IMPROVING A GREAT SKID RESISTANCE POLICY: NEW ZEALAND STATE HIGHWAYS

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ABSTRACT

The success of the New Zealand skid resistance policy has been documented in a series of papers. Davies et al 2005 documented the benefits of improving skid resistance in terms of crash rates, Owen et al 2008 documented the benefits of the skid resistance policy and Cook et al 2010 documented a benefit cost ratio (B/C) for the policy.

This paper discusses the development of the New Zealand skid resistance policy and significant changes that have been made recently. The changes include:

- Prioritisation of treatments to improve skid resistance at both Exception Report stage and following seasonal correction of data.
- Aggregate Performance method for selection of aggregate on historic performance rather than PSV.
- Addition of stress factors to the PSV equation to allow for areas of higher polishing stress.
- Site sampling and testing to check actual PSV of aggregate used.
- Extending the polishing time in the PSV test in an attempt to model the higher polishing stress on critical sections of the network.
- Review of macrotexture requirements for low speed sections of the network.
- Amendment of Investigatory levels to allow for specific site features.
- Use of Glenbrook Melter Slag in higher stress sections of the network
- Guidance on treatment (maintenance) of unstable chipseals
- Bitumen bubbles.
- Waterblasting and scabbling.
- Site investigations
- Reviews of regional programs
- Training
- Extension of skid policy to Local Authorities

1.0 INTRODUCTION

Fig 1 (over) shows a generalised flow chart for the development of a skid resistance policy.

In New Zealand the earliest recorded investigation into the relationship between skid resistance and crashes was Nicholson A. J. [(1)]. This investigation found that sites with higher crashes generally had lower skid resistance. The indications were that actions to improve skid resistance would be economic.

Donbavand J. [(2)] in 1989 details an extensive literature survey resulting in the following recommendations (summarised):

- Standards for Polished Stone Value (PSV) of surfacing aggregate dependant on site classification
- The setup of a skid resistance monitoring system, noting UK experience.
- That further work is done to investigate use of SCRIM for a state highway skid resistance survey.
- That the only facility to measure PSV in New Zealand (Canterbury University) be upgraded and maintained.

