SEASONAL INFLUENCE ON SKID RESISTANCE AND EQUIPMENT CALIBRATION

Grant Mackey, DTEI, Australia

D Poli , DTEI , Australia

D Holloway, DTEI, Australia

ABSTRACT

In-service pavement skid resistance is an important characteristic for the safety engineer as well as the maintenance engineer who will view the results from differing positions and considerations. As part of the developing responsibilities of the Road Asset Manager the field testing service that I manage were requested to undertake a program of work, over an extended period of time, to assess the seasonal influence. The outcomes parallel the work of other researchers demonstrating that there is a long term variability related to general seasonal cycles as well as a short term variability that is influenced by local weather conditions that last only a few weeks. Predictive modelling is possible but it has an associated significant uncertainty thereby depreciating its usefulness.

Added to this were the maintenance of equipment and an assurance that the equipment was accurately reflecting the actual conditions being met. Assurance to the clients is important.

INTRODUCTION

An aspect of the Road Asset Managers role is a responsibility to ensure safety of the road user, part of which requires the determination of the pavement surface skid resistance.

When undertaking this work the question is ever present. Do seasons influence skid resistances test results, and if they do, can the outputs be normalised thereby enabling testing to be undertaken all year round?

Answering the first part of the question is readily achieved, but the latter part is more difficult.

BACKGROUND

Under present operating conditions and to minimise seasonal influences, testing work in South Australia is often completed in the months of late winter and spring, but it is necessary to test and assess sites (accident) at differing times of the year. Correlating outputs is a problem.

Numerous reports support the premise that seasons influence results while others point to the impact of droughts. The latter indicates that the change in results is due more to the immediate environmental conditions (time since the last significant rainfall), rather than the season (Cenek 1999, Descornet 2006, Diringer 1990 and Oliver 1988).

A program covering a range of sites was commenced. There were 16 asphalt and 8 spray seal sites tested monthly. This program operated for two years.

Testing was undertaken in accordance with TP344 Determination of Skid Resistance with the Griptester. Griptesters are mobile skid testing devices developed in Scotland and widely used throughout the world. The test equipment and process were regularly reviewed and maintained thereby minimising any influence of the equipment and error. The equipment has an Uncertainty of Measurement of +/- 6%. Therefore the quantified variability of the data is due to uncontrolled factors for any one site.

Research suggests that any non-conformability to this seasonal variation is related to a range of factors. These factors could be the binder (quality and quantity), traffic loading, type of surfacing and site location (urban and rural) (Wilson 2008, Woodward 2005). The age of the stone/pavement seal may also influence the outcome. With years of wear the surface of the stone permanently polishes and rounds and this level of polishing is typically not readily restorable by the cleansing effects of rainfall.

TEST RESULTS & ANALYSIS

The test results are summarised in Table 3.1 for asphalt and Table 3.2 for spray seal

General Test Results:

Table 1: Annual Overall Results; Asphalt

Asphalt Sites	Skid Resistance Annual Ave	Std Dev	C of V	Max Variation	Result Span % Ave	Traffic AADT One Way	% Commercial Vehicles	Year of Surfacing
AC1 Site 1	0.48	0.07	15.0%	0.20	42%	21000	6	2000
Site 2	0.50	0.07	13.0%	0.19	38%	21000	6	2000
Site 3	0.48	0.05	10%	0.13	27%	21000	6	2000
Site 4	0.53	0.06	12%	0.19	37%	21000	6	2000
Site 5	0.65	0.06	9%	0.20	31%	21000	6	2000
Site 6	0.68	0.05	8%	0.18	27%	21000	6	2000
Site 8	0.53	0.07	13%	0.24	45%	21000	6	2000
AC2 Site 1	0.54	0.07	14%	0.22	41%	4500	3	2005
Site 2	0.57	0.06	10%	0.18	31%	4500	3	2005
AC3 Site 1	0.52	0.09	18%	0.26	50%	15500	6	2004
Site 2	0.51	0.08	16%	0.22	43%	15500	6	2004
Site 3	0.45	0.08	18%	0.22	49%	15500	6	2004
Site 4	0.42	0.08	20%	0.27	65%	15500	6	2004
Site 5	0.50	0.08	16%	0.26	51%	15500	6	2004
Site 6	0.42	0.08	19%	0.23	55%	15500	6	2004
Site 7	0.45	0.08	18%	0.23	51%	15500	6	2004
Site 8	0.46	0.07	16%	0.24	51%	15500	6	2004

Max Variation: The maximum measured data range.

Result Span: Maximum variation divided by the annual average skid resistance test results.

AADT Average Annual Daily Traffic

% Commercial. Percentage commercial vehicles in the traffic count.

Table 2: Annual Overall results, Spray Seal

Spray Seals Site	Skid Resistance Annual Ave	Std Dev	C of V	Max Variation	Results Span % Ave	Traffic AADT One Way	% Commercial Vehicles	Year of Surfacing
SS1	0.70	0.06	8%	0.20	28%	1600	7	1999
SS2 Site 1	0.60	0.06	9%	0.20	34%	3900	18	2005
Site 2	0.52	0.05	10%	0.19	36%	3900	18	2005
SS3	0.60	0.09	15%	0.31	52%	2000	21	2006
SS4 Site 1	0.66	0.03	5%	0.09	14%	1500	26	1997
Site 2	0.59	0.05	9%	0.19	32%	1500	26	1993

The spread of results Standard Deviation and Coefficient of Variation are reasonable when considering the number of uncontrolled variables that may influence an exercise of this nature.

