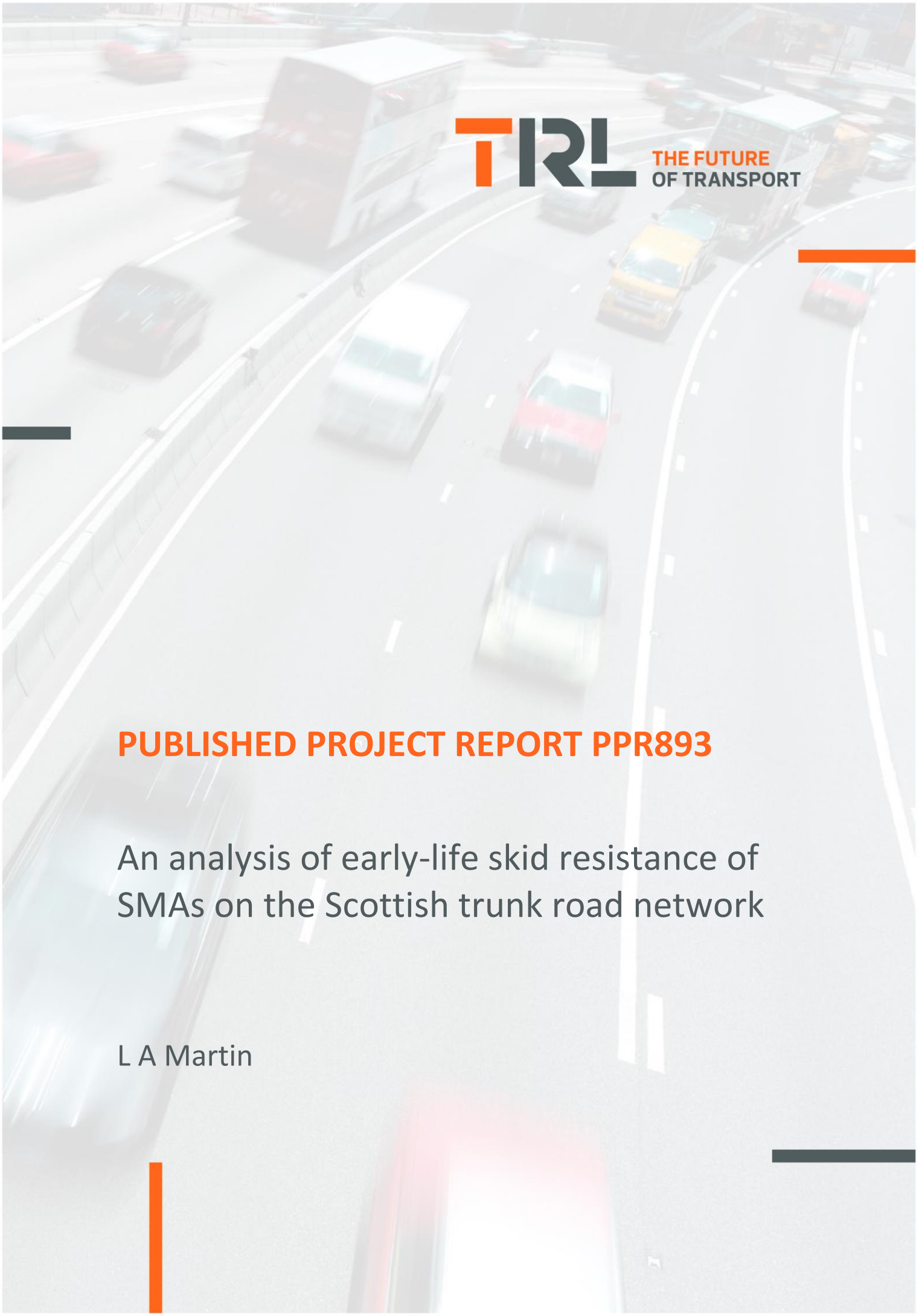

THE FUTURE OF TRANSPORT

PUBLISHED PROJECT REPORT PPR893

An analysis of early-life skid resistance of SMAs on the Scottish trunk road network

L A Martin

Report details

Report prepared for:		Scottish Road Research Board	
Project/customer reference:		TS/TRBO/SER/2012/12/34	
Copyright:		© TRL Limited	
Report date:		22/02/2019	
Report status/version:		Final	
Quality approval:			
P Jones (Project Manager)	**Peter Jones**	M McHale (Technical Reviewer)	**Michael McHale**

Disclaimer

Contents amendment record

This report has been amended and issued as follows:

Version	Date	Description	Editor	Technical Reviewer
Ver 1	14/03/18	Draft for review	LM	
Ver 2	26/03/18	Reviewed by MM		MM
Ver 3	23/07/2018	Client's comments addressed	LM	
Final	01/10/2018	Final		MM

Document last saved on:	22/02/2019 10:10
Document last saved by:	Martin, Luke

Table of Contents

Executive Summary

The GripTester braked-wheel fixed slip device has been used extensively on the Scottish trunk road network since the publication of Transport Scotland's TS2010 surface course specification in 2010. Currently GripTesters are used to test the early-life skid resistance of both TS2010 and standard Clause 942 surface courses at a nominal period of four weeks and six months.

The aim of this study is to determine whether any relations exist between early-life GripTester measurements and other factors such as material characteristics, Site Categories and traffic levels. The data was also examined to see whether any relations existed between the six month GripTester result and subsequent SCRIM surveys.

Measurements taken by GripTesters between 2014 and 2016 were compared to other information held in Transport Scotland's Integrated Road Information System, including material type, traffic data, Site Category and subsequent SCRIM surveys. Preliminary analysis indicated that the study should focus on examining the six month data. Based on the analysis of data the following findings were made:

- GripTester results were observed to be higher during winter months (November – March).
- Six month GripTester results taken on TS2010 surface course show a broad relation to SCRIM results taken when the material is between one and three years old.
- Six month GripTester results show no relation to SCRIM results on Clause 942 materials.
- No TS2010 sites fell below the TS2010 contractual levels and only one Clause 942 site fell below the TS2010 contractual levels.
- No relations were established between six month GripTester results and PSV.
- Smaller aggregate sizes provided higher levels of skid resistance, although this was based on a limited data set.
- No relations could be established between six month GripTester results and traffic levels and Site Class Categories.

