Management of Skid Resistance Under Icy Conditions

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ABSTRACT

This study examined a potential problem with the use of the anti-icing and de-icing agent Calcium Magnesium Acetate (CMA) itself leading to skid crashes. This potential problem was identified in the trial use of CMA on New Zealand state highways. This study examined the impact of CMA on road skid resistance with respect to (1) its behaviour immediately after application, (2) the magnitude and duration of its effects, (3) the degree of migration of CMA through tracking by vehicles, and (4) the effects of different environmental conditions, such as dew-fall, on previously treated areas. Skid resistance was examined using both standard test instruments, British Pendulum Tester (BPT) and GripTester, and also a vehicle doing locked-wheel-braking to ensure that any reduction in skid resistance identified correlated to actual vehicle behaviour. Testing was carried out on surfaces comprised of fine and coarse graded chipseals, asphaltic concrete, slurry seal, and open graded porous asphalt (OGPA). Test conditions included dry, wet, immediately after application of CMA, and following dewfall.

The principal findings were as follows:

- Immediately after application of CMA skid resistance levels were reduced to between 40% and 85% of the dry road values, depending on the surface type and skid tester, with the locked-wheel braking test showing lower reductions than either the GripTester or British Pendulum. The resulting levels of skid resistance are generally of the same order of magnitude as for a wet road, but can in many locations be significantly lower.
- Even three hours after a **night-time** CMA application, skid resistance levels are still significantly below the dry road values.
- Tracking of CMA can reduce skid resistance well below dry road levels for a distance of more than 600m past the end point of an application, even under relatively lightly trafficked situations. Skid resistance levels trend back towards the dry road levels over this distance.
- Dewfall conditions on surfaces where CMA has been applied also caused reductions in skid resistance on all surfaces. While these reductions were generally larger than for dewfall on surfaces where no CMA has been applied, skid resistance levels were mostly markedly higher than those immediately after application of CMA.

1. INTRODUCTION

In New Zealand during winter, certain parts of the state highway network are subject to frost and ice, with varying degrees of regularity and severity. The significant reduction in skid resistance that can occur with such conditions, together with their unexpectedness, can pose a significant hazard to motorists.

Traditionally, treatment of frost, ice and snow by roading contractors has involved spreading of mineral grit on the affected areas. However, the use of grit has its own disadvantages. Grit buildup has been a factor in a numbers of accidents, and motorists are also concerned about potential damage to paintwork and windscreens. Consequently, it was decided to investigate alternative methods for managing issues relating to frost and ice. Common salt was used in New Zealand as a de-icing agent until the early 1980's when public concerns about vehicle corrosion led to its use being discontinued. These continuing concerns and also environmental concerns have largely prevented its reintroduction. De-icing agents commonly used overseas were considered by Transit New Zealand in a major review of options for de-icing of state highways carried out in 1996. This initial review had a particular focus on its use on a state highway within a National Park, where concern for low environmental impact was high. Calcium Magnesium Acetate (CMA) was deemed most suitable for this area, given the low risk of vehicle corrosion and very minor effects on soil and groundwater. Since then it has been the material of choice for ice prone areas for a number of regions of the state highway network.

Since 1998, Transit New Zealand has been trialling the use of Calcium Magnesium Acetate (CMA) as an anti-icing and de-icing agent on state highways in the central North Island and parts of the South Island, mainly coastal Otago. Significant reductions in the number of accidents and road closures due to ice have seen the number of sites treated with CMA increase year by year. These trials are more in the nature of a pilot use rather than a research investigation. That is, the use of CMA is one of the winter maintenance tools to be used by the winter maintenance contractor, but in a way in which its use is a routine measure as well as an exploratory investigation.