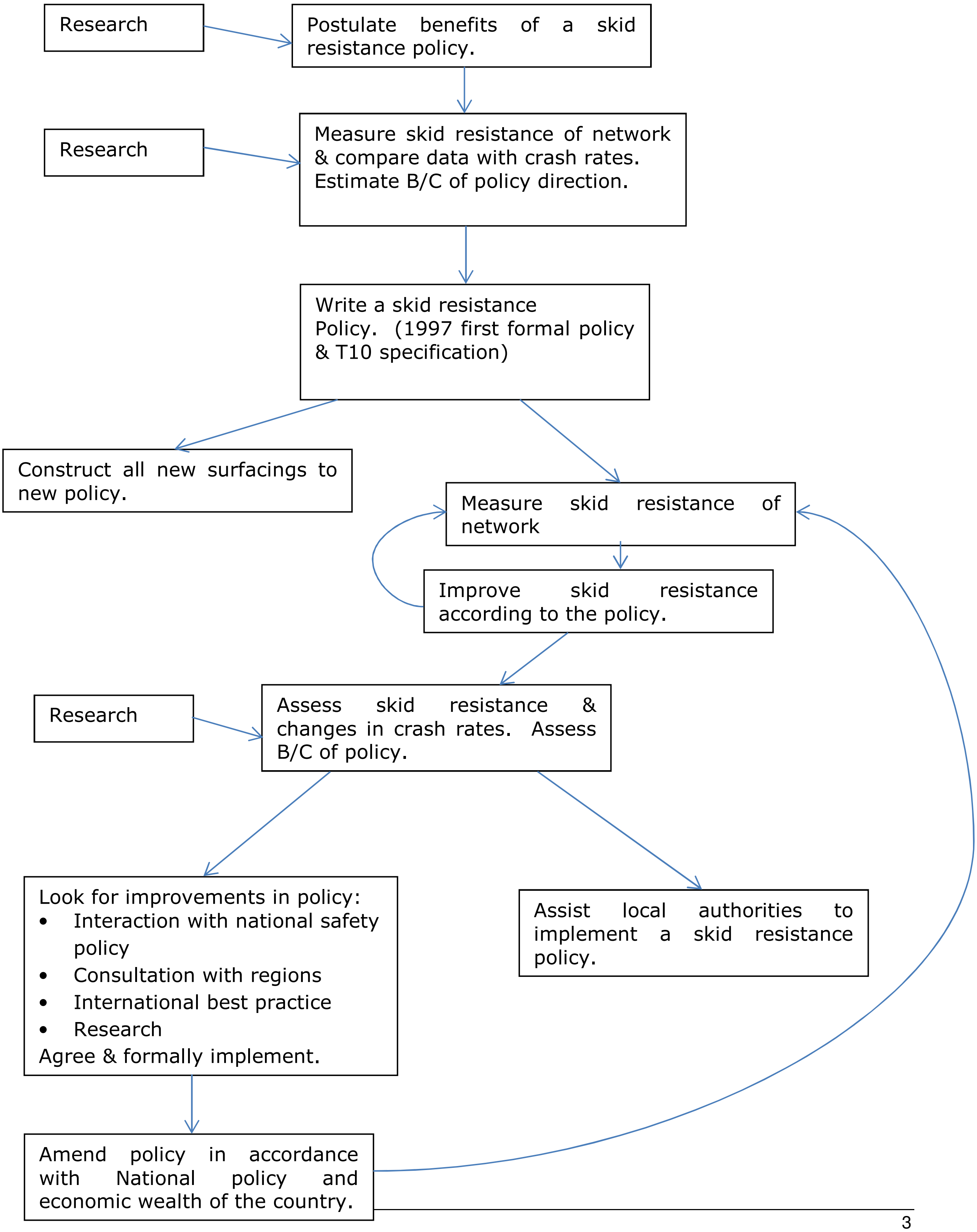
Following this report a survey of the New Zealand network was undertaken. This survey indicated that there would be benefits in managing skid resistance.

In 1996 a full survey of the New Zealand network was undertaken followed by detailed statistical analysis. This indicated the benefit cost ratio of a skid resistance policy could be around 40. In 1997 the first Transit New Zealand Specification was issued: T10: Specification for Skid Resistance Deficiency Investigation and Treatment Selection. (See http://www.nzta.govt.nz/resources/skid-resistance-investigation-treatment-selection/archive.html for text of all specifications referred to in text as T10.)

Following the SCRIM survey in 1998 a structured program for maintenance of the network was undertaken. Since this time annual surveys have been undertaken followed by treatment to make the road adequately safe. The T10 specification has been updated in 1999, 2002, 2010, 2012 and 2013. Associated notes have been written and recently event code diagrams have been added.

All of the above refers to development of skid resistance policy for the state highway network. Local Authorities have followed in a variable manner.

Fig 1: Skid Resistance Policy Flow Chart



2.0 OUTLINE OF T10 POLICY

The T10 policy is based around a survey of skid resistance and setting priorities for treatment. (Treatment includes maintenance to improve the road surfacing, other actions to make the road adequately safe (eg signage) and may include do nothing (for example when the cause of low skid resistance is temporary contamination))

Investigatory levels (IL) are the basis for consideration of survey skid resistance data and decisions as to future treatment. See T10: 2013 Table 1 for SCRIM data and Table 3 for macrotexture.

Priority for skid resistance treatment is addressed in two stages; Exception Report, and after Seasonal Correction of SCRIM data.

The Exception report lists 10m sections of the network where SCRIM Coefficient (SC) and/or macrotexture are less than Threshold levels. (Threshold Level for SCRIM data (TL) is 0.1 below IL and Threshold level for macrotexture (TLM) is defined in T10 Table 3.) These sites are then prioritised in to A and B sites.