The report includes recommendations including restricting GripTester surveys to the summer months and conducting additional analysis to include the 2018 SCRIM survey to provide confidence in establishing a relation between six month GripNumbers and future SCRIM surveys and its potential to be used as a predictive tool. Reviewing the benefit of using GripTesters to test Clause 942 materials is also recommended.

1 Introduction

The GripTester braked-wheel fixed slip device has been used extensively on the Scottish trunk road network since the publication of Transport Scotland's TS2010 surface course specification (TSIA No. 35, 2015) in 2010. GripTester surveys are used to assess the early-life skid performance of TS2010, which must meet certain levels for both approval and contractual requirements at a nominal age of four weeks and six months. In addition to testing TS2010, it was made a requirement by Transport Scotland to conduct GripTester surveys on standard Clause 942 surfacings (MCHW 1) at a nominal four weeks and six months for research purposes, i.e. there are no requirements to meet certain surface friction levels.

This report describes an examination of GripTester data collected on TS2010 and Clause 942 between 2014 and 2016. The analysis of data includes comparisons with Sideways-force Coefficient Routine Investigatory Machine (SCRIM) surveys, aggregate source and size, traffic levels, Site Categories, and the effects of seasonal variation. The report discusses the findings and recommendations are made.

1.1 GripTester

The GripTester is a trailer-based surface friction measuring device manufactured by Findlay Irvine. The trailer unit compromises three wheels: two drive wheels and a smooth single test wheel. It has been used to measure runways and roads since the 1980s. The current model, used for testing surface courses in Scotland, is the Mark 2 D-Type. An image of the GripTester is shown in Figure 1-1. The device is normally towed behind a modified vehicle that is fitted with an automatic watering system which deposits water in front of the test wheel to wet the road surface to a specified water thickness.

1-1: GripTester in operation

In operation, a geared mechanism between the drive wheels and the test wheel, maintains a relative slip of just over 15%. This causes the test wheel to rotate at a slower rate than the drive wheels generating a braking force. For example, at 50km/h the relative slip speed against the surface is approximately 8km/h. Two strain gauges on the axle are used to

continuously measure drag and load. The ratio of these forces is used to calculate what is called a 'GripNumber' (GN).

Collected GripTester data is output in a format which is easily readable using Microsoft Excel. Instantaneous measurements of friction, load, speed and water flow are averaged over a predetermined length, with a minimum length of 1m. The average friction over the length is calculated as the GripNumber. Location referencing markers are inserted by the operators and a Global Positioning System (GPS) records the location of the vehicle.

2 Methodology

2.1 Data collection

GripTester surveys are carried out in accordance with TSIA No. 35 (2015). Each survey area must be tested at least twice and results are checked to see that both runs are within 0.02GN of each other. If not, additional runs are carried out until two subsequent runs are within this range.

Due to the size and formatting of the data output, data was unable to be stored within Transport Scotland's Integrated Road Information System (IRIS) database. However, the GPS reference data collected during each GripTester survey enabled the friction data to be matched with other information held on the IRIS database.

2.2 Data extraction

GripTester survey data was extracted from IRIS along with the following data for each one metre or five meter average:

- **Location referencing within IRIS** including; link/section code and chainage.
- **Material data** including; material type, coarse aggregate source, Polish Stone Value, nominal coarse aggregate size and date the material was laid.
- **Traffic data.**
- **Site Categories** in accordance with HD28.

For each run an average GripNumber was calculated for differing Site Categories and material types. This left a single GripNumber for each material type/ site category with all the relevant data, i.e. start/ end chainages and traffic levels within each run from all surveys. For every survey area the first run to be within 0.02GN of the subsequent run was selected as the test result, if this was not achieved then the run was not used in any further analysis.

In addition to the above, annual SCRIM survey data was also extracted from IRIS. For every averaged GripNumber a corresponding average Characteristic Skid Coefficient (CSC) value was extracted for each subsequent year from when the material was laid.

2.3 Preliminary analysis

An initial 25% of data was sorted, analysed and presented to Transport Scotland. This was carried out to eliminate any uncertainties within the data and explore alternative ways to present data prior to all data being sorted.

From this meeting it was recognised that there was a large quantity of results for four week and six month testing. It was subsequently agreed that owing to early-life effects it was highly unlikely that the four week results would show relations with other factors, or be used to predict longer term skid resistance. The decision was therefore made to concentrate on analysing the six month data, which also permitted more time and resource to be deployed.

3 Results

3.1 Seasonal variation

The skid resistance of surface courses varies with climate and this is a well-documented phenomenon, particularly in more established surface course friction measuring devices such as SCRIM, as declared in HD28.

Figure 3-1 compares all the average GripNumbers for each site against the month that the survey was carried out. The data shows a broad trend that results are higher in winter months and lower in summer months. The increase in winter months is likely to be due to a roughening of the surface caused by winter weather and winter maintenance activities such as the routine gritting of the road surface.