1.1 Current Best Practice Use of CMA

Best practice guidelines have been established for the use of CMA, although there is some regional variation. Coastal Otago's best practice guide was formulated in conjunction with Transit New Zealand's National Best Practice Working Group. It too has a regional perspective, and focuses on characteristics of the Coastal Otago region. The main elements of this guide that are relevant to this study and the application of its results are:

1. CMA will be applied on a "as and when required: basis;
2. It will usually be applied as a liquid, but can also be applied in granular form, or with grit;
3. It is ideally a pre-treatment, but in higher concentrations may be used as a de-icer;
4. It is preferred that application be restricted to specific intermittent sites, rather than area-wide treatments;
5. It is not to be applied unless there is a clear opinion that ice/snow formation has occurred, or is imminent, i.e. as close as possible to the time of ice/snow formation;
6. The standard application rate is 25gms/m^2, made by mixing CMA at a rate of 0.36kg/l of water.

The most relevant of these elements is the requirement that CMA not be applied until there is reasonable certainty that frost/ice/snow will occur. This has come about because of concerns relating to the skid resistance immediately after application of CMA, and the effects of rehydration of CMA under dewfall conditions. Typically, it means that in Coastal Otago, CMA is applied mostly during the night. In contrast, in the adjacent region of Central Otago , CMA can be applied more as a routine preventative measure, with less stringent requirements the certainty of frost/ice formation. Typically it is applied during the day, prior an approximately 3pm cutoff. Figure 1 shows a view of a spray application of CMA being made in the Coastal Otago region.

Figure 1: CMA Application in Liquid Form

The maintenance trials have shown that although CMA works well as a de-icing agent, it is more effectively used in preventing ice formation, particularly when used in conjunction with appropriate ice/frost forecasting and road management tools. Consequently, the preference is to use CMA in a proactive, rather than a reactive, way. However, there have been a number of skid-related accidents on road sections treated with CMA. These have raised issues regarding the effects of CMA on skid resistance, particularly with respect to; (1) its behaviour on different surfaces, (2) its behaviour immediately after application, (3) the magnitude and duration of its effects, (4) the degree of migration of CMA through tracking by vehicles, and (5) the effects of different environmental conditions, such as dew-fall, on previously treated areas.

Given the need to address these issues in relation to the current operational use of CMA, a research test programme of skid resistance measurements was designed. This was intended to improve the understanding of the behaviour of CMA on different surfaces and under different conditions, particularly immediately after application and under dewfall conditions, thereby providing inputs for the refinement of current “best practice” guides for CMA use.

2. RESEARCH TEST PROGRAMME

A research test programme was designed around on-road measurements to be carried out during the winter of 2003/2004. It was planned to be undertaken in two main stages, with Stage 1 being a survey of baseline skid resistance on an extensive range of sites using a single skid tester, and Stage 2 a focused series of skid resistance measurements using a range of different skid testers.

2.1 Baseline Skid Resistance Survey

The baseline skid resistance survey of selected road sections was undertaken using Central Laboratories' GripTester. It was intended to (1) establish baseline wet and dry skid resistance data for the selected road sections, and (2) determine the makeup of the specific sites for the second stage of the test programme. It was also intended to take advantage of any CMA applications made to investigate post application skid resistance changes and also migration of CMA through tracking by vehicles.

Selection of potential baseline test sections for this study was based on histories of (1) exposure to frosty or icy conditions, and (2) previous use of CMA. Accordingly, records of road sections in coastal Otago where CMA was applied during the winter of 2003 were obtained. From these a range of test sections covering all the primary surfacing types used in the coastal Otago area were selected, these being fine and coarse chipseals, open graded porous asphalt (OGPA), asphaltic concrete, and slurry seal.

Central Laboratories' GripTester is a trailer based skid tester. It operates on the principle of a treadless measuring wheel on a strain-gauged axle that slips at a speed that is approximately 15% of the test speed. The skid resistance, or Grip Number (GN), is the ratio of the horizontal drag on the wheel to the vertical load on the wheel. The GripTester can be towed behind a vehicle, as seen in Figure 2, or pushed by hand, as also seen in Figure 2. Testing can also be done either with or without water applied in front of the measuring wheel at a rate proportional to the test speed. Tests with water is more normal in skid resistance assessments, but as this study was examining the skid effects of CMA, testing was also carried out without using an additional water film.