Priority A sites are those that meet at least one of the following criteria:

- sites that are below the TL or the TLM and have had at least two wet skid crashes in the previous five years.
- sites that are flushed.
- sites where the SC is low.

All other 10m lengths are assigned priority B

Only sites that are in priority A are investigated.

The exception report is produced promptly after SCRIM data becomes available to enable programming of treatments for the sections of the network with greatest need.

The second stage for consideration for skid resistance uses SCRIM data that has been seasonally corrected. The network is divided into Skid Assessment Lengths (SALs), see Table 2 of T10. Each SAL is given a score based on number of wet skid crashes, quantum SC is below IL averaged over the SAL, quantum macrotexture is below Investigatory level macrotexture (ILM) averaged over the SAL and traffic. (See T10 table 4). A decision is then made on how many sites will be investigated, and a final priority list produced based on the site investigation the SAL score and the financial allocation. Note the SAL score may be amended, based on the site investigation.

Treatment selection ranges from a new surfacing to do nothing. Do nothing may be appropriate where the cause of the low skid resistance is temporary contamination or the crashes are not influenced by improving skid resistance.

Aggregate for new surfacing (both new pavements and resurfacing) is selected by one of two methods:

- The PSV method. This uses the basic PSV formula with the constant of 2.4 replaced by a Polishing Stress Factor (PSF) that ranges from 3 to 9 or higher.
- The Aggregate Performance method. This requires the surfacing to be constructed with an aggregate that has performed adequately under similar or higher polishing stress. This is the preferred method for higher polishing stress sections of the network.

Where higher PSV aggregate is required (57+) samples of aggregate must be taken and tested.

While IL is defined in Table 1 regional staff are required to review ILs on a 3 year cycle.

Unstable chipseals and review of regional programmes is also addressed within the specification.

3.0 BENEFITS OF THE T10 SKID RESISTANCE POLICY

Both Nicholson and Donbavand's work (1979 and 1989 respectively) showed significant benefits would ensue from an appropriate skid resistance policy. As already stated the 1996 statistical analysis indicated the benefit / cost ratio could be around 40.

The T10 policy was implemented in 1997 and in 2005 Davies R B et al [(3)] used crash and SCRIM survey data to calculate that an increase in SC of 0.1 reduced crash rates by around 30% on average over the state highway network. They did not address the cost side of the equation.

Owen et al [(4)] 2008 analysed crash rate changes since the inception of the T10 policy and concluded that it had reduced the rural state highway wet crash rate by around 20% as well as reducing the rural state highway dry crash rate by a significant amount.

Cook et al [(5)] extended the 2008 analysis and added costs to enable calculation of a B/C. It was concluded that the B/C of the T10 policy was between 13 and 35.

In addition, a wealth of anecdotal evidence exists, showing reductions in crash rates when road surface skid resistance is increased.

The benefits of New Transport Agency skid resistance policy are so well accepted that to date we have been unable to gain funding to improve our understanding of the benefits.

4.0 RECENT DEVELOPMENTS OF THE SKID RESISTANCE POLICY

The skid policy is under constant review in response to perceived improvements and changes in economic policy. The major recent improvements are outlined below.

4.1 PRIORITISATION OF TREATMENTS TO IMPROVE SKID RESISTANCE

Prioritisation at both the Exception Report and Seasonally Corrected stages has been outlined in section 2. This policy is a significant development in moving from prioritisation based on skid resistance and general safety to explicitly include wet road crashes and traffic. It will enable skid treatments to be managed according to funding availability. This will not be discussed further here as it is the subject of a full paper Prioritising State Highway Skid Resistance in New Zealand – A Policy for all Budgets. Whitehead D et al 2014 [(6)] to be presented later.

4.2 UPGRADING THE PSV EQUATION

In New Zealand there are few aggregates with a high resistance to polishing. The better aggregates tend to be soft and are not durable. Some give reasonable life in mixes but very short life in chipseals.