Seal types, traffic counts and traffic composition, when assessed relative to the test results, do not exhibit any immediate significant relationships. This could however be attributed to low traffic levels.

As an initial investigation into any relationship between skid resistance, rainfall and seasons, the monthly data for each site was correlated with the associated rainfall. A similar correlation was also made at a one month offset as initially determined from the data and preliminary investigations concerning the work of Oliver (1998). Those correlations are detailed in Table 3.3 for asphaltic concrete and Tables 3.4 for spray seals.

Table 3: Correlations

Site	Rainfall & Skid Resistance	
	Same Month	One Month Forward Offset for Rainfall
AC1 Site 1	0.54	0.80
Site 2	0.52	0.52
Site 3	0.38	0.63
Site 4	0.55	0.70
Site 5	0.56	0.51
Site 6	0.55	0.46
Site 8	0.44	0.59
AC2 Site 1	0.58	0.75
Site 2	0.56	0.63
AC3 Site 1	0.51	0.72
Site 2	0.54	0.83
Site 3	0.54	0.67
Site 4	0.52	0.54

Site 5	0.50	0.59
Site 6	0.53	0.63
Site 7	0.50	0.70
Site 8	0.51	0.61

Table 4: Correlations

Site	Rainfall & Skid Resistance.	
	Same Month	One Month Forward Offset for Rainfall
SS1	0.31	0.65
SS2 Site 1	0.33	0.23
SS2 Site 2	0.21	0.23
SS3	0.00	0.36
SS4 Site 1	0.42	0.28
SS4 Site 2	-0.08	0.27
SS4 Old Site 1	0.26	0.31
SS4 Old Site 2	0.40	0.58

Correlations:

- Below 0.5 are considered here to be of some interest.
- Between 0.5 and 0.7 were considered to be of interest and should be further investigated.
- Above the level of 0.7 were considered to be significant
- # The correlation coefficient is a useful summary measure for bivariate data, in the same sense that the mean and standard deviation are useful summary measures for Univariate data. The possible values for the correlation coefficient range from -1 (exact negative correlation, with all points falling on a downward sloping straight line) through 0 (no linear relationship) to +1 (exact positive correlation, with all points falling on an upward sloping straight line (Middleton, 2000).

All results indicate some relationship between the two but the correlation appears to generally improve when the rainfall data was offset by a month. This indicates about a 4 week delay after significant rain for improvements in skid resistance.

There is some concern when considering the test result span as the test data can range up to 70% around the result as shown in Table 3.5. The overall average range is 50%. The spans for the asphalt surfaces are often higher than for spray seals as presented in Table 3.6. Such spans are not unusual as reported by Descornet (2006) in the Hermes report.

Table 5: Asphalt Surfacing Sites:

Asphalt	Max Difference	Mean	% of Average
AC1			
Site 1	0.24	0.48	50.9%
Site 2	0.20	0.50	41.2%
Site 3	0.17	0.46	37.2%

Site 4	0.22	0.52	42.5%
Site 5	0.21	0.65	32.5%
Site 6	0.19	0.67	28.2%
Site 7			
Site 8	0.24	0.53	44.4%
AC2			
Site 1	0.32	0.56	56.9%
Site 2	0.34	0.59	57.2%
AC3			
Site 1	0.33	0.52	62.3%
Site 2	0.32	0.52	62.1%
Site 3	0.32	0.45	71.3%
Site 4	0.33	0.41	80.6%
Site 5	0.32	0.50	64.1%
Site 6	0.26	0.42	61.1%
Site 7	0.29	0.46	63.5%
Site 8	0.29	0.47	62.1%

Spray seal sites SS4, Site 1 and Site 2 have seals that are some years older than the other test sites and the variation of the testing is reduced in comparison to other spray seal sites. However, the sample set is too small to use other than for observation.

Table 6: Spray Seal Surfacing Sites

Spray Seals	Max Difference	Average	% of Ave
SS1	0.19	0.71	27.5%
SS2, Site 1	0.33	0.61	53.4%
Site 2	0.28	0.54	52.2%
SS3	0.32	0.60	53.7%
SS4, Site 1	0.22	0.64	34.8%
Site 2	0.20	0.59	34.5%
Old Site 1	0.21	0.41	50.3%
Old Site 2	0.25	0.59	42.1%

DISCUSSION

Seasonal Variation

In the late 1970's and early 1980's a national project was undertaken to investigate seasonal variation and skid resistance. The following graph is a reproduction of the overview of South Australian data collected by Oliver when reporting on this project. A lag between rainfall and the change in skid resistance is evident and can be 4 to 6 weeks long.