(a) Tow Mode

(b) Push Mode

Figure 2: Central Laboratories GripTester

Testing on each of the selected test section lengths was carried out in June 2004 using the GripTester in towed mode at 50km/h, with the appropriate water rate applied, thus giving a measure of the "wet" skid resistance level. Shorter sections covering a range of different surface types were also tested dry, without any applied water. Testing was done in both increasing and decreasing directions, for the left hand wheelpath only.

2.2 GripTester Survey – Post CMA Application

During the course of the GripTester baseline survey, advantage was taken of a night-time application of CMA to (1) study the duration of its effects in the hours after application, and (2) investigate whether passing vehicles can cause migration of CMA outside the application area. This CMA application was made by Works Infrastructure in anticipation of freezing conditions. The Griptester followed the CMA truck minutes after application began, measuring in both increasing and decreasing directions, with no added water. Measurements were begun approximately 600m prior to the start point of the CMA application. This means that measuring in one direction, 600m would potentially be subject to CMA being tracked by other vehicles, while in the other direction this 600m would not be subject to any tracking of CMA, and the skid resistance measured would be a dry road value. The GripTester measurements were repeated at reasonably regular intervals over a three-hour period.

2.3 Comparative Skid Resistance Measurements

From the test sections used for the GripTester baseline skid resistance survey, five test sites were selected for a series of comparative skid resistance measurements. These sites, which were already known to be prone to ice or frost and had histories of CMA applied during previous winters, were selected on the basis of being relatively straight and flat, and comprising of (1) a coarse chipseal, (2) a fine chipseal, (3) an asphaltic conrete, (4)an open graded porous asphalt (OGPA), and (5) a slurry seal .

Three different skid testers were used for the comparative skid resistance measurements, these being (1) the GripTester, (2) the British Pendulum Tester, and (3) an instrumented car. The GripTester has already been described above. For the comparative tests it was operated in tow mode, at a speed of 5km/h.

The British Pendulum Tester (BPT) is a one of the stationary type of skid testers. It comprises a support frame that can be levelled on the road. Attached to the support frame is a swinging arm, at the bottom of which is a spring loaded ASTM rubber measuring foot. This swinging arm, when released from a fixed point, sweeps across the surface underneath. The skid resistance of the surface determines how far the arm swings up on the follow-through. The arm also moves a measuring pointer that gives a value on the attached scale. Figure 3 shows the BPT being used on the coarse chipseal test site.

Figure 3: The British Pendulum Tester on Coarse Chipseal

The primary issue with skid testing instruments is their ability to simulate the behaviour of a vehicle, under emergency (locked-wheel) braking. Accordingly, a Holden Vectra passenger car fitted with non ABS brakes was chosen to perform locked-wheel-braking tests as part of the test programme. The only instrumentation installed on the vehicle was a Vericom^{TM} VC 2000 “Traffic Accident Computer” borrowed from the New Zealand Police. This accelerometer-based instrument, which is shown in Figure 4, is routinely used by the New Zealand Police to determine tyre-road friction values at the scenes of fatal crashes for use in crash reconstruction modelling.

