DEVELOPMENT OF THE SAFE APPLICATION AND USAGE OF CALCIUM MAGNESIUM ACETATE AS AN ANTI-ICING AGENT UNDER NEW ZEALAND CONDITIONS

Murray Clarke*, Vince Dravitzki** and Peter Cenek**

*Transit New Zealand
Otago Region
P O Box 5241, Dunedin, New Zealand
TEL +64-3-477-857/FAX +64-3-477-9237
E-mail address:Murray.Clarke@transit.govt.nz

** Opus International Consultants
Central Laboratories
P O Box 30-845, Lower Hutt, New Zealand
TEL +64-4-587-0600/FAX +64-4-587-0604
E-mail address:Vince.Dravitzki@opus.co.nz
Peter.Cenek@opus.co.nz

1. Abstract

Since 1998, Calcium Magnesium Acetate (CMA) has been trailed by Transit New Zealand in the Coastal Otago region of New Zealand as an anti-icing and de-icing agent for state highways. During the trials, there were instances where vehicles had lost control on a road surface that had been treated with CMA to prevent ice formation. This raised the issue as to whether or not skid resistance was reduced by the presence of CMA. The time of day the CMA was applied also appeared to be an important consideration, application in late afternoon resulting in a greater likelihood of a loss of control incident occurring than application in the early hours of the morning, close to ice formation.

Unlike countries where CMA has been successfully introduced for winter road maintenance, New Zealand has far less severe winter temperatures, higher relative humidity, and more highly textured road surfaces with 90% of the state highway network being coarse chip seal. Therefore, a controlled study, which utilized a climate chamber, was conducted to establish whether or not the addition of CMA to representative New Zealand road surfaces would initiate a temporary reduction in skid resistance and to quantify the magnitude and duration of this reduction under different climatic conditions experienced during the course of a typical winter's day.

It was found that a CMA solution reduces the skid resistance of a dry road surface more than water alone under identical climatic conditions, the additional reduction in the coefficient of friction being of the order of 0.15 to 0.3. In addition, a sensitivity to humidity level was observed, this being especially noticeable when the CMA solution had partially dried, confirming Canadian findings. CMA also encourages the road to stay moist and slippery much longer than occurs for water alone. When dry, CMA on a road surface had no effect on the skid resistance, but was reactivated with an attendant reduction in skid resistance by "dew-like" quantities of water. This reduction lies midway between the wet only condition and the CMA wet value. However, compared with a "black ice" situation, CMA results in a significant improvement in the road's coefficient of friction of between 0.1 and 0.25 depending on surface type and so its continued use in New Zealand for winter road

maintenance is advocated but with modified application procedures to better manage any potential temporary hazards for motorists.

2. Introduction

The principle method of mitigating ice hazards on New Zealand roads is by applying mineral grit to the road surface. However, the build-up of grit can create its own safety hazards and has been known to be a contributory factor in loss of control crashes. Furthermore, New Zealand motorists have become increasingly concerned about the damage loose grit on the road surface does to vehicle paintwork and windscreens. As a consequence, Transit New Zealand, a statutory authority tasked with managing national roads (state highways), decided it was appropriate to investigate alternative methods for managing ice hazards.

In past years, common salt (sodium chloride) was used in New Zealand as a de-icer but the practice was largely discontinued in the early 1980's due to public concerns relating to its effect on vehicle corrosion. Common salt was again considered by Transit New Zealand as part of its investigation of anti-icing and de-icing agents, but only on the basis of minimal application as a last resort de-icer. However, even with this restricted application, Transit New Zealand was unable to allay general public and conservationists fears regarding common salt, despite the knowledge that major advances had been made in vehicle protection over recent years and also the history of previous use in New Zealand indicating that any effects of salt on vegetation and streams may be only minor. As a result, public opinion was instrumental in Transit New Zealand precluding the re-introduction of common salt to assist with de-icing. Anti-icing and de-icing agents in common use in North America, therefore, were considered. Calcium Magnesium Acetate (CMA) was identified as being most appropriate for New Zealand conditions because of its benign nature from both corrosive and environmental perspectives, thereby addressing the publics' concerns with common salt. It is also effective over the temperature range experienced on New Zealand roads.

