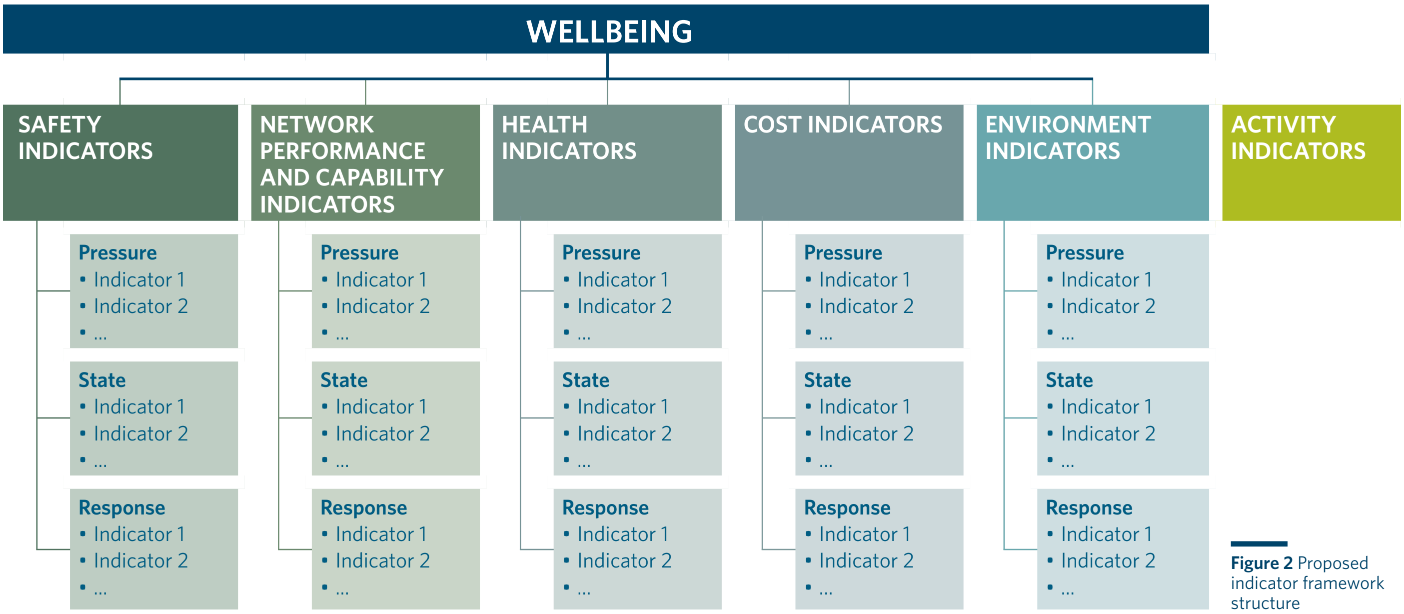


Figure 2 Proposed indicator framework structure

HOW THE INDICATORS WERE CHOSEN

The research team recommended indicators to be included within each category. Where possible, these were based on international best practice, although suitable indicators were not always available.

In general, for the safety, and health and environmental effects categories, there are well-established and widely used indicators available, and these were adopted to facilitate international benchmarking in these areas. However, in other areas there was no single international best practice approach, with different countries using different methods to measure network performance and capability, and costs.

Aaron says, 'We took this as an opportunity to innovate and develop indicators best suited to measuring wellbeing in New Zealand. What we were looking for were indicators that were most suitable for use in the local context, and in terms of local data availability, without being unduly constrained by concepts of international best practice, given that there is so much variety across countries. We did, however, keep in mind international benchmarking as a desirable secondary objective, where this is feasible.'

HOW THE INDICATORS WILL BE USED

The team anticipates that the recommended framework and indicators will be useful to support transport-related decision making at all levels of government.

- Central government will be able to draw on the framework to formulate policy directions and assess their impacts on wellbeing.
- The Transport Agency will be able to use the indicators to assess whether transport policies, directions and initiatives are achieving the government's strategic priorities and desired long-term impacts.
- Local government will be able to use the indicators to monitor national trends, and to assess policies and strategies at the local level to the extent that local data is available.

Aaron says that the framework will be most useful for high-level strategic planning, formulating transport policy, and evaluation of policies and strategies.