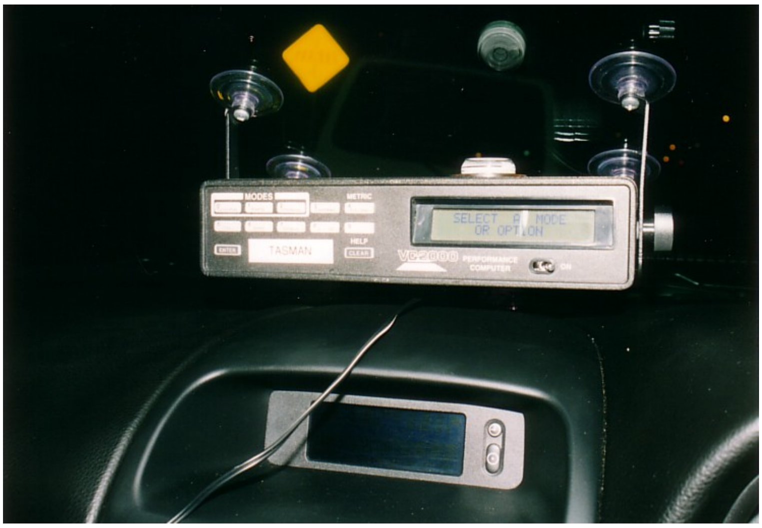

Figure 4: Vericom VC2000 unit mounted on the windshield of the test vehicle

The VC 2000 measures motion as a rate-of-change of speed. It is set to activate when the deceleration exceeds 0.2 g’s and deactivated a 0 g’s (1 g equals acceleration due to gravity, i.e. 9.81m/s^2). The test data can either be read from the display, or downloaded direct to a computer. The display data comprises time to stop; speed at which braking was initiated; braking distance; peak friction; and average friction. The computer program provides the deceleration time history at 0.01-second intervals, which can be processed or interpreted at the user’s discretion, together with the processed results of instantaneous g-force, speed and distance. For this test programme, only the standard displayed parameters were utilised. Testing was limited to a speed of 30km/h.

On each of the five test sites, skid resistance measurements were made with the three test instruments for a range of conditions, including (1) dry, (2) wet, (3) dewfall, (4) post CMA application, (5) dewfall post CMA application, and (6) frost or ice. Testing was concentrated around those conditions involving the use of CMA. Measurements were repeated several times using the mobile testers (GripTester and instrumented car) and at several locations with the BPT.

3. RESULTS

3.1 Baseline GripTester Survey

To illustrate the typical variation in skid resistance, Figure 5 shows the GripTester data for a representative section from the baseline survey. The skid resistance data is presented in terms of the Grip Number (GN), as described earlier. This shows that there can be considerable variation in the wet skid resistance within the test section, in this instance, with the Grip Number (G.N) ranging between around 0.5 and 1.1. It also shows that skid resistance can change very quickly, over a very short distance. Similarly, even over the relatively short distances measured, the dry skid resistance also varied considerably, from around 0.8 to 1.3 (G.N). Figure 5 also shows that the wet road skid resistance on a section of this particular test site was similar in magnitude to the dry values measured on another section of the site.