Over the winters of 1999 and 2000, CMA trials have been performed in the Coastal Otago region of New Zealand to determine:

- the most effective and safe methods for applying CMA;
- the cost effectiveness of CMA; and
- the effect of CMA application on crash rates.

During these trials there had been some instances where vehicles had lost control on a road surface that had CMA applied to it, raising the issue as to whether or not skid resistance is reduced when CMA is applied to New Zealand roads as an anti-icing agent. To date, there is nothing conclusive to indicate that CMA may introduce "chemical slipperiness" to a road surface apart from recent Canadian research (Leggett, 1999). This research established that most liquid anti-icing chemicals tend to pass through a "slippery" phase during their transition from liquid to solid. The transition phase occurs at low humidity levels and is generally of short duration. However, the Canadian research was limited in scope, covering only one road surface type, asphaltic concrete, and environmental conditions that were not representative of New Zealand winters.

In order to better understand how CMA affects the skid resistance provided by a road surface, a controlled study was commissioned by Transit New Zealand. The aims of this study were to establish whether or not the addition of CMA as an anti-icing agent to representative New Zealand road surfaces would initiate a temporary reduction in skid resistance under different climatic conditions experienced during the course of a typical winters day, and, to determine the magnitude and duration of this effect.

This paper summarizes the study undertaken and resultant key findings.

3. Experimental Procedure

A key requirement for testing the effects of CMA on the skid resistance of different road surfaces was the close control of climate related environmental factors to allow sensitivities to temperature and humidity to be identified. Accordingly, controlled environment rooms of the National Climate Laboratory (NCL) were utilised. Each room is approximately 3m by 3m by 3m in size and has full microprocessor programming and control capability allowing temperatures and humidity to be controlled to ±0.5°C over a range of -25°C to 48°C and ±3%RH over a range of 10%RH to 95%RH, respectively. Additional details on the NCL's controlled environment rooms can be found on their web site (http://www.hortresearch.co.nz/products/ncl/capabilities/).

In using CMA as an anti-icing agent, application as a precautionary agent can occur anytime between several hours before to just prior frost or ice formation. The decision to treat, or when to apply, is based on short and long range weather forecasts coupled with local knowledge of the applicator and road maintenance engineer. Two conditions were chosen for simulation in the NCL controlled environment rooms, late afternoon and early morning, since these represented the time extremes for applying CMA as an anti-icing agent to mitigate early morning road slipperiness caused by overnight frost or ice formation.

After a review of air temperature, atmospheric data and pavement temperature profiles for Dunedin City and consultation with NCL personnel, the conditions of 5°C and 90% RH were taken as representative of cold afternoon conditions leading to an early morning frost and -2°C and 90%RH as the early morning conditions immediately prior to a frost forming.

Four representative road surfaces listed below were selected for testing:

- trafficked open graded porous asphalt
- untrafficked grade 3 chipseal (16mm nominal aggregate size)
- trafficked grade 3 chipseal (16mm nominal aggregate size)
- untrafficked grade 5 chipseal (9mm nominal aggregate size)

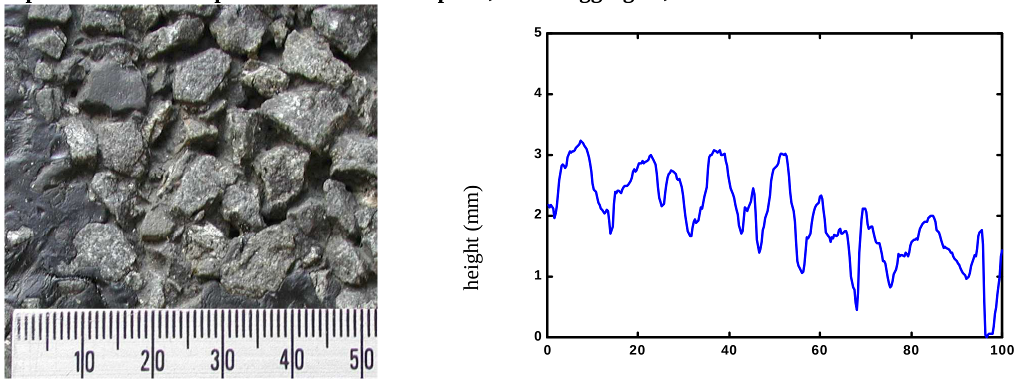
Samples of these surfaces where obtained by extracting 300mm diameter cores from actual roads, trafficked samples being taken in the wheel tracks whereas the untrafficked samples were taken mid lane. These cores were cut down to 120mm by 250mm rectangles and each sample mounted on a solid base so that they remained stable throughout the environmental simulations.