'We're not expecting the framework to be very useful for detailed evaluation of individual transport projects or small-to-medium scale investments, because the indicators are generally high level, and it may not be possible to distinguish the impacts of smaller projects or investments in the high-level data,' he says.

'However, the framework may be useful for evaluating the effects of very large transformational projects or programmes that are expected to have a significant impact on the land transport system as a whole, such as the roads of national significance programme. At the regional or local level, the usefulness of indicators will depend crucially on the quality of data that is available.'

Although there are currently data issues affecting the use of some of the recommended indicators, the research team is confident that these can be addressed.

'While the basic set of indicators will not change, we expect the quality of data and the number of indicators that can be populated will increase over time,' says Aaron.

Although the team recommends that indicators should be collected at a regional, as well as national, level where possible, issues with the quality and existence of regional data mean that, once again, this might not be possible initially, but should be worked towards for the future.

Aaron says, 'We expect that the indicator framework will become increasingly useful over time, as a time series of each indicator is built up and trends can be determined. In addition, some indicators are expected to benefit from improvements in data collection technology, such as the public transport activity data that will be available from integrated ticketing systems. While we have designed the underlying indicator framework to be robust to changes in the external environment, there are opportunities to improve individual indicators within the framework, and such improvements should be undertaken continuously, as the opportunities arise.'

The team also recognises broader opportunities, beyond the scope of the current project, for the concept of wellbeing-based frameworks to be applied to sectors other than transport.

'There's scope for the wellbeing based indicator framework to be worked up into a model for use by government departments and other stakeholders,' says Aaron.

Blueprint for a best practice measurement indicator set and benchmarking, NZ Transport Agency research report 522

Available online at **www.nzta.govt.nz/resources/research/reports/522**

IMPROVING THE PERFORMANCE OF ASPHALT SURFACES

Frequent premature failures of thin hotmix asphalt pavements in New Zealand have led to a series of recommendations for how their use could be monitored and managed.

Open-graded porous asphalt (OGPA) is widely used on New Zealand motorways. This research into asphalt pavements was undertaken in response to the situation. The concern was that although the cost of resurfacing using asphalt was escalating, the lives being obtained from the pavements were relatively short. (At the time of the research, around one quarter of new asphalt surfaces were being laid on existing asphalt surfaces that were only four years old or less).

There is a database that provides information on the road conditions which prompt asphaltic surfacing treatments. However, there is no database that records the reasons for premature failures or data that could be collated and analysed to help prevent their reoccurrence.

The research sought to identify areas where changes could be made in how thin layers of asphalt are used on New Zealand roads, in order to get better performance from these pavements. The focus was on materials and treatment selection, as these were two of the commonly cited reasons for failure. Construction quality, the third common area, was not looked at.

The outcome was a series of recommendations encompassing how asphalt pavements are selected and designed, as well as the acceptance schemes that apply to their construction. If a pavement does fail, the way that information about the reasons for the failure is collected and stored was also looked at.

THE CURRENT SITUATION

The research investigated six areas in framing its recommendations: currently achieved lives, whole-of-life costs, fatigue of thin surfacings, shear strength, durability of OGPA and acceptance schemes.

With respect to current lives, the research found that, on average, asphaltic concrete and OGPA pavement surfaces on New Zealand state highways are lasting for 82.4% and 86.7 % respectively of their standard default lives. There is a wide range of lifetimes represented within this average, and the figures do not reflect the impact of the recent addition of polymers to OGPA pavements in the Auckland region (which appears to have extended the life of these surfaces). However, the figures being achieved are comparable to some other countries. The data tends to suggest that the current performance of dense-graded asphalt in New Zealand is similar to that being achieved in the US. Austroads suggests a minimum of eight years and is in the same range as expected for the higher traffic volumes in New Zealand.

Nichols states that the asphalt in the UK lasts longer but all trunk roads there use structural asphalt and so are very resistant to fatigue cracking. There is also very little use of OGPA in the UK so the asphalt lives cannot be easily compared.

As a result, the research recommends better recording of the reasons why particular surfaces are chosen for specific roads and undertaking more thorough investigations and reporting of the reasons when they fail.