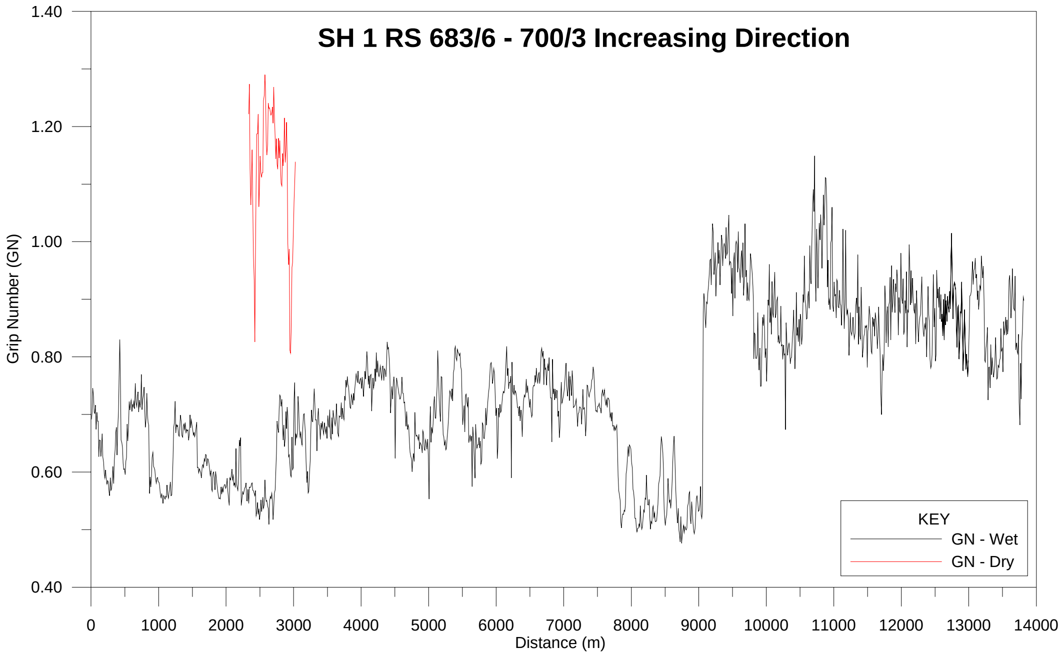

Figure 5: Wet and Dry Skid Resistance – Representative Baseline Test Section

3.2 GripTester Survey – Post CMA Application

The results of the series of GripTester measurements made following a standard night-time application of CMA, together with the wet and dry GrpTester measurements made on the same road section several days earlier are illustrated in Figure 6. Note that the results of tests in fully dry conditions can be seen at approximately 7300m to 7600m. With reference to Figure 6, the following observations can be made regarding the duration of the effects of CMA, and its migration further along the road through tracking by vehicles:

1. Skid resistance on the section where no tracking of CMA is possible (7750m onwards in the decreasing direction), i.e. a dry road value, is consistently high for all test runs, and is similar across all the test runs.
2. Skid resistance on the section sprayed with CMA (5600m to 7750m in both directions) is much lower than the unsprayed section, and levels are similar to the range of wet skid resistance values measured several days earlier. On some parts of this section, the skid resistance is significantly lower than the corresponding wet value.
3. The skid resistance on the CMA sprayed section gradually increases over the approximately 3 hour period after application, but does not approach the dry road skid resistance values measured either on the 600m non CMA sprayed section, or the dry skid resistance values measured several days earlier.

4. On the section where tracking is likely (7900m to 8600m), the skid resistance is quite high for the first test run after application, and is consistent with the dry road values. However, by the next run, approximately half an hour after application, it has dropped to a level that is similar to both the wet road and post CMA section values. Over the subsequent testing, the skid resistance on this section gradually rises, until, two hours after application, the skid resistance is approximately back to the dry road value, at around 500m to 600m past the end point of the CMA application.