Figure 1 shows photographs of the samples along with corresponding surface profile plots. The surface profiles were obtained with Transit New Zealand's stationary laser profiler (SLP), which enables surface heights to be measured to within an accuracy of ±0.03mm over a wavelength range of 0.63mm and 500mm (Cenek et al, 1997). The SLP calculates mean profile depth (MPD) to ISO standard 13473-1, 1996, "Characterisation of Pavement Texture Utilising Surface Profiles, Part 1."

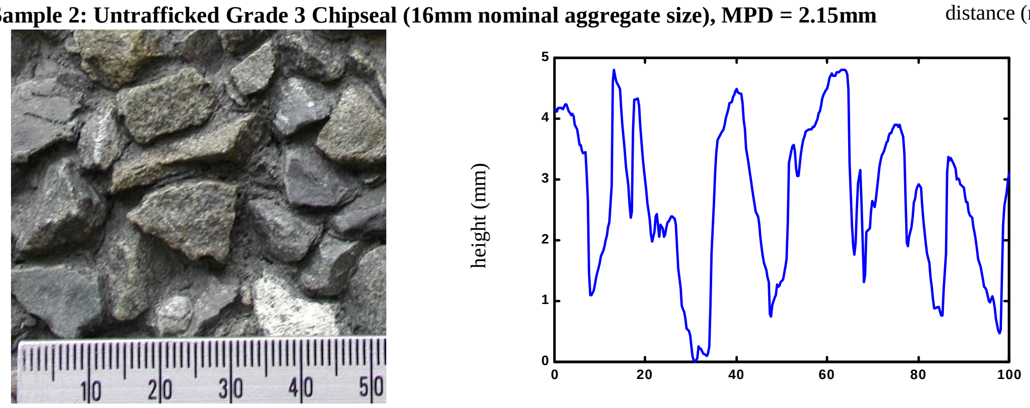
With reference to Figure 1, the MPD of the samples varied from 1.03mm to 2.15mm. By comparison, the limiting MPD specified by Transit New Zealand for state highways is 0.9mm for traffic speeds greater than or equal to70 km/h and 0.7mm for traffic speeds less than 70 km/h.

In order to quantify the effect of CMA application, each road surface sample was tested in pairs. The first member of the pair was tested wetted dry with water only. The second member of the pair was wetted dry with CMA solution.

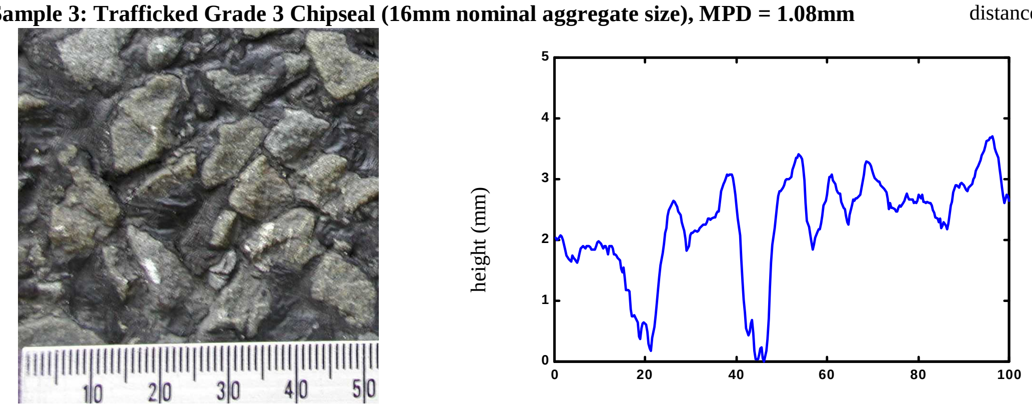
Sample 1: Trafficked Open Graded Porous Asphalt, 14mm aggregate, MPD = 1.03mm