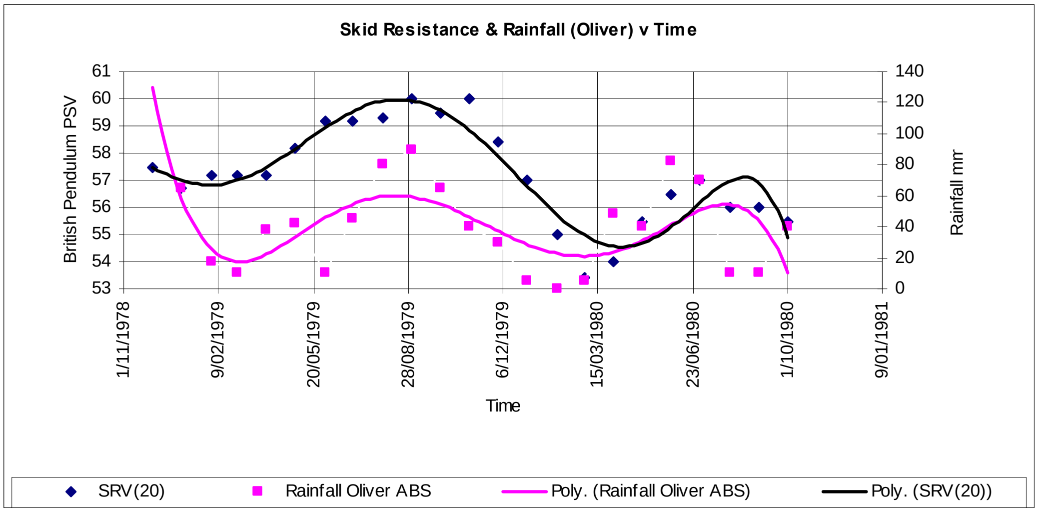


Figure 1: Skid Resistance & Rainfall v Time

The work of Oliver in general, demonstrates that rainfall can be considered to be the variable primarily responsible for seasonal changes in skid resistance. However, the relationship is not consistent throughout Australia. No clear association between skid resistance and rainfall was determined, although a pattern was reported. Oliver refers to other reports regarding the influence of seasonal changes, in particular from France and the USA. (Oliver, 1988)

The following graphs have been prepared as comparative examples to the work of Oliver and shows that relationships do exist but the strength of the relationships vary and cannot be clearly identified.

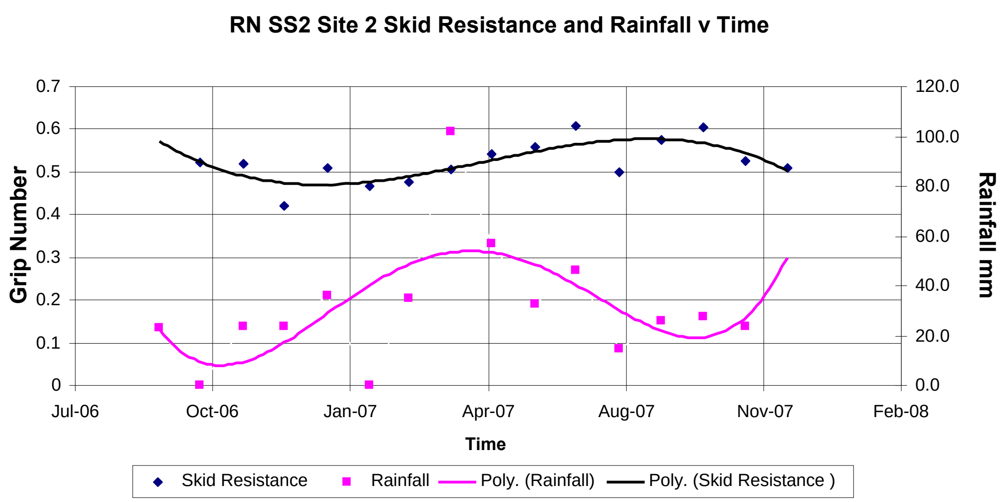


Figure 2: Spray Seal

This seasonal variation was identified by Oliver in his work and is reflected in Figure 4.2, but the relationship between rainfall and skid resistance is weak. Figure 4.3 is an example of the recent work that reflects the influence of seasonal variation and the relationship with rainfall. Again this relationship is not strong and cannot be confidently modeled. There are other sites that do show the seasonal variation but barely reflect any relationship with rainfall. The R2 (Pearson Coefficient) rarely exceeds 0.5, which means that more than half of the data cannot be explained by the model.

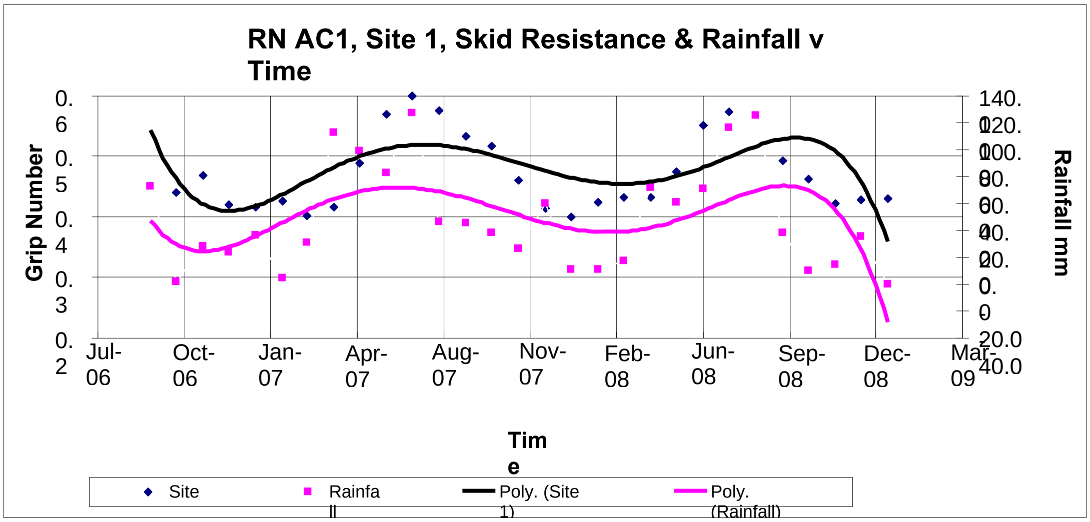


Figure 3: Asphalt AC1, Site 1

Using the data obtained, the old seal results range by 20% and for newer seals the range is wider.