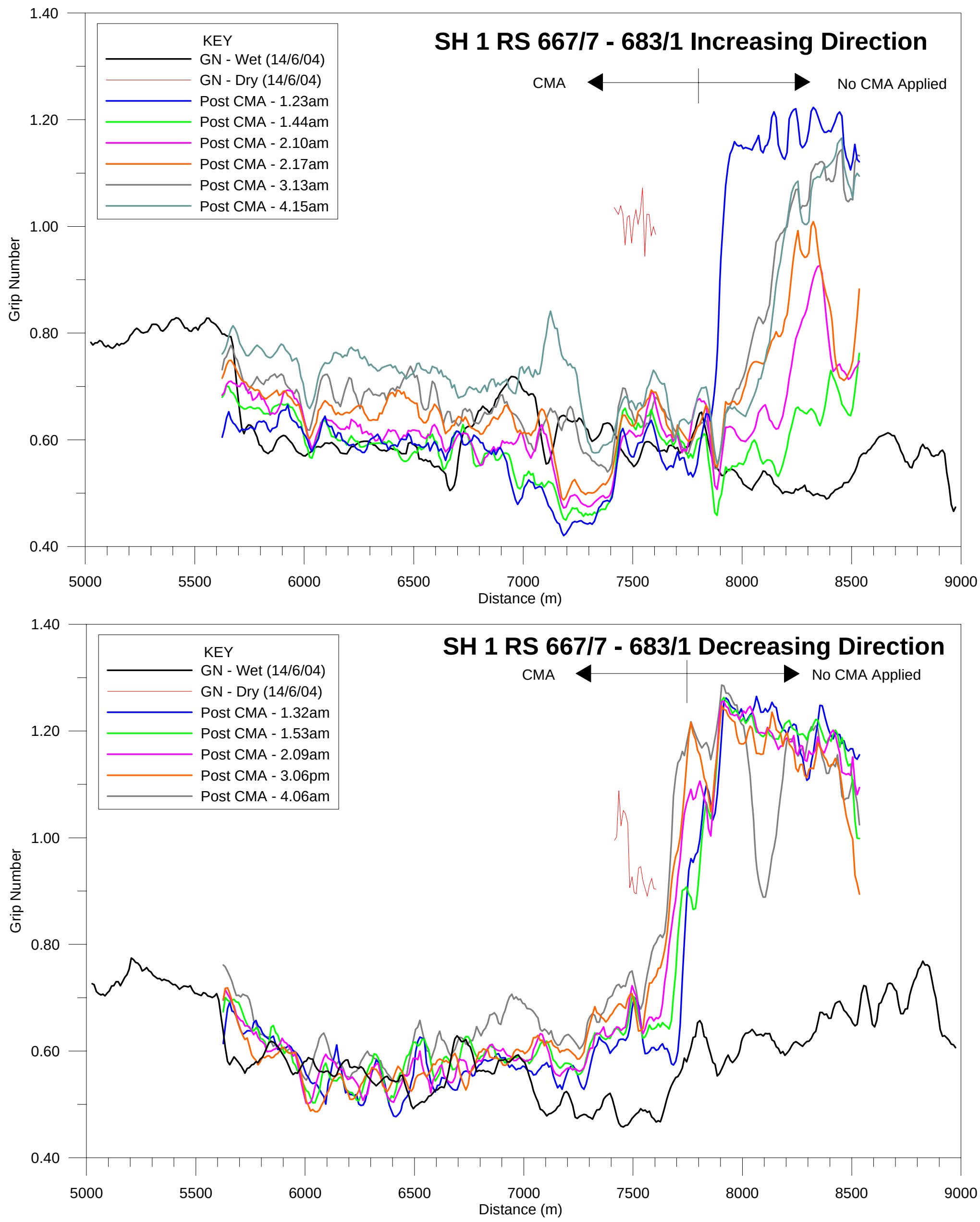

Figure 6: Skid Resistance Post CMA Application – Duration and Tracking

3.3 Comparative Skid Resistance Measurements

Rather than presenting all of the results of the comparative skid resistance measurements, some of the more salient findings are presented. Accordingly, Figure 7 shows the variation of skid resistance across the different surfaces in dry conditions and immediately after application of CMA for each of the three skid testers. It also shows the ratio of the post CMA value to the dry value.