Sample 2: Untrafficked Grade 3 Chipseal (16mm nominal aggregate size), MPD = 2.15mm



Sample 3: Trafficked Grade 3 Chipseal (16mm nominal aggregate size), MPD = 1.08mm



Sample 4: Untrafficked Grade 5 Chipseal (9mm nominal aggregate size), MPD = 1.88mm

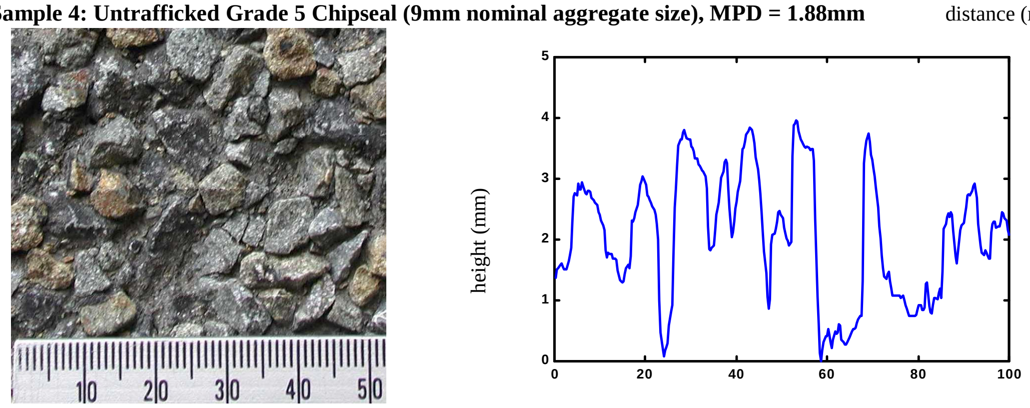


Figure 1: Close-up Photographs and Elevation Profiles of Road Surface Samples Tested

Testing comprised placing all the road surface samples in a controlled environment room and measuring the skid resistance of each sample at 10 minute intervals over an extended time period of about an hour. The skid resistance measurements were made with a British Pendulum Tester (BPT), a portable device that has been widely used in laboratory and field testing of frictional properties of road surfaces for over 35 years. The value measured by the BPT, the British Pendulum Number (BPN) represents a measure of the coefficient of sliding friction between the road surface and a spring-loaded rubber slider mounted on the end of a pendulum arm. The BPN correlates with the performance of a vehicle with treaded tyres performing emergency braking (locked wheels) initiated at 50 km/h on a wet road (Road Research Laboratory, 1969). Each measurement made with the BPT covers an area of about $0.01m^2$. Because the resilience of the slider rubber on the BPT is temperature dependent, all measurements were corrected to 20°C, this being the accepted reference test temperature.

All the samples were tested as close as possible to simultaneously. This was achieved by having all the samples in one controlled environment room and performing the BPT measurements within a 10 minute interval. Because the BPT measurements on a sample took about 2 minutes to set up and complete, a full test sequence at one environmental condition took approximately two hours.

Therefore, BPT measurements were performed on the samples wetted with CMA solution in the first hour and on the control samples wetted with water only in the second hour. Care was taken to ensure that the samples were tested in the same order in each 10 minute interval.

To allow the benefit of CMA to be assessed, heavy ice was allowed to form on the control samples and BPT measurements taken for comparative purposes.

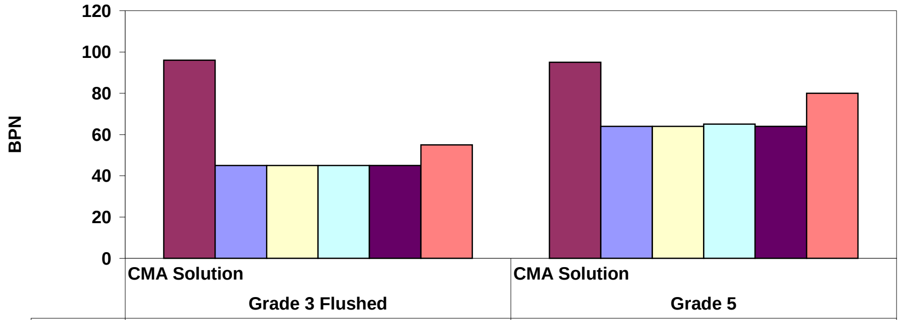
Two additional investigations were carried out under room temperature conditions. The first involved examining the sensitivity of measured skid resistance to CMA concentration. This was achieved by varying the quantity of CMA from –50% to +400% the specified dose and applying the resulting solutions to road surface samples 3 and 4 (trafficked Grade 3 and untrafficked Grade 5 respectively). The second considered whether or not CMA, when dried on a road surface, could be reactivated by a small quantity of surface water. All the paired samples, therefore, were left to dry out for a day and then BPT measurements made for the following three conditions:

- dry;
- application of “fine” spray of water to simulate dew; and
- wet after being washed and scrubbed.

4. Results

4.1 Quantity of CMA Applied

With reference to Figure 2, wet skid resistance of both the coarse (Grade 3) and smooth (Grade 5) textured road surfaces demonstrated no sensitivity to the concentration of the CMA solution when the dose of CMA was varied from half to four times that specified by the supplier. Therefore, correct dosing of the CMA solution is not a critical consideration when evaluating the effect of CMA on the skid resistance provided by road surfaces.

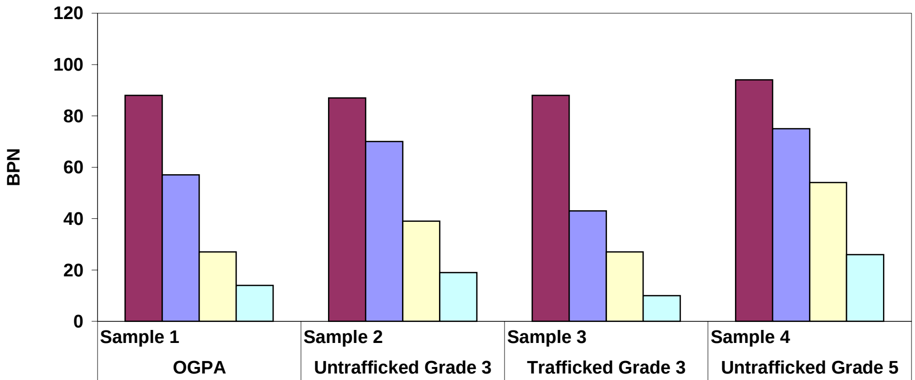


	CMA Solution Grade 3 Flushed	CMA Solution Grade 5
Dry	96	95
0.5	45	64
1	45	64
2	45	65
4	45	64
Washed	55	80

Figure 2: Effect on Skid Resistance of Varying CMA Quantity from Half to Four Times the Specified Dose

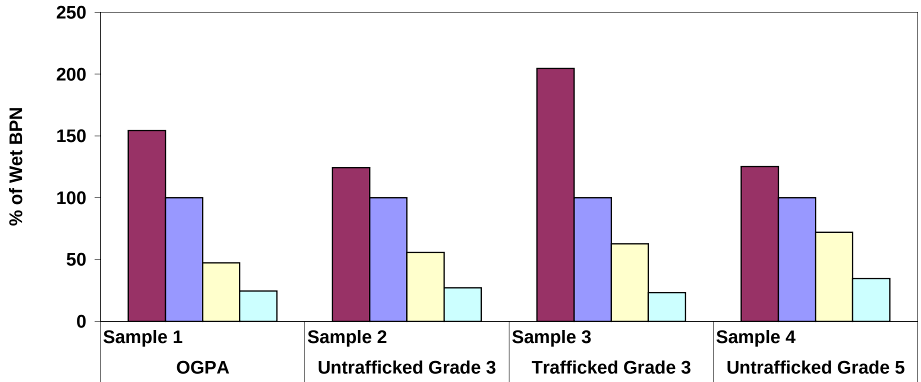
4.2 Effect of CMA on Road Surface Skid Resistance

Figures 3 and 5 compare BPN values measured after the CMA solution was applied to the four representative road surfaces with the dry, wet (water only), and heavily iced states for mid-winter afternoon and early morning climatic conditions respectively. These figures show that the CMA solution appears to significantly reduce the skid resistance below that which occurs with water alone. Companion Figures 4 and 6 present the BPN values expressed as a percentage of the BPN value obtained for the control "wet with water" state.