In addition, we have not been well served by the Polished Stone Value (PSV) equation, in that it underestimates the PSV of the aggregate required in higher stress sections of the network.

Action taken includes:

a. Removing the single constant of 2.4 in PSV equation and including a variable Polishing Stress Factor (PSF) to the equation.
b. Using an additional test for determining the polishing characteristics which extends the aggregate polishing time to 12 hours. (PSV12)
c. Site sampling to test PSV of aggregate used.
d. Review of PSV methodology used by the test laboratories.

Further comment is included below.

4.3 POLISHING STRESS FACTORS (PSF)

The PSV equation with the constant of 2.4 was derived for low polishing stress sections of pavement. As we investigated reasons for aggregate polishing it became evident that polishing stress was much higher on some sections than assumed. Frequently these were also the sections where higher skid resistance was required for safety and only the best aggregates could perform adequately.

Therefore a Polishing Stress Factor (PSF) was added in place of the constant of 2.4

The new equation is:

PSV = 100*SR + 0.00663*HCV + PSF

SR = investigatory level for the site (table 1 below or as defined in contract documents)
HCV = estimated heavy commercial vehicles per lane per day at the end of the surfacing life
PSF = polishing stress factor selected for the site in accordance with table 1 below (Table 5 in T10)
PSV = polished stone value

It can be seen from table 1 that the PSF varies between 3 and 9. In practice the PSF may exceed 9.
This requirement is addressed through the Aggregate Performance Method, see later.

Table 1 (Table 5 from T10) Polishing stress factors

Polishing stress factor	Site description
3	Site category 5, event-free: where no other geometrical constraint, or situations where vehicles may be required to brake suddenly, could increase the skid resistance requirements. Site category 4, straight level road, less than 5,000VPD, very seldom any congestion and few low-volume access points.
4	Site category 4, greater than 5,000VPD, very seldom any congestion, grades < 3%, Site category 3a, state highway approach to a local road junction. Low-risk curves.
5	Site category 4, where congestion may occur or grades ≥ 3% Site category 3b, down gradients 5-10%. Site category 3c, including 200m before off ramps. Urban site category 2 curves.
6	Site category 1, with average approach speeds and infrequent emergency braking. Rural site category 2, curves medium risk.
7	Site category 1, with average braking Rolling country with frequent curves requiring frequent acceleration and deceleration.
8	Site category 1, with frequent heavy braking Site category 2, curves that are high risk. Any site with frequent heavy braking, eg curve requiring braking at end of down grade.
9	Sections of the network with highest stress due to braking or cornering eg curve requiring braking at end of steeper down grade (≥8%).

The NZTA Regional Operations Manager or their nominee within the NZTA may amend table 5 following discussion with the National Pavements Manager.

4.4 EXTENDING THE POLISHING TIME IN THE PSV TEST

It has been found that some high PSV aggregates tend to continue polishing to low values of skid resistance on higher stress sections of the network. It has also been found that these same aggregates tend to continue polishing if the fine polishing continues beyond the standard 3 hours in the PSV test. The extended fine polishing time has been standardised to 12 hours and has led to a new test, referred to as (PSV12).

More work is required to include the PSV12 test as a formal requirement, but the PSV12 test has been included in the T10 notes as another tool regions may use to assist in selection of aggregate for surfacing in high polishing stress areas.

4.5 SITE SAMPLING OF AGGREGATE

A whole variety of reasons has been offered for the poor correlation between the PSV value of an aggregate as determined by the quarries quality assurance program and the polishing of the aggregate on the road.

In an attempt to refine the process regions are required to sample and test some aggregates used on higher polishing stress sections. The test includes the standard PSV test and to a lesser extent the PSV12 test.

There is a natural variability in the quarried seams, and we are investigating ways to identify where changes in the aggregate characteristics are occurring in the quarry and how these are tracked. This whole issue is still under investigation and will be reported at a later time.