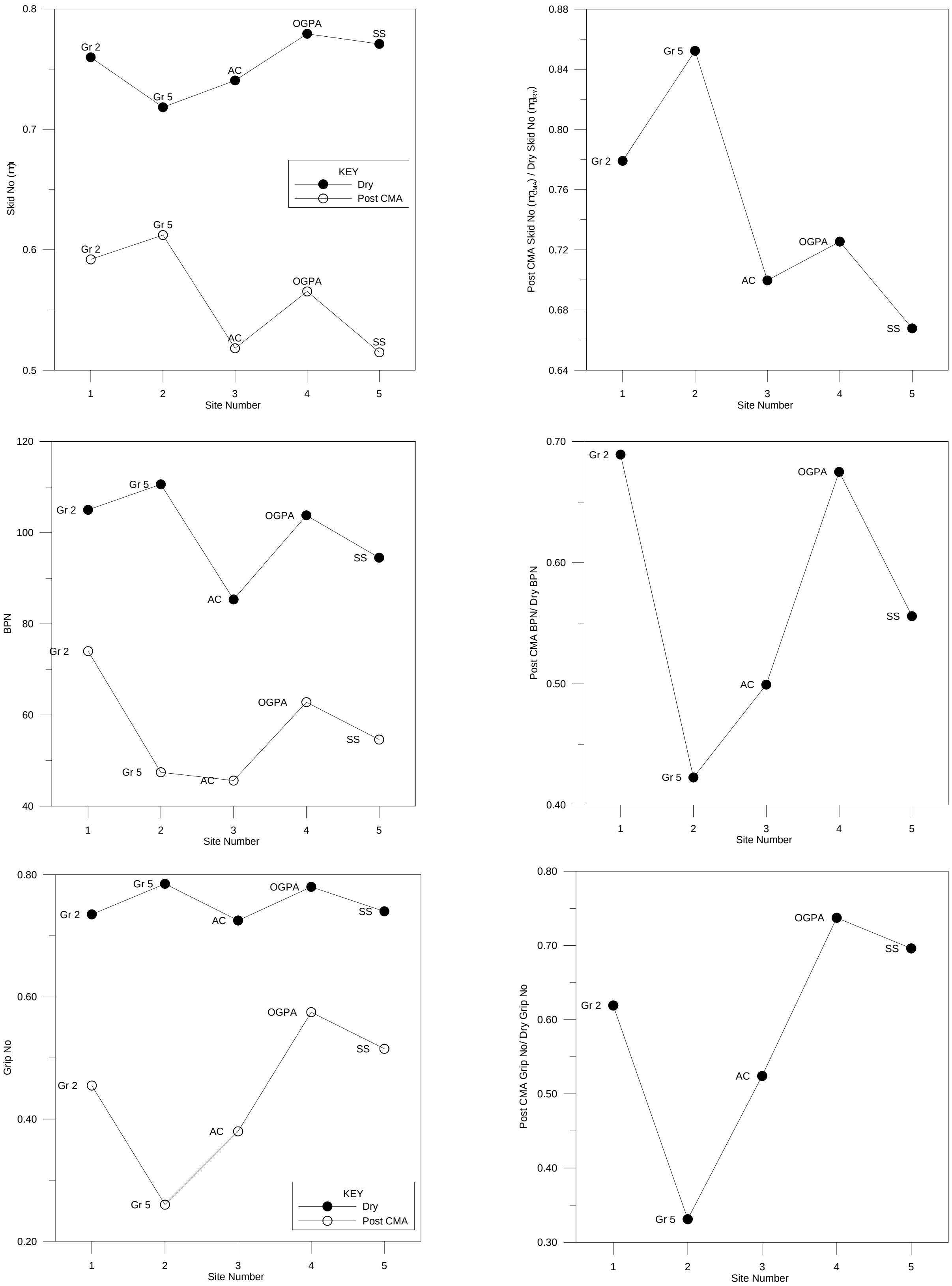

Figure 7: Comparison of Dry and Post CMA Skid Resistance – Surface Type

Figure 7 shows that, in general, the British Pendulum and GripTester show the same trends across the test sites and also in terms of the drop in skid resistance following application of CMA, i.e. to between 70% and 30% of the dry skid resistance value. In fact the percentage drops with CMA between the two instruments are very similar for all of the surfaces, except on Site 5, the Slurry Seal. These results suggest that the GripTester and British Pendulum perform similarly under the test conditions encountered. However, the results from the locked-wheel-braking tests do not show the same trends as the other two skid testers. Here, the Grade 5 chipseal, which, according to the GripTester and British Pendulum, performed worst of all the surfaces, performed best. Also, the magnitude of the drop in skid resistance is not as great as with the GripTester and British Pendulum, being to between 85% and 65%. These results suggested that the skid testers' performance is not similar enough to use relationships to directly predict results for different surfaces and conditions

Figure 8 shows a comparison of the results for tests conducted in dry conditions, post CMA, with dewfall (no CMA), and with dewfall on surfaces treated with CMA the day before. These results are for the GripTester and British Pendulum only.