The less-than-expected lifetimes being achieved for asphalt surfaces will have obvious implications for their selection. The research found that the average lifetimes of thin asphalt layers are not significantly greater than for chipseal, but the cost can be four to six times higher. As a result, significant benefits of using asphalt should be identified before selecting it instead of chipseal. The main benefits relate to smoothness of ride, rolling resistance, noise and aesthetics. Asphalt is also good for areas where chipseal would be expected to fail early in the pavement's life.

The research also looked at fatigue and shear strength in asphalt surfaces, making various recommendations for how these could be measured and addressed to improve pavement performance.

The use of warranties, contract form and specifications, proportional payments and certified products was also all considered, with a view to improving performance. The Highway Authorities Product Approval Scheme (HAPAS) certification scheme, as used in the UK, was looked at as a way of encouraging proprietary surfacing systems. The scheme would need adaptation for New Zealand conditions, but otherwise showed promise as a means of assessing suppliers' claims about the durability of their surfaces (amongst other things).

THE RECOMMENDATIONS

CURRENT LIVES:

- Premature failures should be investigated more fully and a system devised to alert the Transport Agency's National Office of the occurrence of premature failure, and an appropriate level of investigation should be performed to identify the reasons for it.
- A system to record the reasons for the choice of surface treatment and the reasons for any estimate of life is needed.
- The report mentions that skid resistance was given as a reason for the large number of premature asphalt resurfacings. However, the T10 skid resistance policy has substantially changed, which allows for a lower macrotexture, since this research was undertaken. Also, there is now more emphasis on selecting aggregate with the right skid resistance properties. It is believed this is now being controlled appropriately.

WHOLE-OF-LIFE COSTS:

- The cost of noise detailed in the Transport Agency's Economic evaluation manual needs to be evaluated to ensure it is reflecting current user expectations.

FATIGUE:

- At this stage of knowledge it is recommended that the Circly-calculated results for strains at the top of the pavement, where they are higher than those at the bottom of the asphalt layer, be used as the 'critical' strains for fatigue in the pavement design.

SHEAR STRENGTH:

- The relationship between the plateau density of asphalt achieved under different traffic conditions, and the density obtained in a gyratory compaction of asphalt mixes (known as the Servopac method), needs to be quantified.
- The benefits of changing to the US Superpave method design, which is continuing to be developed and fine tuned, should be investigated.
- The effect of changes in binder grade and type on rut resistance, and the effect this could have on fatigue resistance, needs to be quantified and included in the Transport Agency asphalt guides.
- The use of the Asphalt Mixture Performance Tester in the New Zealand context should be investigated.

ACCEPTANCE SCHEMES:

- An approval scheme based on the HAPAS model should be developed and introduced.
- A performance-related specification for asphalt should be developed.
- More emphasis should be placed on 5 to 10-year performance warranties, initially as trials.
- A statistical approach should be developed for acceptance of and payment for thin asphalt surfacings.

The research report also includes guidelines for choosing suitable pavement surfaces, including a surface selection flowchart to assist decision making.

Improvement of the performance of hotmix asphalt surfacings in New Zealand, NZ Transport Agency research report 508

Available online at **www.nzta.govt.nz/resources/research/reports/508**

FRICTION TESTING RESULTS UNAFFECTED BY ROUGHNESS

Research into the relationship between road roughness and skid resistance measurement has returned some unexpected results.

Skid resistance, although known to play a crucial role in loss-of-control crashes in wet conditions, is notoriously hard to manage, mainly due to the variability of skid resistance measurements and in interpreting results from measurement devices.

This research focused on one of the main variables thought to influence the accuracy of skid resistance measurement, namely road roughness, investigating the effect that road roughness, macro-texture and testing speed have on GripTester measurements.

The conclusion was reached that, while test speed and texture would appear to have an impact on the measurement of the grip number, surprisingly, road roughness did not appear to have an influence on the grip number as hypothesised.

Doug Wilson of the Department of Civil and Environmental Engineering at the University of Auckland, who headed the project, says, 'Our results don't fit with accepted skid resistance theory, namely that skid resistance should reduce as measurement speed increases, and that this happens at a greater rate where a section of road has a high macro-texture. As a result, it's raised some questions about the behaviour of skid resistance and the various devices we use here in New Zealand to measure friction that will need further research to resolve.