Statistically, the test results are too close and going to a second decimal place for further clarification is not justifiable. The number of uncontrolled variables affecting the process makes it an unsuitable decision making situation. The actual application of the findings requires further consideration.

Figure 4.4 is of an asphalt surface that is basically unused apart from equipment verification testing undertaken at a number of times a year. The cyclical nature of the results is quite evident and the range is again significant. The cyclical nature in this situation is predominantly the result of seasonal influences.

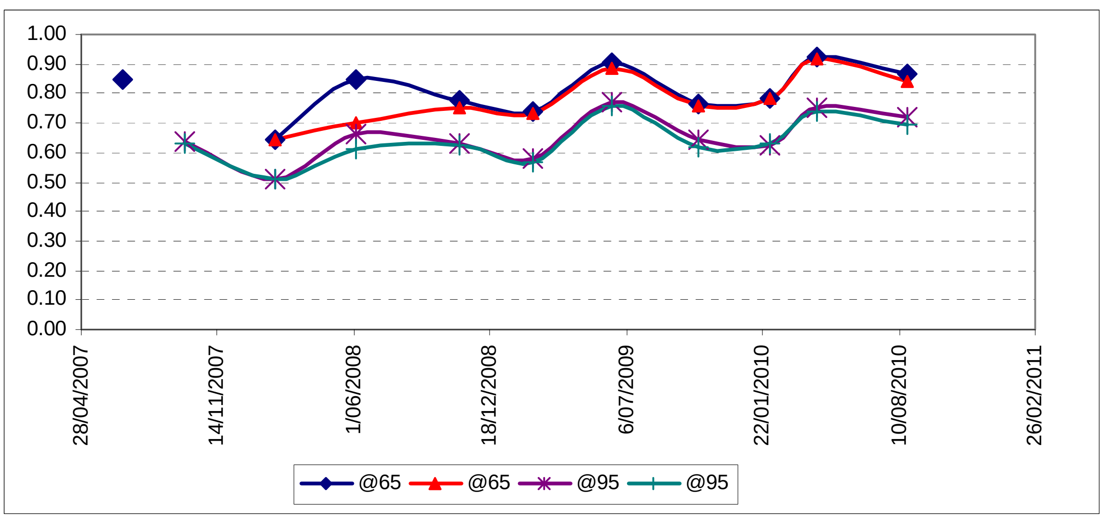


Figure 4: Asphalt Pavement and Seasonal Influence

Cenek (1999), Opus NZ identified effects due to site, season, operator and wet road surface temperature. However, the best seasonal adjustment appeared to be a simple cosine curve, but the available meteorological data does not perform as well as the simple cosine curve and does not appear to add extra value.

The following researchers Diringer and Barros (1990) proposed that seasonal fluctuation relates to the particular day in the year and offered the following model.

Skid Number = B1 x Sin(B2 x JDay + B3)

Where JDay = Julian calendar day

B2 Constant (360/365)

B1 and B3 are estimated regression coefficients.

Cenek also offers similar models in ‘Seasonal and weather normalisation of skid resistance measurements’.

PN = BPN terminal – 5 x Cos(2π/365.25 x Jday)

GN = GN terminal + 0.002 x Cos(2π/365.25 x Jday) (towed)

None of the models provide accuracy factors and without this information the models cannot be used with confidence.

Aggregate type

In research from New Zealand, Cenek (1999) suggests that the amplitude of seasonal variation depends upon the aggregate type and in particular the construct of the aggregate. The more polish susceptible the stones were observed to be, then the more pronounced the seasonal changes were. The age of the aggregate in the seal was also thought to necessitate consideration.

The importance of the contribution that the aggregate makes to skid resistance has been recognised by Department for Transport Energy and Infrastructure (DTEI) staff.

Assessment of aggregates and the final pavement surface have both progressively become topics of considerable discussion as the results have emerged during this initial year of testing.

The testing results for Polished Stone Values and Polished Aggregate Friction Value using the vertical and horizontal test bed procedures have been thoroughly scrutinised debated and analysed over the years.

The focus of assessing surfacings, as they are in the field, is important but the investigator is not able to control the various external factors such as the environment, traffic conditions and the deterioration of the pavement. Some recent work has been undertaken to address this situation and the reader is referred to one paper in particular, that of Wilson and Dunn (2006) who have addressed many of these issues and been able to demonstrate how to undertake work of this nature in a controlled environment.

STANDARDISING RESULTS

The intent of addressing variations in test results by determining a ‘correction’ method is difficult to resolve given the basic correlation data as presented here. Although conclusive in relation to influence, the accuracy of any such method would be low, given that the correlations are poor and the span of data is significant.

When reporting test data, analysts may introduce a range in which the results will fluctuate dependent upon the season/ drought but they cannot assure the actual result on the day of an accident and data from police reports. This problem has been identified by Cenek. (1999) Accuracy of the accident conditions can only be verified if testing is immediate, possibly within 24 hours and without changes in the weather.

Normalising Results

Figure 5.1 is a recent example of local climatic influences over a few weeks and is of significant concern to the road asset manager and engineers. After two weeks of rain the skid resistance has improved over 50%.

This change is something many find difficult to accept and understand. This problem often reflects in a doubting of the testing service and the quality of testing equipment. This is not the case as training and equipment are all well maintained.