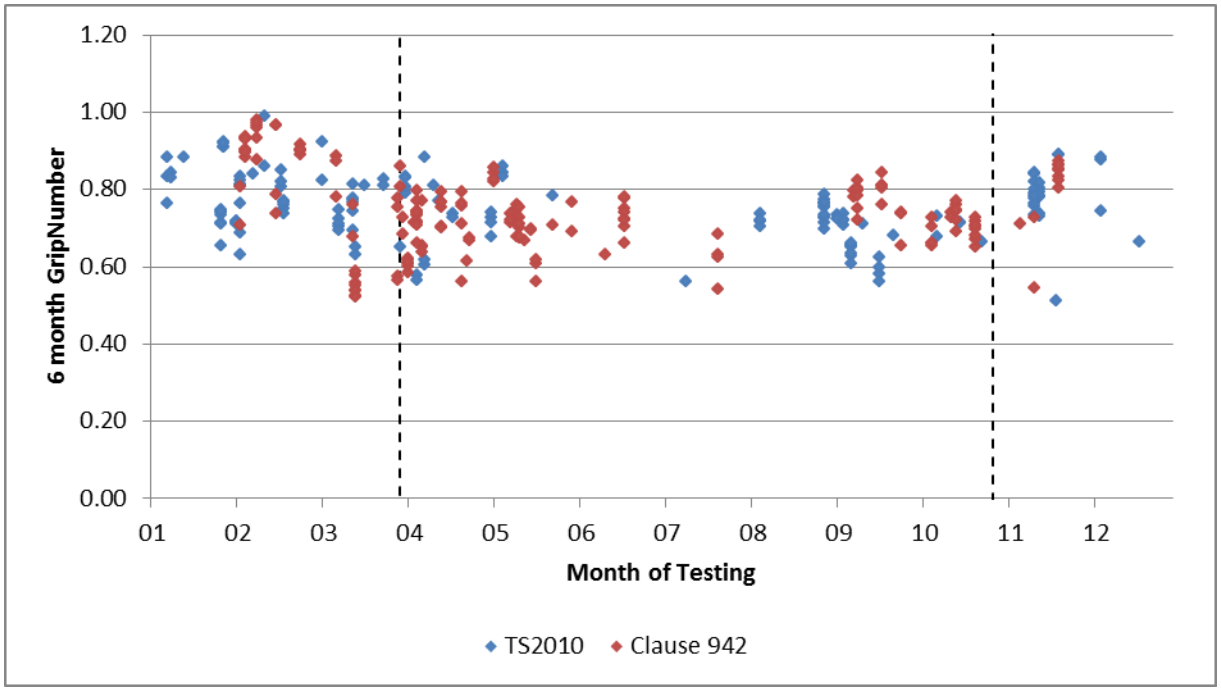

Figure 3-1: Seasonal variation of GripTester surveys

Due to the findings of Figure 3-1 it was deemed appropriate to exclude data collected in winter months as it may lead to unrepresentative results. All further results only include data taken between 1st April and 1st November (shown in Figure 3-1 as black dotted lines) unless specifically stated otherwise.

3.2 Annual SCRIM survey

Every year SCRIM surveys are carried out over the Scottish trunk road network in accordance with HD28. Measurements are taken by a freely-rotating test wheel, attached to a lorry at an angle of 20° to the direction of the vehicle. Similar to the GripTester, an automatic watering system in front of the test wheel is used to wet the surface. Results collected are corrected for seasonal effect, termed Characteristic Skid Coefficient (CSC), and are used to monitor the skid-resistance of the trunk road network. Although both GripTester and SCRIM are different low speed friction measuring devices, it was of interest to see if there was any relation between six month GripTester results and CSC results, and weather GripTester results could be used to predict or estimate how materials would perform in future SCRIM surveys.

Figure 3-2 shows a comparison of six month GripTester results with average CSC for materials aged between zero and three years. Graphs on the left show results for TS2010 and graphs on the right give results for Clause 942. Graphs show the nominal age of materials at the SCRIM survey with youngest (zero years) at the top and oldest (three years) at the bottom. The data points in each graph have been divided into three respective Polish Stone Value (PSV) ranges, i.e. ≤55, 56-60 and ≥61.

Results show that for Clause 942 materials there is no obvious trend or relation between six month GripTester surveys and SCRIM surveys, between the age of zero and three years. TS2010 materials show no relation at zero years, but a broad trend starts to appear between one and two years where high GripNumbers correspond to relatively high CSC values. A clearer trend is present in TS2010 at three years of age but this may be as a result of limited data.

In addition results on most graphs show that all ranges of PSV can give varied results for both SCRIM and GripTester results. This is further discussed in Chapter 3.3.