'We suggest that future research into the topic could include better controlled test sites and larger samples to clarify the effect that macro-texture has on friction with increasing speed and hence the grip number. This will also help to pin down the unidentified factors that we observed, but couldn't identify in our own research, which can have an influence on GripTester output. It would also be helpful to incorporate a greater range of skid resistance measurement devices in the testing to determine whether the results observed applied only to the GripTester device.'

The research team conducted field tests using the GripTester at various speeds on sites with varying road roughness in South Auckland. The sites were identified from the Franklin District Council road asset and maintenance management (RAMM) database, with some additional sites selected in the Waipa District. Sites were chosen to represent five predefined roughness bands and three macro-texture levels, with site visits used to verify that the roughness and texture data on the database was still valid.

The team then carried out field tests at all the sites, with measurements taken for the three variables being looked at – road roughness, texture and test speeds. The measurements were plotted against each other, along with the grip number, as obtained from the GripTester. (During the field tests the grip number was recorded for each road section at 1m and 10m averaged intervals. The 10m interval reflects the GripTester's normal operation when used for network and project surveys.)

The team also carried out tests with a Dynamic Friction Tester (a stationary skid resistance measurement device) at some locations and correlated the results with those taken from the GripTester at various towing speeds.

Doug says, 'What we found is that while the grip number does not appear to be affected by test speeds while testing at speeds lower than 75km/h, there is a relationship at higher speeds. Contrary to what we expected, road roughness had no significant effect on GripTester measurements and texture appeared to be only a minor factor. The effect of texture would be usefully clarified through more extensive testing.'

One related outcome of the research was the confirmation that the Dynamic Friction Tester is a highly repeatable device (with a coefficient of variation of ≤2.5%) and is useful for calibrating continuous friction devices, such as the GripTester. On the test sections where both devices were used there was a high degree of correlation between the coefficient of friction results obtained from the two machines, and this was found to be independent of the speed the GripTester was operating at.

THE GRIPTESTER

(a) The GripTester (side view)

(b) GripTester measuring wheel and chain transmission

Figure 1 The GripTester (Findlay Irvine Ltd 2005)

The GripTester is one of the continuous skid resistance measurement devices used in New Zealand. Other commonly used devices include the Sideway-force Coefficient Routine Investigation Machine (SCRIM) and road analyser and recorder machine (RoAR) continuous measurement devices, but the findings of the research do not relate to these.

The GripTester is commonly used in New Zealand and overseas to measure surface friction on airport runways, road pavement surfaces, walkways and for research purposes. It is a three-wheeled trailer (one test wheel and two bogey wheels) that can be towed behind a vehicle with a water-delivery system (for simulating wet weather conditions). Compared with the truck-based SCRIM measurement device (currently used by the NZ Transport Agency for the annual measurement of skid resistance on New Zealand's state highways) it is a relatively lightweight device at 85kg in total.

The GripTester measures the magnitude of friction between two surfaces (a road surface and a rubber tyre) and this is expressed as the coefficient of friction. The coefficient is essentially the ratio of two forces: one parallel to the road surface and the tyre contact area that is opposed to vehicle motion (the friction force); and the other perpendicular to this surface of contact (the normal force generated from the vehicle load). This coefficient of friction ratio is known as the grip number.

Previous research and anecdotal evidence had suggested that the GripTester's operation and accuracy were adversely affected by road surfaces with rough road surfaces or bumps. The current project aimed to look into this to determine what effect roughness and testing speeds had on GripTester measurements, if any. In particular, the project's objectives were to:

- quantify the effect of longitudinal road roughness on the GripTester device
- measure the effects of surface texture on the results produced by the GripTester in comparison with the Dynamic Friction Tester
- measure the effects of travelling speeds on the results obtained by the GripTester, on various road surfaces with various levels of road roughness.

The research team's hope was that the outcomes from the research would enable road controlling authorities and consultants to specify skid resistance testing protocols, which would help ensure that measurements undertaken by the GripTester were not affected by external variables, such as speed and road roughness. This in turn would provide authorities with greater confidence in GripTester measurements. However, the findings of the research mean that more extensive research is needed to fully understand the factors that affect GripTester output.

The effect of road roughness (and test speed) on GripTester measurements, NZ Transport Agency research report 523

Available online at **www.nzta.govt.nz/resources/research/reports/523**

A NOTE FOR READERS

NZTA research newsletter

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