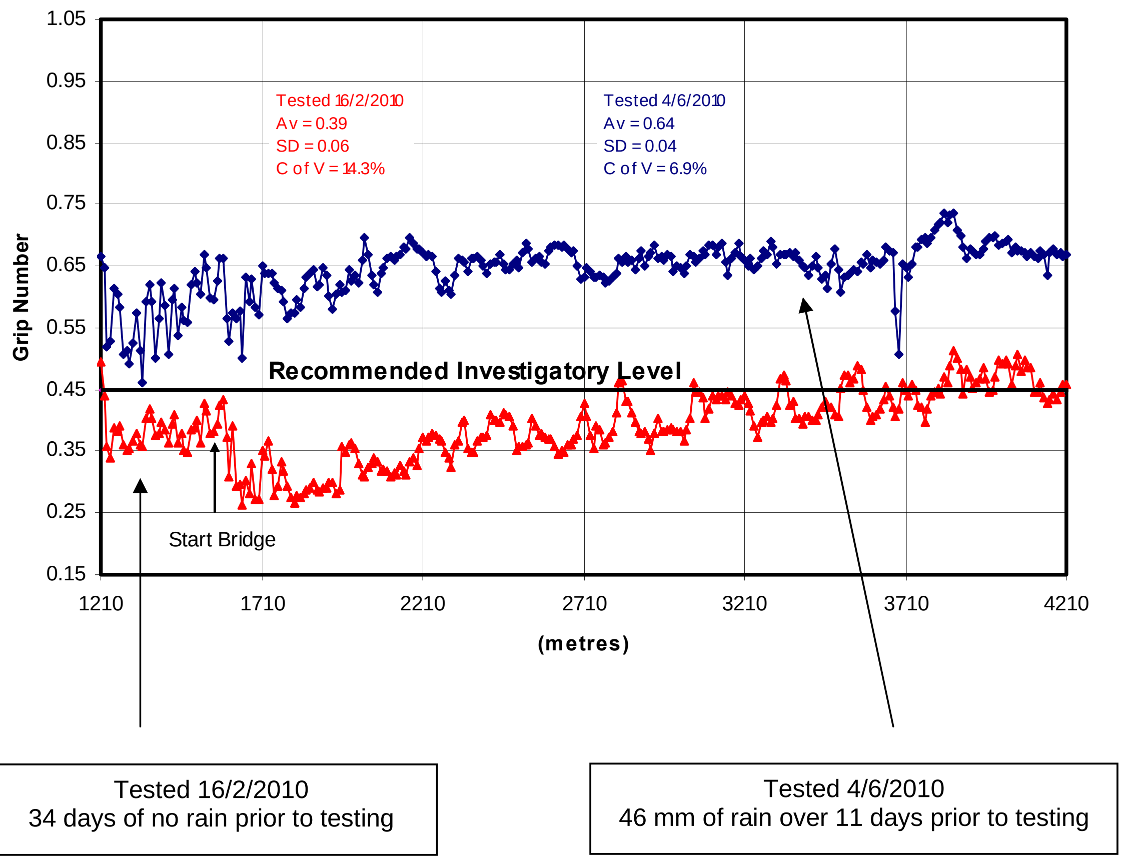


Figure 5: Local Seasonal Influences

As part of this segment of the project the activities of other road authorities was investigated. The Highways Agency of the UK has recognised that test results will vary throughout a test period in one year and also between years. To correct such variations the network may be tested at three differing times throughout the test period so a mean value can be determined. Such work can be undertaken on set regional test sites. The period of testing is also reduced to the summer months.

Transit NZ has also recognised this variability between years of testing and testing within a year. Three equally spaced tests are undertaken on specified test sites throughout the country which are used for normalisation purposes (Cenek 1999).

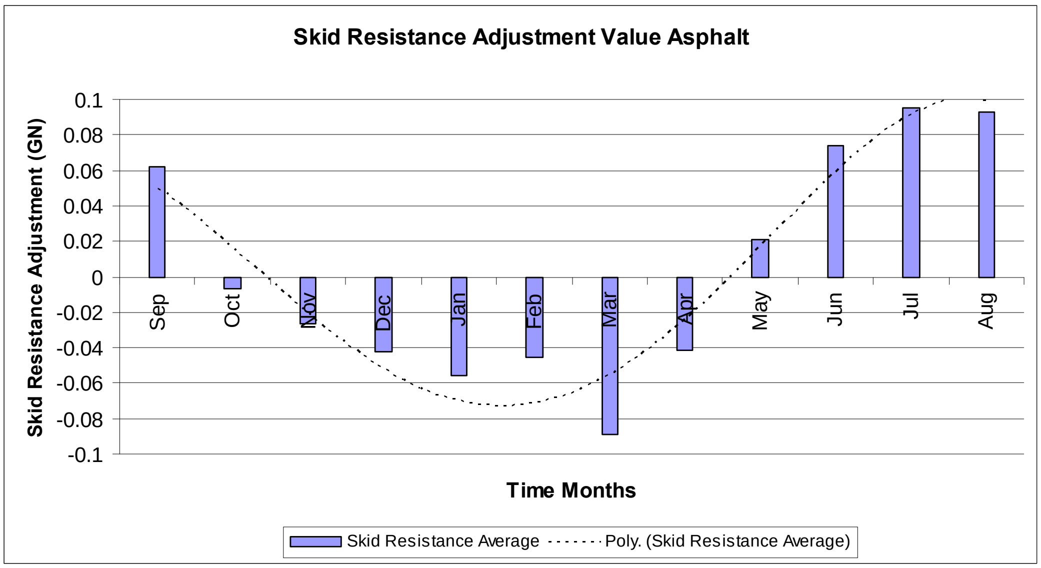
METHODS OF ADJUSTMENT

Method 1 By Month

In this method of analysis the skid resistance data has been tabulated into monthly blocks enabling the determination of the variation of the monthly averages from the test sites. The data was then blocked to produce an overall variation factor for all sites that has been plotted in Figures 6.1 to 6.3. The three figures deal with the variation of skid resistance over time by type of surfacing and by combining the whole of the collected data.