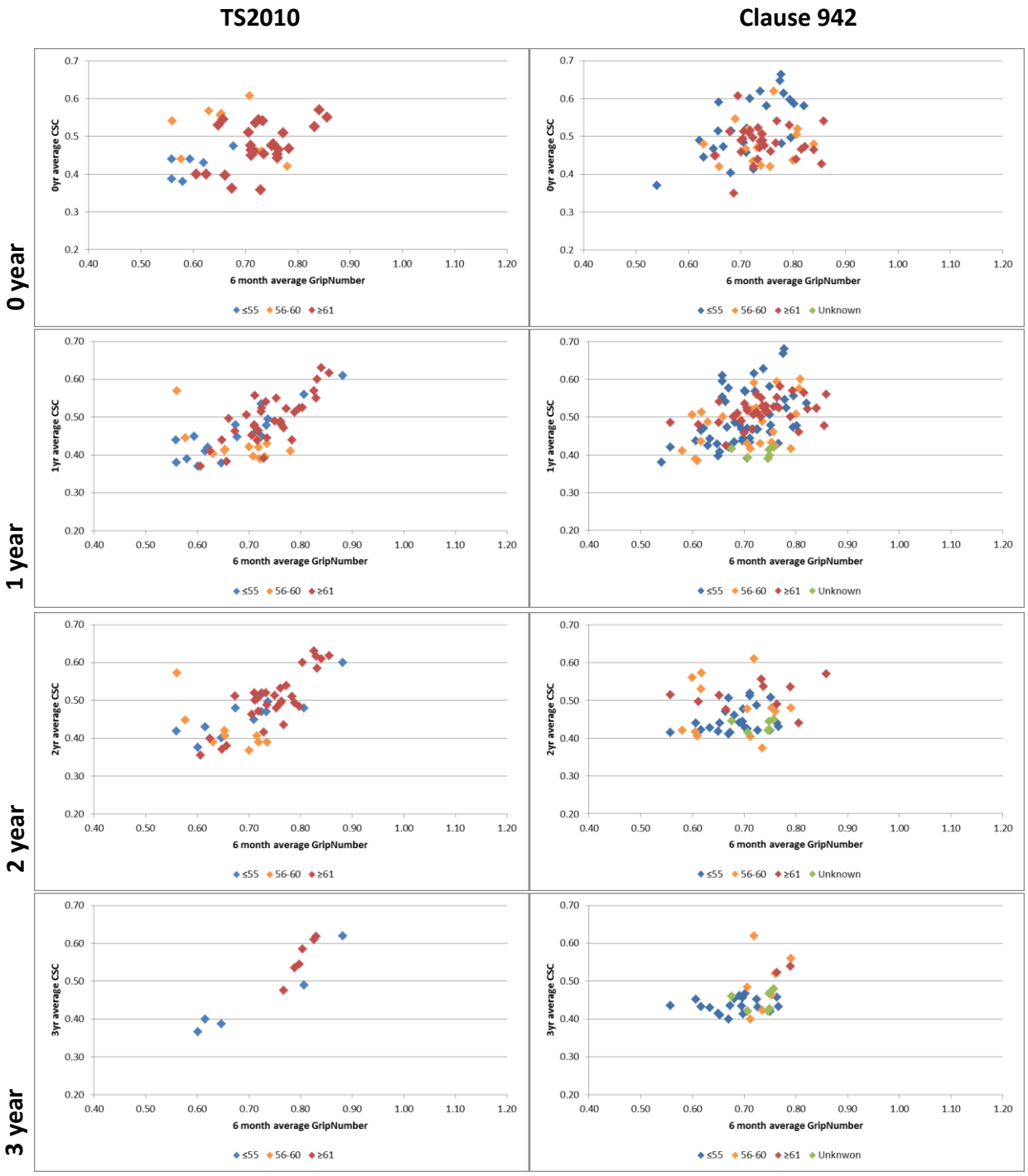

Figure 3-2: A comparison of 6 months GripTester to annual SCRIM surveys

3.3 Aggregate source

Following the removal of data that was collected in winter months, a total of 12 different aggregate sources were examined in the study. Figure 3-3 displays the results which have been divided into their respective aggregate sources (each source being given a random letter for anonymity). The top of the graph shows the PSV of the aggregates increasing from left to right, the key shows that data points have been split in to either TS2010 or Clause 942.

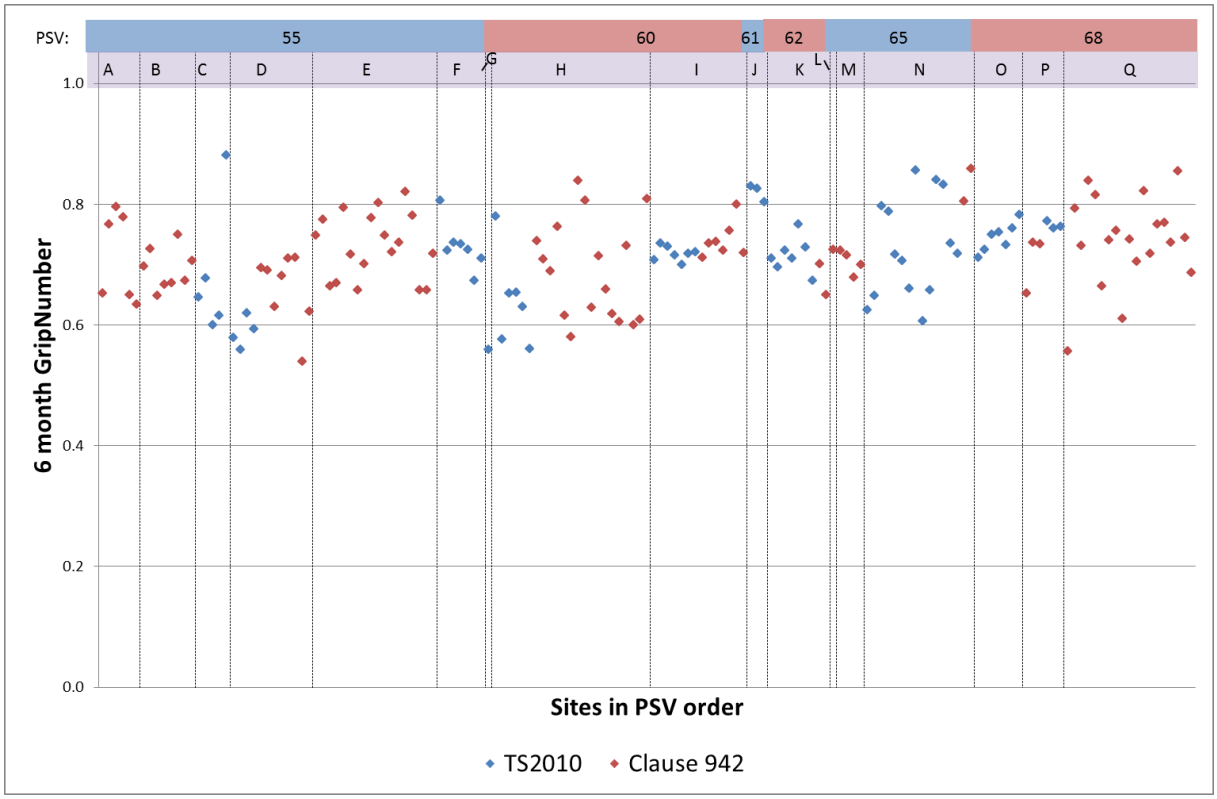

Figure 3-3: GripTester results at 6 months arranged in aggregate source order

Figure 3-4 gives the average GripNumber for each aggregate source, divided into both TS2010 and Clause 942. The figure also includes the PSV for the aggregate sources and how many sites are included in the average value; where both TS2010 and Clause 942 are in the same aggregate source the value on the left gives the quantity of TS2010 sites and the value on the right give the quantity of Clause 942 sites. The black error bars indicate the range of the 90th percentile; results with only one site do not have this statistic as there is no range.

Both Figure 3-3 and 3-4 highlight that there is no trend between low speed skid-resistance and the PSV of aggregates at a nominal six months old. From Figure 3-4 the lowest average performing aggregate is identified as aggregate source G, although this is only from a single site, and the highest average performing aggregate is source J. Figure 3-4 shows that, although TS2010 and Clause 942 give a similar range of GripTester results from the same aggregate source, on average Clause 942 produces higher levels of friction at six months.