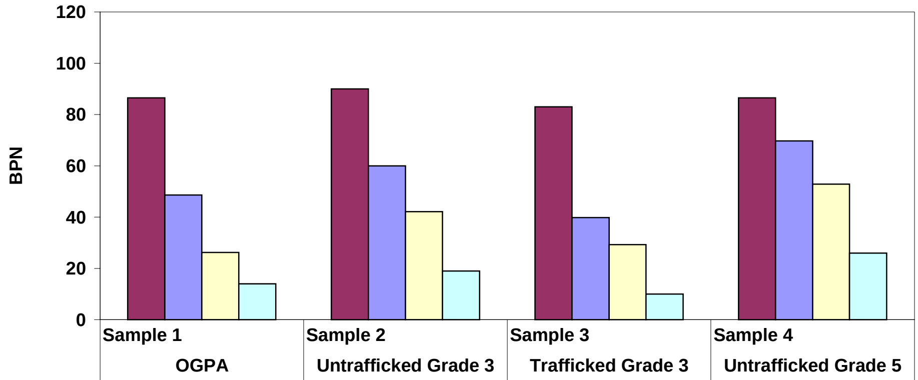
	Sample 1 OGPA	Sample 2 Untrafficked Grade 3	Sample 3 Trafficked Grade 3	Sample 4 Untrafficked Grade 5
Dry	88	87	88	94
Wet	57	70	43	75
CMA	27	39	27	54
Ice	14	19	10	26

Figure 3: Comparison of Skid Resistance Values (BPN) – Midwinter Afternoon Climatic Conditions (5°C, 90% RH)



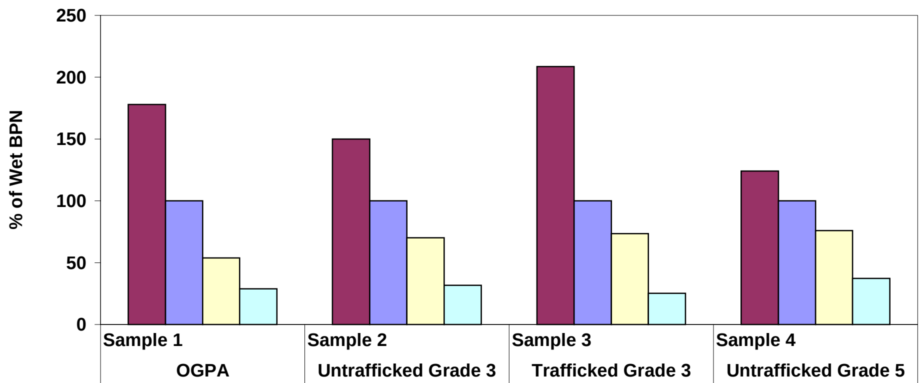
	Sample 1 OGPA	Sample 2 Untrafficked Grade 3	Sample 3 Trafficked Grade 3	Sample 4 Untrafficked Grade 5
Dry	154	124	205	125
Wet	100	100	100	100
CMA	47	56	63	72
Ice	25	27	23	35

Figure 4: Percentage Change in Skid Resistance Relative to Wet State – Midwinter Afternoon Climatic Conditions (5°C, 90% RH)



	Sample 1 OGPA	Sample 2 Untrafficked Grade 3	Sample 3 Trafficked Grade 3	Sample 4 Untrafficked Grade 5
Dry	87	90	83	87
Wet	49	60	40	70
CMA	26	42	29	53
Ice	14	19	10	26

Figure 5: Comparison of Skid Resistance Values (BPN) – Midwinter Early Morning Climatic Conditions (-2°C, 90% RH)



	Sample 1 OGPA	Sample 2 Untrafficked Grade 3	Sample 3 Trafficked Grade 3	Sample 4 Untrafficked Grade 5
Dry	178	150	209	124
Wet	100	100	100	100
CMA	54	70	74	76
Ice	29	32	25	37

Figure 6: Percentage Change in Skid Resistance Relative to Wet State – Midwinter Early Morning Climatic Conditions (-2°C, 90% RH)

The reduction in skid resistance caused by the CMA solution is of the order of 15 to 30 BPN. This results in the road surface displaying a skid resistance that is 47 to 76% of the water alone value. The extent of the reduction is about the same for the afternoon as for early morning. However, a sensitivity to humidity level was observed for the early morning climatic conditions tested (-2°C, 90% RH). This sensitivity was especially prevalent when the CMA solution had partially dried.