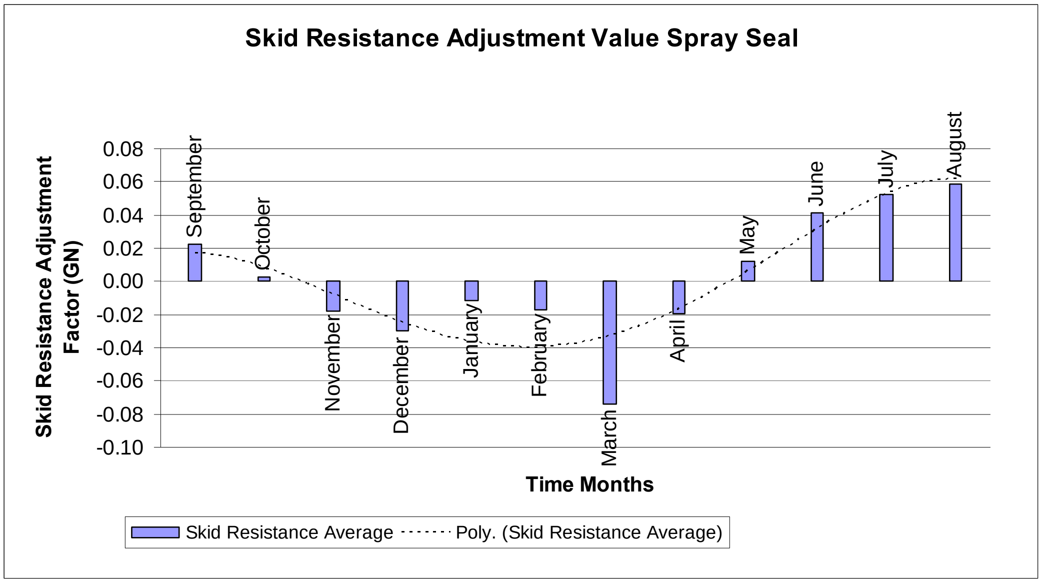
Each modeling action results in a smoothing effect on the data giving an ‘apparent’ improvement to the reader.

This approach will include influencing variables such as age of surfacing, type of stone, vehicle loadings and vehicle types. Not all variations have been accounted for but to address all issues would involve detailed analyses and a series of adjustment/ correction methods rather than one or two such models. This pathway was initially followed, but was terminated when it became evident that the probability of a successful, robust model was not good.



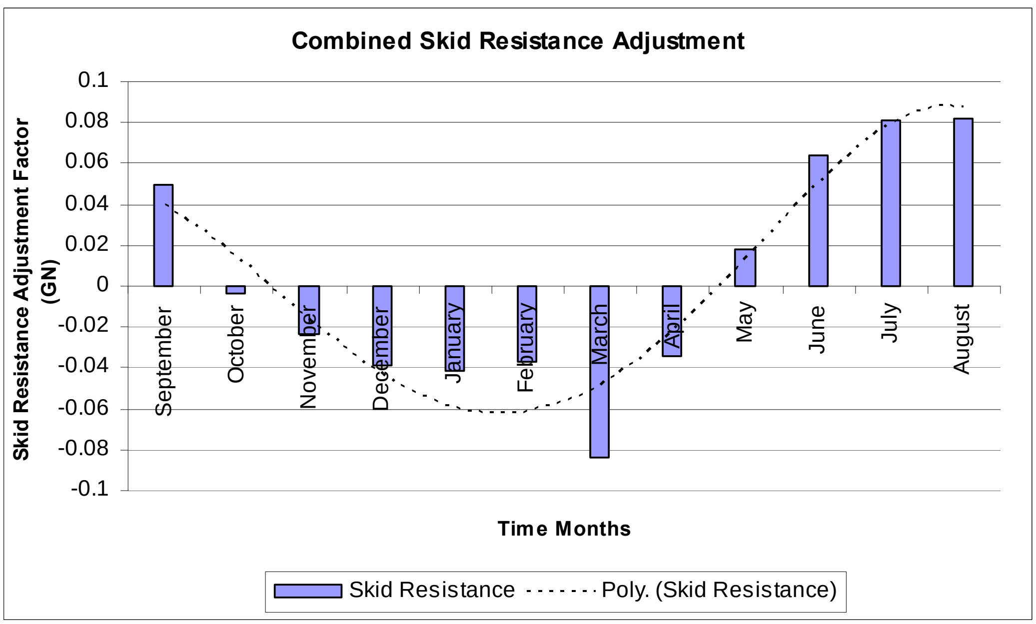
Polynomial: $y = -0.0001x^4 + 0.0029x^3 - 0.0161x^2 - 0.0036x + 0.0666$. $R^2 = 0.92$

Figure 6: Monthly Skid Resistance Normalisation Factors, Asphalt.