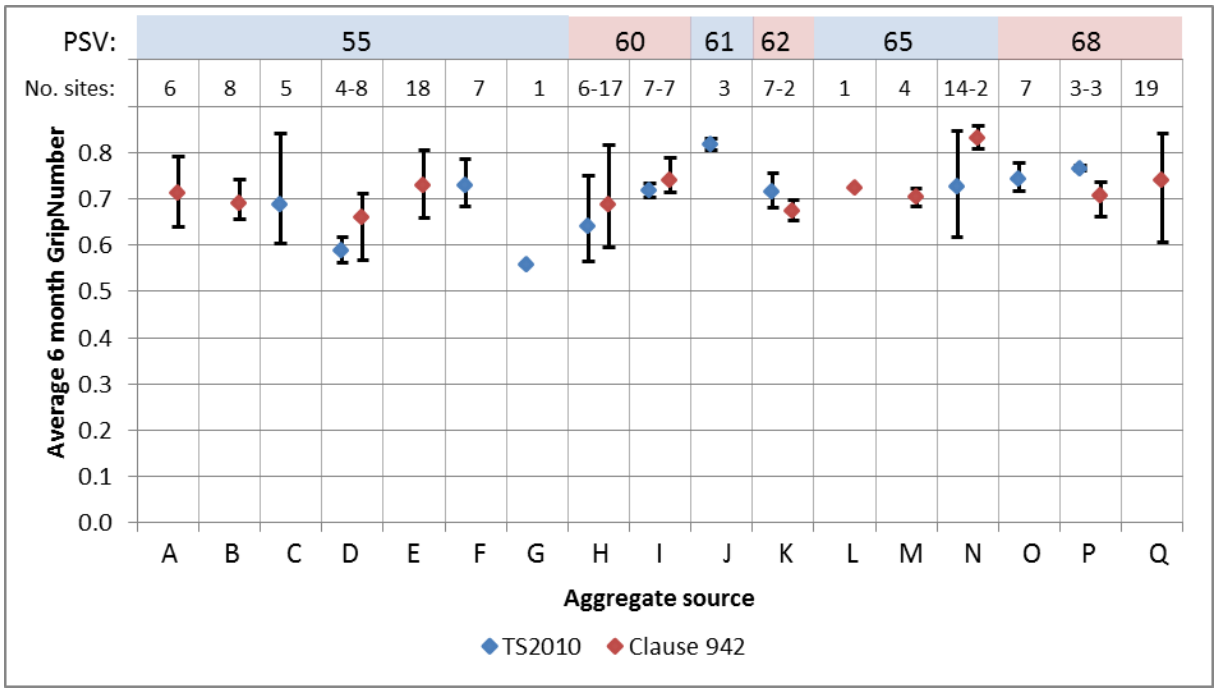

Figure 3-4: Average 6 month GripNumber of TS2010 and Clause 942 for each aggregate source

3.4 Aggregate size

Figure 3-5 shows six month average GripNumbers divided into their respective nominal aggregate sizes: 0/6, 0/10 and 0/14mm. The key in the figure indicates the coarse aggregate's PSV. It should be noted that only measurements taken on Clause 942 materials have been used as all TS2010 materials were 0/10 and therefore could not be used as a comparison of nominal aggregate size. The Figure also shows the 90th percentile range for each nominal aggregate size as a horizontal black dotted line.

Although the quantity of data is not distributed evenly, Figure 3-5 shows that smaller aggregate sizes tend to produce higher skid resistance, particularly when combined with higher PSV aggregates. The results show that larger aggregate sizes can still provide a high level of friction but can also produce lower levels.

A similar trend is also present when looking at the results from annual SCRIM survey when materials are approximately two years of age as shown in Figure 3-6. It should be noted that this figure includes some additional sites (i.e. all Clause 942 sites) as all measurements were taken in summer months and have been converted into CSC values, i.e. converted for seasonal variation.

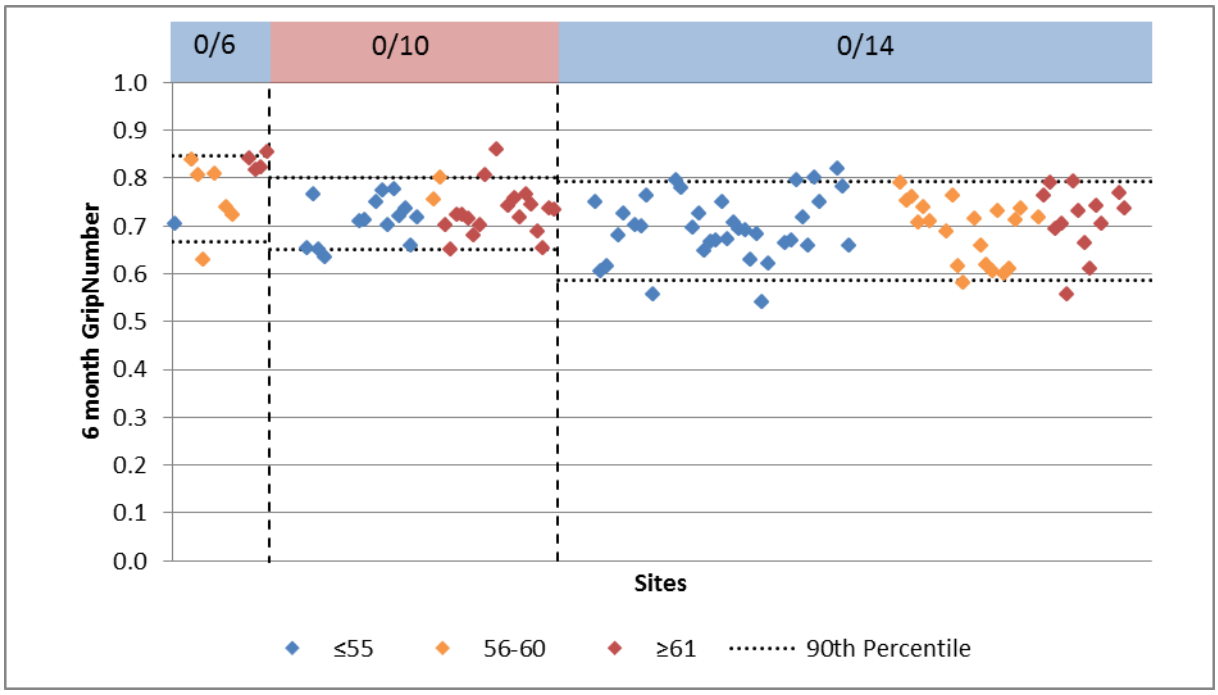

Figure 3-5: GripTester survey at six months on Clause 942 in aggregate size order