4.6 REVIEW OF PSV TESTING

In New Zealand, round robin testing has shown that the repeatability and reproducibility of the PSV test of +/- 3 and +/-5 respectively is in line with international experience. However, it is believed that these precision limits could be improved with additional training for the laboratory staff.

We are investigating the possibility of a change to the control stone to Canterbury Greywacke. This aggregate is widely used, is freely available and has produced a very consistent value of PSV over a long time. However we are also aware of the work to produce a new reference stone and are proceeding with caution.

The issues are all under consideration by an NZTA and industry working group.

4.7 AGGREGATE PERFORMANCE METHOD

With all of the problems associated with use of the PSV method further work is required. In a sidestep of the problem the Aggregate Performance Method was developed. In essence the Aggregate Performance Method is very simple. For a new surfacing the aggregate to be

used must be shown to have performed adequately on a site with similar or higher polishing stress. All comparisons to be based on formal skid resistance measurement.
In practice any skid data must be normalised for:

- Age of surfacing, particularly the high polishing in the early life.
- Heavy traffic, generally we assume the 0.00663 factor in the PSV equation is accurate.
- Site polishing stress
- For chipseals the chip size is also a factor.
- Less well understood is the effect of weather and in particular rain, quantity and seasonal patterns. For example we tend to get good skid resistance from aggregates on the West Coast of the South Island of New Zealand, possibly due to high rainfall.

4.8 GLENBROOK MELTER SLAG (GMS)

Glenbrook Melter Slag (GMS) is a typical example of an aggregate with a moderate PSV (around 60), but very good resistance to polishing. In fact it is better than the best natural aggregate available in New Zealand. GMS also has good durability and performs well in both chipseals and asphaltic mixes.

Fortunately there is currently a large stockpile of GMS and the steel mill is prepared to produce a consistent material to enable sale as a Coproduct of the steel mill. A later paper will detail the use and investigation of the GMS as a surfacing aggregate.

There are two other similar products.

- GMS is the slag from the iron making plant. At Glenbrook the iron is further processed to make steel. The slag from this process contains free lime and is quite soft. It is unsuitable for surfacing aggregate but good for addition to basecourse, particularly where reactive clays are present.
- Pacific Steel (New Zealand) market a slag from their steel plant. It is claimed to be a good surfacing product but to date we have not been able to obtain data on its performance.

Calcined Bauxite is the only known product with better skid performance than GMS. However the cost is eight to ten times that of GMS and the life is frequently less. For these reasons use of calcined bauxite is often not economic.

4.9 REVIEW OF INVESTIGATORY LEVELS

Below is Table 2 (Table 1 from T10). This defines the default investigatory levels (IL) used on the New Zealand state highway network. Regions have always been given the ability to amend the ILs but in the past have been reticent to do so for two reasons:

- Each year the IL reverted to the default value allocated by the survey vehicle. This has now been changed in that both the default value and the hard wired value (value permanently recorded in RAMM) are recorded, but default reporting is by hard wired ILs.
- In addition consultants have been reticent to accept the liability of reducing an IL. This has been overcome by making review of ILs mandatory both on a three year

cycle and as part of the investigation of a site. Explicit guidance is also included in an appendix to T10.

Table 2, (Table 1 from T10) Skid resistance investigatory levels

Site category	Skid site description	Investigatory level (IL), units ESC					
		0.35	0.40	0.45	0.50	0.55	0.60
1	Approaches to: a) Railway level crossings b) Traffic signals c) Pedestrian crossings d) Stop and Give Way controlled intersections (where state highway traffic is required to stop or give way) e) Roundabouts. One lane bridges: a) Approaches and bridge deck.						
2	b) Urban curves <250m radius						
	c) Rural curves <250m radius			L	M	H	
	d) Rural curves 250-400m radius		L	L	M	H	
	e) Down gradients >10%. f) On ramps with ramp metering.						
3	g) State highway approach to a local road junction. h) Down gradients 5-10% i) Motorway junction area including on/off Ramps j) Roundabouts, circular section only.						
4	Undivided carriageways (event-free).						
5	Divided carriageways (event-free).						