Polynomial : y = 8E-0.5x^4 + 0.0021x^3 – 0.0142x^2 + 0.0208x + 0.0084. R^2 = 0.80

Figure 7: Monthly Skid Resistance Normalisation Factors, Spray Seal

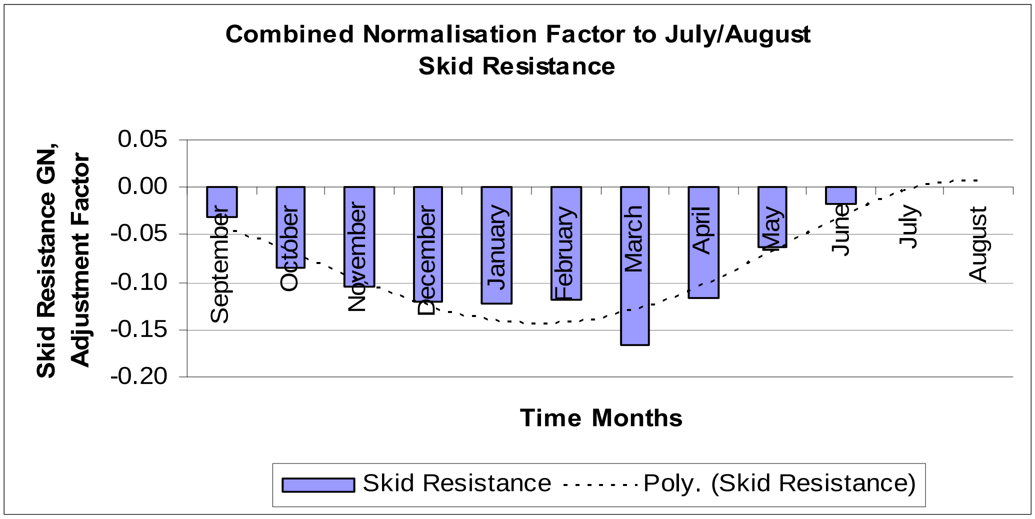


Polynomial: y = -0.001x^4 + 0.0026x^3 – 0.0155x^2 + 0.0042x + 0.048. R^2 = 0.91

Figure 8: Combined Skid Resistance Normalisation Factors

Method 2 Adjustment to Month (July/August)

Method 2 is a variation on method 1 where the months of July or August are used as the datum, chosen as those months that provide the better skid resistance results.



Polynomial $y = -0.0001x^4 + 0.0026x^3 - 0.0155x^2 + 0.0042x - 0.0338$. $R^2 = 0.91$

Figure 9: Combined Skid Resistance Normalisation factor to July/August

Neither methods 1 or 2 account for the local seasonal variations that will occur.

Method 3 Confidence Limits Data Bands:

An alternative approach to this apparent problem is to have uncertainty bands around the data (test results). For a 95% confidence of capturing the data the bands would be as presented in Table 6.1. The span of uncertainty here is quite large and would therefore be unacceptable to those responsible for the monitoring of this surface characteristic.

Table 7: Confidence Levels for Data Collected.

<table>
<tr><td colspan="2"></td><td colspan="2">Skid Resistance</td></tr>
<tr><td colspan="2">Mean</td><td colspan="2">0.59</td></tr>
<tr><td colspan="2">Standard Deviation</td><td colspan="2">0.09</td></tr>
<tr><td colspan="2">Mean Confidence Level (95%)</td><td colspan="2">+/-0.07</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Lower Limit</td><td colspan="2">Mean</td><td>Upper Limit</td></tr>
<tr><td>0.52</td><td colspan="2">0.59</td><td>0.66</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="2">Data Confidence Level (95%)</td><td colspan="2">0.59 +/- 0.17 (+/-29%)</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Lower Limit</td><td colspan="2">Mean</td><td>Upper Limit</td></tr>
<tr><td>0.42</td><td colspan="2">0.59</td><td>0.75</td></tr>
</table>

Summary

The data collected over the two years of the testing program has confirmed the skid resistance variability for particular roads throughout the seasons indicating that some relationship does exist.

Result variability is identified as being ongoing and must be accommodated by any parties measuring pavement skid resistance and it is not unique to any particular piece of equipment or climate.

OPTIMAL TEST PERIODS

Network testing for skid resistance is commonly undertaken at prescribed periods of the year to address the variation that is met due to seasonal or climate influences. This practice has been adopted in the process of network testing undertaken by DTEI.

The general period for network testing has been during spring and to preclude the summer months, November to April. The data is then presented without seasonal correction.

The Highways Agency of the UK in their document ‘Design Manual for Roads and Bridges’ recognise that seasonal variation of test result exists and that it is addressed in an overall sense by controlling testing in the summer months. During a specified test period the test vehicles are regularly passed over standard test sites to determine a correction/ adjustment factor for all results.