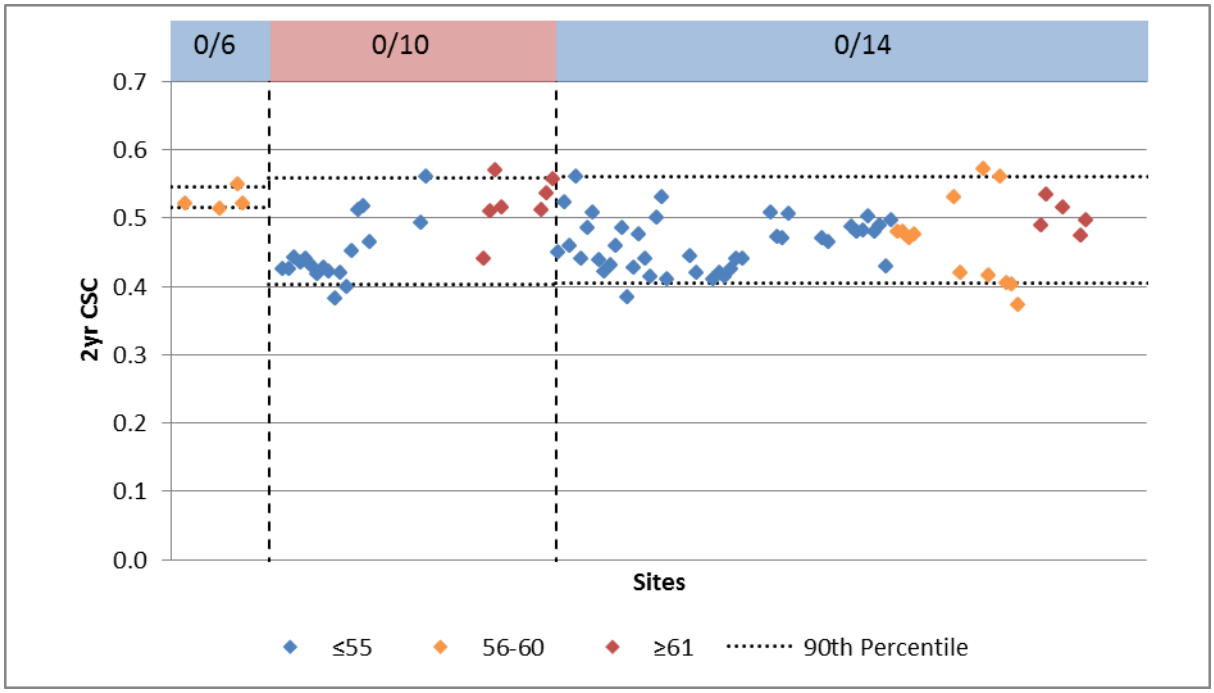

Figure 3-6: SCRIM survey at two years on Clause 942 in aggregate size order

3.5 Traffic

Figure 3-7 and Figure 3-8 compare commercial traffic levels against the 6 month GripNumber for both TS2010 and Clause 942, respectively. Results have been divided into the respective Site Class (see Chapter 3.6 for further details).

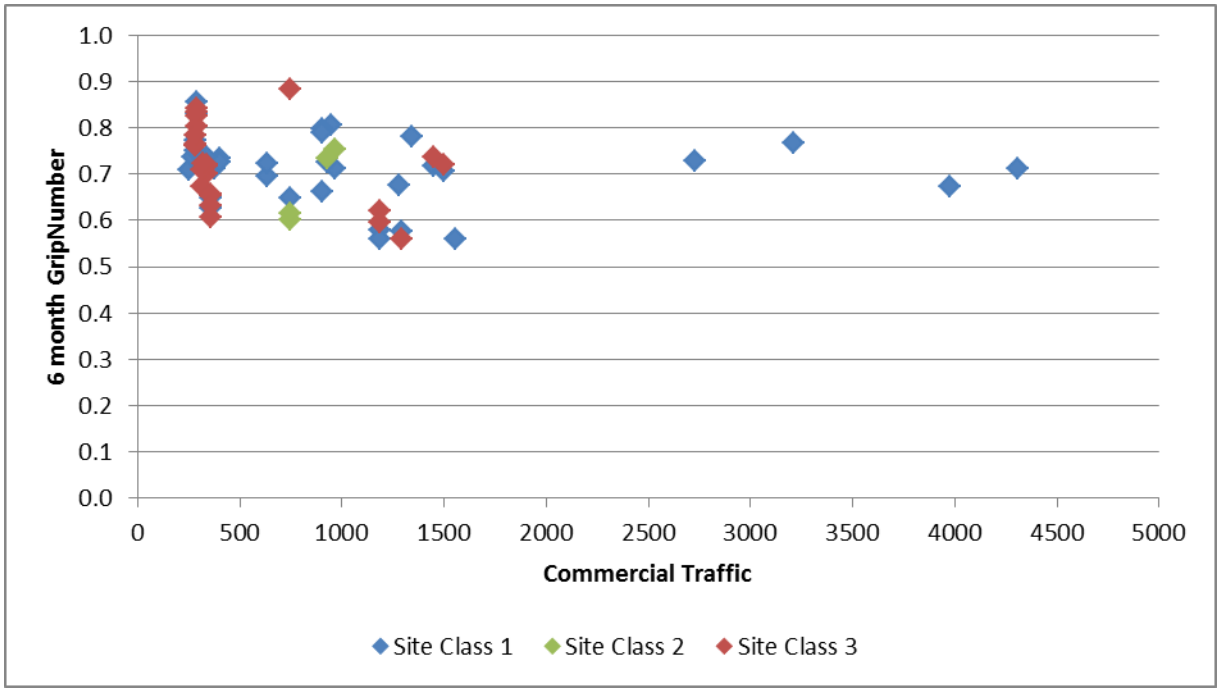

Figure 3-7: Commercial traffic levels compared to TS2010 GripNumbers at six months