4.10 REVIEW OF INVESTGATORY LEVELS FOR MACROTEXTURE (ILM)

ILM have been reviewed for lower speed sections of the state highway network. Details of current requirements are given in Table 3 below.

Reference the notes to T10 Table 3:

- The relaxation for low speed curves (not the approaches) acknowledges the low operating speed.
- On chipseals as the bitumen rises up the sides of the chips tyres start to take some of the normal force on the bitumen. This has very low SCRIM Coefficient and there is a large drop in total surfacing SCRIM Coefficient.

Table 3 (Table 3 T10) Minimum macrotexture requirements

Minimum macrotexture – mean profile depth (MPD mm)						
Permanent speed limit	Chipseal		Asphaltic concrete, ESC ≥ 0.4		Asphaltic concrete, ESC < 0.4	
	ILM	TLM	ILM	TLM	ILM	TLM
50km/h and less	1.0	0.7	0.4	0.3	0.5	0.5
Less than or equal to 70km/h but >50km/h	1.0	0.7	0.4	0.3	0.7	0.5
Greater than 70km/h	1.0	0.7	0.9	0.7	0.9	0.7

Notes to Table 3

- On curves where the advisory speed limit is 45km/h or less, consideration may be given to the use of ILM and TLM (as per table 3) for asphaltic concrete where the permanent speed limit is 50km/h and less
- The TLM for chipseals is set at 0.7mm MPD. In urban areas, where the surveyed macrotexture is equal to or higher than required for asphaltic concrete (ie 0.5mm MPD), maintenance to improve the macrotexture may be delayed provided that:
  - the ESC is above TL
  - ESC levels are stable, ie they have not reduced by more than 0.05ESC since the previous annual survey
  - Inspections are programmed and resources are available to ensure prompt treatment is undertaken, should macrotexture levels continue to drop.

4.11 WATERBLASTING & SCABBLING

When low skid resistance is due to bitumen rise in a chipseal treatment to improve the skid resistance may include Water Blasting (spraying very small quantities of very high pressure water on to the chipseal to remove bitumen from between the chips.). This process is a similar price per square metre to a new chipseal and so is generally only economic if the flushing occurs in small isolated areas.

Where low skid resistance is due to polishing of the aggregate the only equipment available in New Zealand is a Scabbler. This has a series of triangular plates placed loosely on the circumference of the drum. As the drum rotates the plates impact the surface of the aggregate and improve the microtexture. The cost is generally half that of a new chipseal, but the expected life of the scabbled surface would not be longer than the original surface.

4.12 UNSTABLE CHIPSEALS

As successive chipseal layers are constructed binder stone ratios increase and eventually the chipseal becomes unstable.

A chipseal may be unstable if the previous chipseal had a life of 5 years or less and there are 5 or more chipseal layers. Further confirmation may be obtained by checking the binder stone ratio. (Note binder is any material passing 2.36mm sieve, the remainder is stone.) If the ratio is greater than 15% we assume the chipseal is unstable.

Note: Strictly the pavement should be rehabilitated when the NPV of successive treatments to maintain the surfacing in accordance with the T10 specification is greater than rehabilitation and resurfacing to obtain the same objective, but the above is a good first cut.

4.13 BITUMEN BUBBLES

Bitumen bubbles are caused by water pressure on hot days. They are generally no more than a few millimetres across, and transport the bitumen to the surface leading to bleeding, pickup of bitumen on vehicle tyres, further blackening of the road surface both around the area and down the road from tracking. This leads to dramatic reduction in skid resistance on the road. The driving force for the bubble is heated water vapour, cores indicate the bitumen has been stripped from chip at lower layers in the chipseal matrix. However little is understood as to why the process occurs. Further research is underway.

Photo of bitumen bubble. Note also vent holes from former bubbles now partially closed by traffic.