Heavy ice formation results in skid resistance values being about 10 to 30 BPN less than that measured on surfaces with CMA. This corresponds to 25-35% of the skid resistance provided by a wet (water only) road surface. Therefore, the use of CMA can make a significant contribution to improving the skid resistance characteristics of road surfaces that are prone to icing.

With reference to Figures 3 to 6, it can be seen that the largest differences between wet, CMA and heavy ice skid resistance measurements occur for fine textured road surfaces. This result suggests that coarse texture road surfaces are preferable to fine textured surfaces in areas predisposed to icing.

4.3 Reactivation of CMA

With reference to Table 1, the results show that when dry the CMA on the road surface had no effect on skid resistance despite the samples treated with CMA appearing darker and more glazed in appearance than the control samples treated with water only. However, addition of "dew-like" quantities of water was sufficient to reactivate the CMA. The corresponding reduction in skid resistance lies midway between the wet with water only and wet with CMA solution states.

It could not be established whether the smaller reduction in skid resistance with rewetting was related to a lessening of the effect or a result of reduced mixing by the applied water spray. This finding illustrates that a reduction in skid resistance is possible each time the road is wet for several days after the CMA is applied.

Table 1: Reactivation of CMA due to droplets of water

Sample	British Pendulum Number (BPN)		
	Dry after application of CMA	Application of fine water mist	Washed, scrubbed and tested wet
No 1,OGPA	108	44	43
No 2, Untrafficked, Grade 3	108	60	74
No 3, Trafficked, Grade 3	107	44	51
No 4, Untrafficked, Grade 5	81-106*	60-66*	74

*Unstable

5. Main Issues

5.1 Reduced Skid Resistance due to CMA Application

The tests performed in the controlled environment room indicate that application of CMA solution will reduce the skid resistance of a typical New Zealand state highway surface by 25 to 50% more than when it is wet from rain. Therefore, an issue to consider is whether or not CMA should be used at all given that skid resistance is reduced to a near hazardous condition on low textured road surfaces.

A choice must be made between the following two options:

- Apply CMA solution as a de-icer which:
  - reduces skid resistance to a near hazardous condition
  - removes any "icy" appearance so the driver expectation is that the surface is merely wet and drives accordingly.

• Leave the surface in an icy condition with the associated icy appearance so that the driver is appropriately signalled, although the surface is now more hazardous if the signal is not properly noted. However, the surface could still be treacherous, even if the impaired skid resistance was noted.

CMA, despite introducing some additional slipperiness over the wet condition, results in a road surface coefficient of friction that is 2 to 3 times greater than the iced condition. Clearly the first option of applying CMA is the better option for managing ice hazards than the second, especially as the use of appropriate signage can offset the problem of drivers being unprepared for the potential skid hazard created by the presence of CMA. If signage is used, it is very important that the existence of a potential skid hazard is conveyed despite de-icing action being taken.

This approach to managing ice hazards is supported by Swedish crash rate data for the hours before and after salting. With reference to Figure 7, the important point to note is that the risk of being involved in a crash increases significantly in the one to two hours before ice forms on the road, the crash rate increasing approximately six-fold. Pre-emptive anti-icing action, therefore, is shown to be preferable to both no action or de-icing action because it mitigates this increased crash risk.

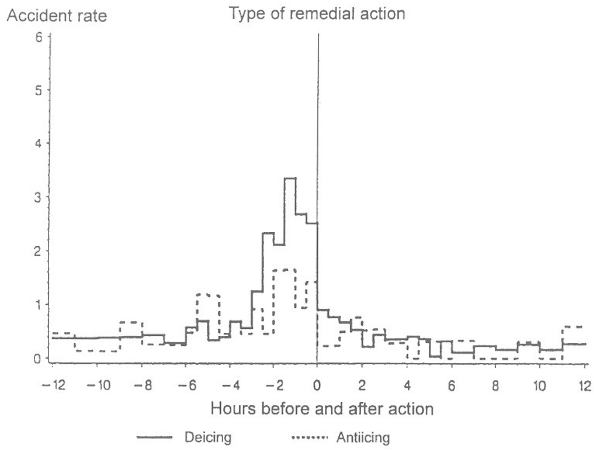


Figure 7: Crash rate (crashes per million axle-pair kilometres) during the hours before and after salting (Wallman and Astrom, 2001)