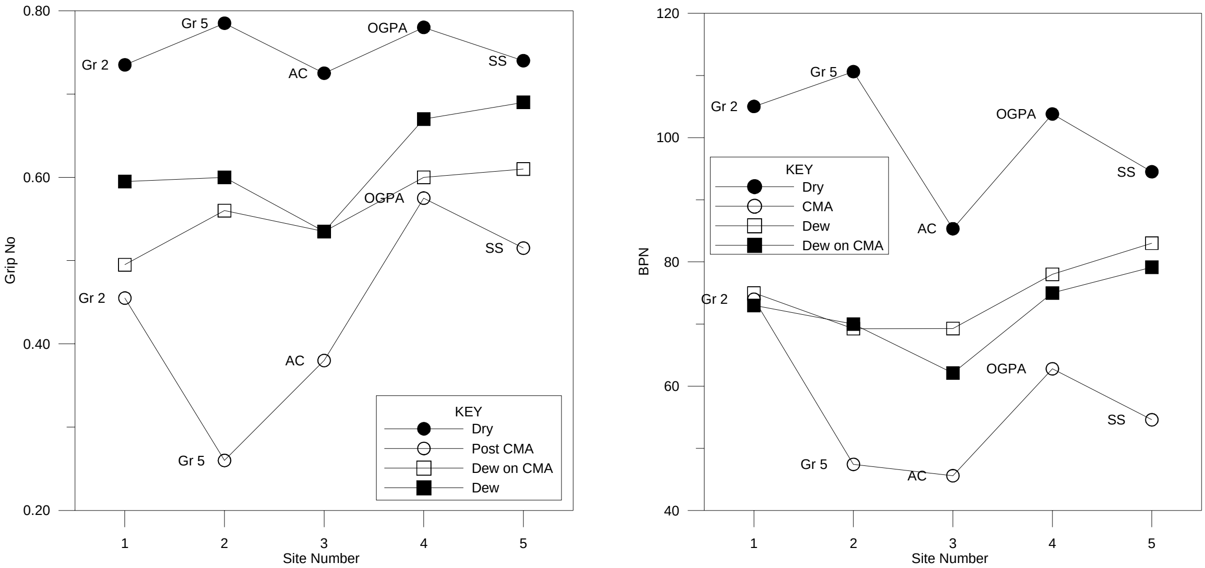

Figure 8: Comparison of Dry, post CMA, Dewfall and Dewfall on CMA Conditions

These results show that, according to both skid testers, dewfall on a surface the day after CMA has been applied does "reactivate" the CMA, in that skid resistance levels are generally lower than dewfall on the surface alone. The difference is more marked for the GripTester than for the Bristish Pendulum. In general, the skid resistance with CMA under dewfall conditions is closer to that for dewfall conditions than those measured immediately post CMA.

4. CONCLUSIONS

Within in the scope of the research test programme, the following conclusions have been drawn.

1. Immediately after application of CMA skid resistance levels were reduced to between 40% and 85% of the dry road values, depending on the surface type and skid tester, with the locked-wheel braking test showing lower reductions than either the GripTester or British Pendulum. Although the resulting levels of skid resistance are generally of the same order of magnitude as for a wet road, they can in many locations be significantly lower.

2. Following a night-time application of CMA skid resistance levels drop and then rise gradually over time as the CMA dries or drains off the surface. However, even three hours after application, skid resistance levels are still significantly below the dry road values.

3. Vehicles can track CMA significantly past the end point of an application, with consequent reductions in skid resistance well below dry road values. Even on lightly trafficked roads skid resistance can be reduced for more than 600m past the end point of an application. With time, skid resistance levels in the tracked area trend back towards the dry road levels.

4. Dewfall on surfaces where CMA has been applied will also cause reductions in skid resistance on all surfaces. While these reductions were generally larger than for dewfall on surfaces where no CMA has been applied, skid resistance levels were mostly markedly higher than those immediately after application of CMA.

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