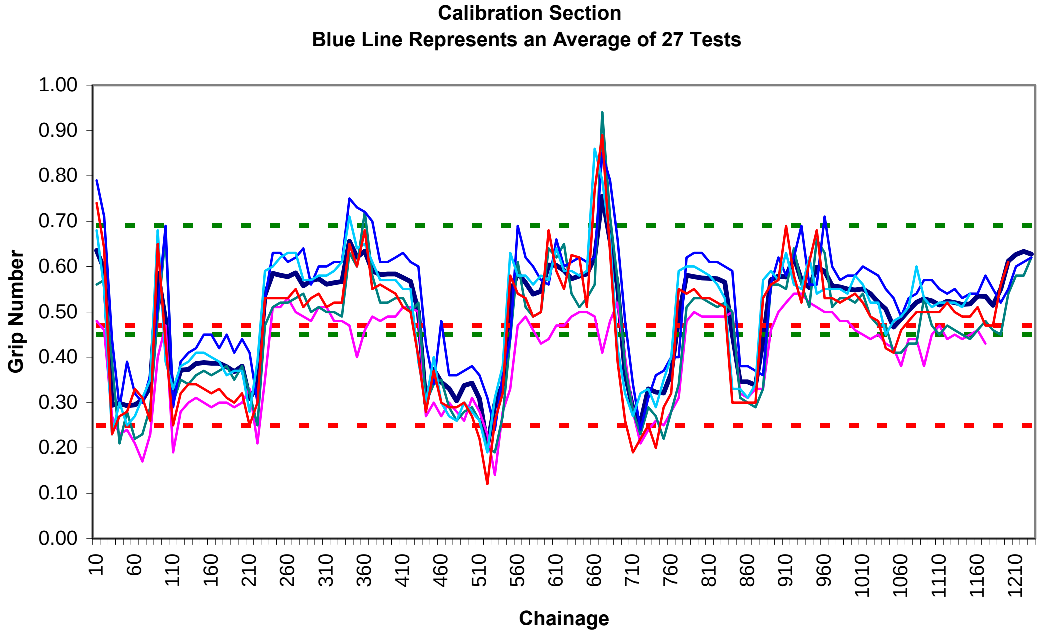
Transit New Zealand have a significant program of pavement skid testing and they also undertake the programmed network testing over a limited time period (November to February) and also have a series of test sites that are regularly tested during any assessment period, to determine a correction/adjustment factor.

RTA and VicRoads recognise that seasonal factors will influence results but do not recommend a correction factor. This would appear to be due to the consideration of significant climatic changes throughout Victoria and New South Wales.

EQUIPMENT CALIBRATION AND MAINTENANCE

Skid testing equipment is maintained regularly with associated calibration checks. The equipment is maintained and checked monthly; user spot checks are made prior to test and full calibrations every two years against a NATA endorsed British Pendulum. Calibration checks are made after any repairs when the equipment is passed over a local test site that has significant variability. This procedure has been undertaken for some years

The results do indicate that the equipment is operating correctly, but the check site is also adversely influenced with the seasonal and local climatic conditions. The equipment reflects the characteristics of the pavement, but gives different results each time, see Figure 8.1. Therefore the site can only be used as a general confirmation tool.



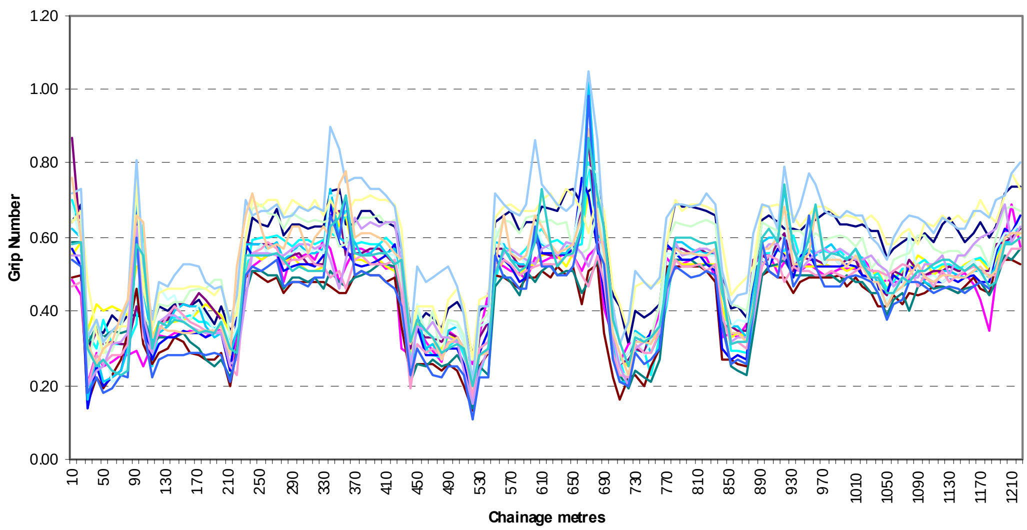


Figure 10: Grip Tester Verification

STATISTICAL OPINION

After some considerable work DTEI engaged an expert statistician on the matter of harmonisation and predictive modeling, who concluded in the negative. In summary " Experience has shown that predicting skid resistance… is very difficult due to inherent variability of skid resistance measurement. The variability is due largely to environment factors (temperature, detritus building up, rainfall and cyclical polishing/abrading rejuvenation cycles) and the skid testing equipment and methodology used. Separating out these factors and determining their individual statistical significance has been difficult historically" [Wilson and Dunn, 2005, p69. (Lester, 2010).

CONCLUSIONS

The following conclusions can be added:

- The base conclusion reached was that no accurate or reliable harmonisation or correlation of results can be achieved between tests of the same section of road at different times using the same or similar equipment.
- Seasons do have an influence on skid resistance.
- Local seasonal changes are of greater importance
- Predictive modeling is possible to estimate results at another point in time but with the results come an unacceptably wide uncertainty band.
- With such a wide uncertainty, then skid resistance results can form only part of the process when assessing the condition of a road.

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AUTHOR BIOGRAPHY

I hold the position Manager of Technical Services within the Department for Transport Energy and Infrastructure and have worked in the field of materials testing for 25 years with some 12 of these associated with the provision of pavement testing services that cover skid resistance testings, texture measurement, roughness, rutting and pave strength measurement.