5.2 Timing of CMA Application

The research findings showed that application of CMA appears to encourage the road to stay moist (and slippery) much longer than occurs for water alone. An application in late afternoon is, therefore, likely to remain damp overnight subjecting traffic to unnecessary additional hazard over the period late afternoon to early morning due to impaired skid resistance. Again, with reference to Figure 7, the best time to apply CMA is one to two hours prior to the ice/frost event if this is practicable.

5.3 Adequacy of Temperature Corrections for Skid Resistance Measurements

Rubber resilience decreases and hysteresis losses become greater as temperature falls. These effects combine to increase the measured value of skid resistance as temperatures reduce. Application of the temperature correction procedure put forward by the manufacturers of the British Pendulum Tester and presented in Road Note 27 result in corrections of – 5 BPN at 5°C and –7 BPN at -2°C. However, British Pendulum Tester measurements made at room temperature, 5°C and -2°C on the control road samples (wet with water only) indicate the temperature corrections should be –15 BPN at 5°C and –17 BPN at -2°C. These greater correction values are consistent with findings of Visser (1974), who noted that temperature effects are greater at temperatures below 10°C due to a change in the viscosity of the water. Better quantification of air, water, road surface, and rubber slider temperature effects on BPN values is necessary so that the extent of skid resistance reduction on textured road surfaces caused by CMA application can be better defined.

5.4 Tracking of CMA

This experimental programme showed that when dry, CMA on a road surface had no effect on the skid resistance but was reactivated with an attendant reduction in skid resistance by “dew-like” quantities of water. Therefore, CMA picked up by tyres and tracked along the road may create an unexpected hazard. Accordingly, on-road performance of CMA over a number of days should be monitored using a mobile tester such as the GripTester to enable the following effects to be quantified:

- Magnitude and duration of changes in skid resistance brought about by CMA. Rubber temperature effects are expected to be reduced because previous work has shown the temperature sensitivity of GripTester measurements to be a third that of the British Pendulum Tester (Cenek et al, 1999).
- Migration of CMA through tracking.

6. Conclusions

Within the scope of the study undertaken, the following conclusions may be drawn:

- CMA solution appears to reduce the skid resistance of a road surface by 25 to 50% below that which occurs with water alone. This effect is more pronounced for smooth textured road surfaces.
- The extent of the reduction in skid resistance is not influenced by time of CMA application, although a sensitivity to humidity level was evident under early morning conditions (-2°C, 90% relative humidity).
- CMA appears to encourage the road to stay moist (and slippery) much longer than occurs for water alone.
- CMA, despite introducing an additional slipperiness over the wet condition, results in a road surface coefficient of friction that is 2 to 3 times greater than the iced condition.

7. References

Cenek, P.D., Brown, D.N., Carpenter, P., Jamieson, N.J., McLarin, M.W.(1997) Replication of VTI’s Stationary Laser Profilometer for Measuring Road Surface Profiles, Transfund New Zealand Research Report No.84, Wellington.

Cenek,P.D., Alabaster, D.J., Davies, R.B.(1999) Seasonal and Weather Normalisation of Skid Resistance Measurements, Transfund New Zealand Research Report No.139, Wellington.

Leggett, T.S. (1999) Temperature and Humidity Effects on the Co-efficient of Friction Value after Application of Liquid Anti-Icing Chemicals, Forensic Dynamics Inc, Vancouver.

Road Research Laboratory (1969) Instructions for Using the Portable Skid-Resistance Tester, Her Majesty’s Stationary Office, London.

Visser, A.T. (1974), An Investigation of the Skid-Resistance of Roads Under South African Conditions, MSc Thesis, University of Witwatersrand, Johannesburg.

Wallman, C.-G., and Astrom,H. (2001) Friction Measurement Methods and the Correlation Between Road Friction and Safety – A Literature Review, Swedish National Road and Transport Research Institute Report 911A, Linkoping.

8. Disclaimer

The views expressed in this paper are those of the authors and are not necessarily those of Transit New Zealand or Opus International Consultants.