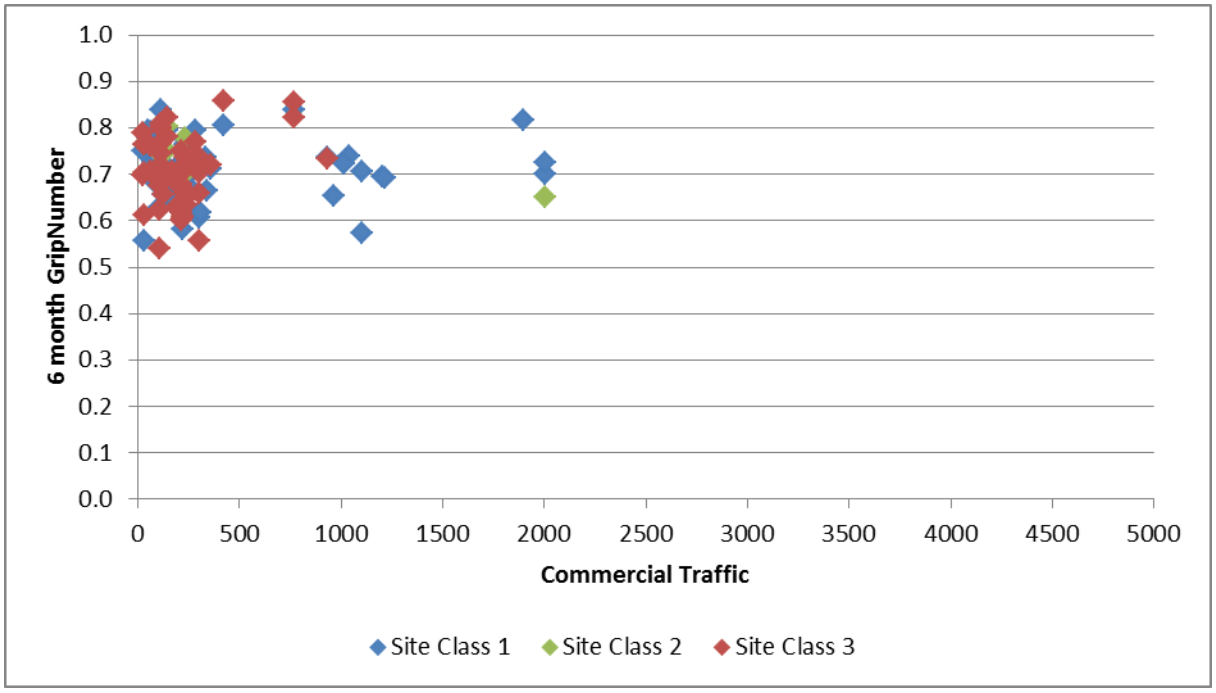

Figure 3-8: Commercial traffic levels compared to Clause 942 GripNumber at six months

Results show that GripNumbers do not have a tendency to increase or decrease dependant on commercial traffic levels at six months. It should be noted that the majority of sites that carry higher levels of commercial vehicles are on Site Class 1 which is considered as low stress.

3.6 Site Class Category

The TS2010 specification simplifies Site Categories from HD28 into three Site Classes; 1, 2 & 3 with Site Class 1 requiring lowest skid resistance and Site Class 3 requiring highest. Table 3-1 has been taken from the TS2010 surface course specification (TSIA No. 35, 2015) and shows which Site Categories from HD 28 are covered in which Site Class. The table also includes the minimum mean GN (over a 10m rolling-average) after 6 months in service required for contractual purposes.

Table 3-1: Site Class categories in accordance with TSIA No. 35

Site Class	HD 28 Site Category[a)]	Minimum mean GN (10m average)
1	A, B & C	0.39
2	R, G1 & S1	0.51
3	Q, K, G2 & S2	0.56

a) Table 4.1 of HD28 (DMRB 7.3.1)

Figure 3-9 and Figure 3-10 display all the six month GripNumbers collected over the summer months for both TS2010 and Clause 942 and divides them into their respective Site Class (in accordance with Table 3-1). Figure 3-9 shows the nominal coarse aggregate size at each site, whereas Figure 3-10 shows the PSV of the coarse aggregate at each site. Included in both figures is a horizontal black dotted line which shows the minimum mean GN for each Site Class in accordance with the TS2010 specification, it should be noted that although this level is intended for TS2010 materials it has been used for all materials for comparison purposes.

Both Figure 3-9 and Figure 3-10 show that there is very little difference in the spread of data between any of the Site Classes. Figure 3-9 shows that within Site Class 1 and Site Class 3 smaller aggregate sizes are typically producing the highest levels of friction. There are three sites within Site Class 3 that are on or slightly below the contractual level. It is noted that one of the sites on the contractual level is a 10mm TS2010 (60 PSV). However, subsequent CSC readings at this site suggest the low GN is an outlier; high CSC values for this site can be seen in Figure 3-2 (TS2010 at one and two years old). The other two sites are both 14mm Clause 942 materials.