4.14 REVIEWS OF REGIONAL PROGRAMS

Reviews of regional skid resistance programs are undertaken to check the processes and skid resistance treatments undertaken or programmed are appropriate. It is also an opportunity to discuss any good ideas with the regional staff.

Some reviews are undertaken on a random basis and some regions are chosen because the volume of work to improve the skid resistance is high on a national basis. These areas are generally given additional assistance.

4.15 CONTRACTS AND TRAINING

The New Zealand Transport Agency is moving towards Network Outcome Contracts (NOC) where the Transport Agency staff will be required to undertake the responsibility of both the consultant and the client. This has produced a demand for further training in all aspects of road maintenance, including surfacings and skid resistance.

4.16 EXTENSION OF THE STATE HIGHWAY SKID POLICY TO LOCAL AUTHORITIES

The New Zealand Transport Agency requires Local Authorities to have a skid resistance policy, but frequently it has been very basic. Some local authorities have roads that are similar in character to heavily trafficked state highways but the network may include cul-de-sacs or roads with less than 100vpd. This implies that local authority policy should be graduated for the full range of roads. It could range from a policy similar to that used on state highways where warranted down to a visual inspection only for the lowest traffic volumes.

We are currently in discussion with a major urban authority to assist with a skid policy. Once trialled we expect this policy will be developed further to enable acceptance by all local authorities progressively.

5.0 CONCLUSIONS

The objective of the New Zealand T10 skid resistance policy is to reduce the number and severity of crashes by applying an appropriate skid resistance. This necessitates managing the use of aggregate to ensure that the right stone is placed in the right location and that the macrotexture is adequate. This policy has been shown to be very effective in reducing wet road crashes and also, to a lesser extent, dry road crashes. Further this strategy has a very high benefit cost ratio (>20) for reducing crashes.

The policy is under continuous development utilising both experience and more formal research.

This paper is presented with the objective that others may benefit from the experience gained and that discussion at the conference may assist New Zealand to find further ways to improve the policy.

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Author Biographies

David M Cook, Senior Surfacings Engineer, New Zealand Transport Agency, New Zealand

David holds the position of Senior Surfacing Engineer working in National Office of NZTA. He has over 40 years' experience in a wide range of roading issues from construction supervision, major project development and roading maintenance and construction. He has been involved in a variety of roles relating to the development of the state highway skid resistance policy. He managed the initial High Speed Data Collection contract that included skid resistance. Recently he retired as chairman of STAG (Skid Technical Advisory Group), the group responsible for overview and management of the state highway skid resistance policy, following a period of 8 years as chairman. He currently works for New Zealand Transport agency on skid resistance, surfacings and associated safety areas.

John Donbavand

John arrived in NZ in 1983 and stayed for 18 years during this time he has held a number of positions including Bitumen Chemist, Surfacing Scientist and Engineering Policy Manager for Transit New Zealand.

John returned to the UK in 2001 to take up the position as Project Development Manager at W.D.M. Limited. In this position, John has been involved with a wide range of projects, including, developing procedures to estimate the national maintenance budgets for the Highway Agencies, asset valuation for local roads, providing scheme prioritisation techniques for Highway Authorities and providing skid policies for numerous Highway authorities, including London and Scotland.

John returned to New Zealand in March 2012 and started work with the New Zealand Transport Agency as the National Pavements Manager. In this role his principal responsibility is to maintain and develop the technical standards, specifications and guidelines for State Highway pavements.

Dave Whitehead

Dave has over 30 years of experience in a variety of roles within the highways engineering sector of which the last 25 have been in highway maintenance and asset management. He has worked largely in the UK in both the private and public sectors but prior to moving to New Zealand in 2008 had previous overseas experience in Sri Lanka.

Dave currently holds the position of Senior Pavements Engineer within the Pavement Group at the NZ Transport Agency's National Office in Wellington. He has been part of the team responsible for developing the T10 specification relating to skid resistance as well as involvement in a range of technical projects related to asset management. Dave recently stepped down as the chair on the Skid Technical Advisory Group (STAG) within NZTA but still retains membership on the group.