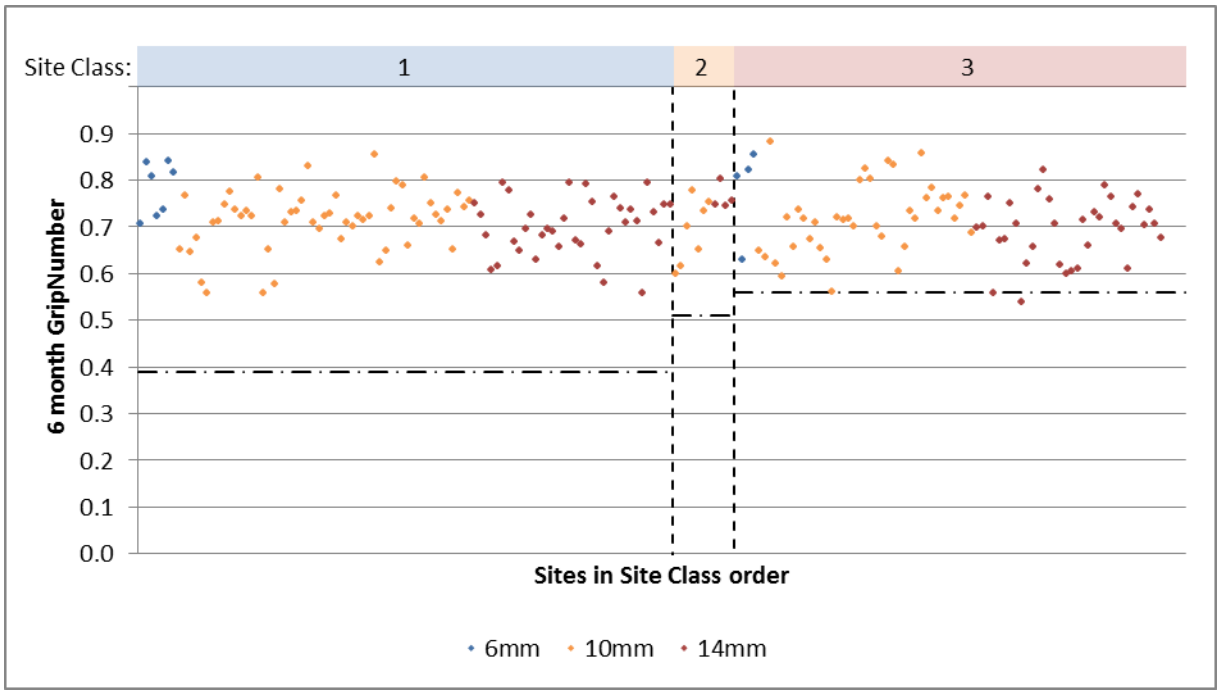

Figure 3-9: GripNumbers at six month in Site Class order with aggregate size

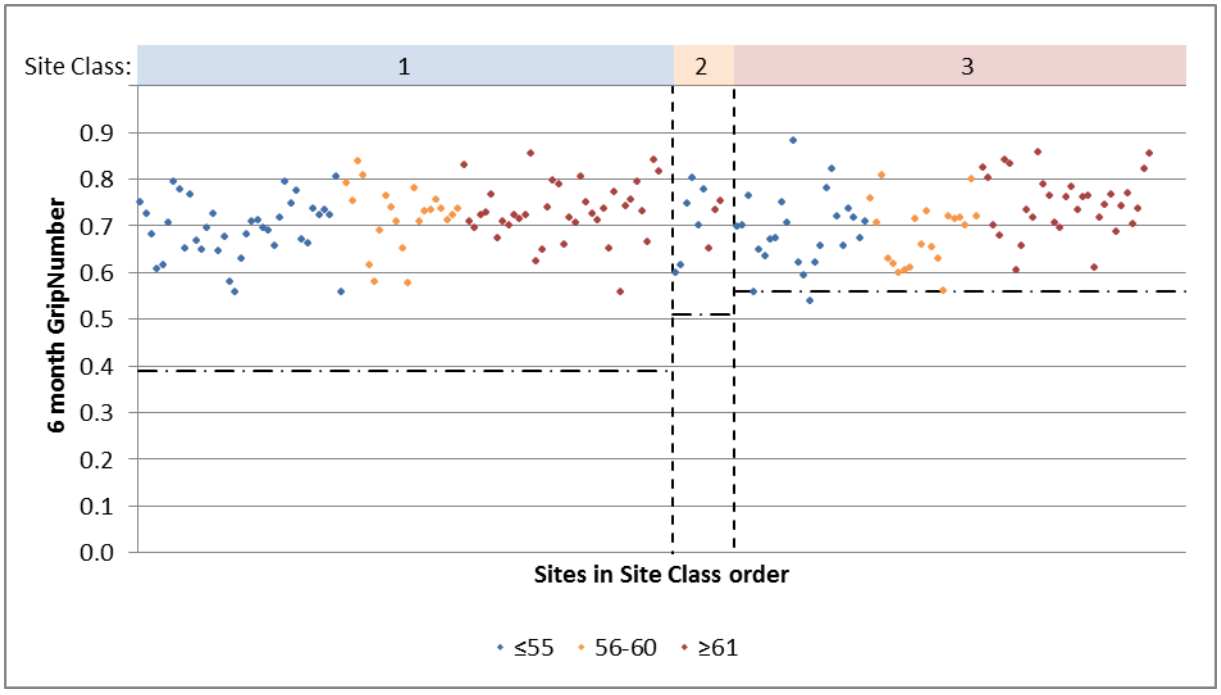

Figure 3-10: GripNumber at Six months in Site Class order with PSV

4 Discussion

GripTester surveys on Scottish trunk road network were primarily introduced as part of the TS2010 specification (TSIA No. 35, 2015) to ensure the surface course met minimum skid resistance requirements. In the early life of a surface course a film of bitumen gradually wears away to expose the aggregate that will provide skid resistance over the majority of the service life of the road. The removal of the binder will depend on the binder thickness and properties, and on the traffic and other conditions to which the road is subject. As a result there is a risk that early life effects could influence or mask any relations between other factors.

The purpose of this study is to analyse the early-life skid performance, measured by six month GripTester measurements, and to determine whether any trends or relations existed with other factors, such as SCRIM, material characteristics, Site Categories and traffic levels. This chapter discusses the results presented in Chapter 3.

Results clearly show that the time of the year influences the measured GNs. Regardless of the type of material, Site Category or traffic levels, the highest results are measured during the winter months, i.e. November – March. Low GNs can be measured at this time, but the magnitude of the higher GNs are not seen between the months of April and October. Due to this effect it may be appropriate to consider avoiding testing between the months of November and March where possible. This seasonal effect is likely a result of surface maintenance such as gritting rather than the wearing of aggregate as it would not have had time to be fully exposed at such an early life.

One objective of this study was to see if six month GripTester surveys could be used to predict how a material would perform in the future and this was explored by comparing six month GNs with annual SCRIM data. The graphs shown in Figure 3-2 show that little or no relation appears to exist between GN and SCRIM for Clause 942 materials. However, data collected on TS2010 suggests that six month GNs may provide an indication of future skid performance, i.e. could be used to broadly predict the CSC of TS2010 material one to three years after being laid. A factor that may explain why a better relation exists with TS2010 may relate to the fact that it possesses more consistent properties in terms of surface characteristics. It is important to note that these graphs were created using data that was only collected between the months of April and October, had data outwith this period been used the trend would not be so obvious.

Figure 4-1 provides three graphs with broad prediction envelopes for years one to three after the laying of material, these envelopes are based on regression lines using results described in chapter 3.2 (excluding the outlier with low GN and high CSC mentioned in Chapter 3.6). The envelope only ranges between 0.5GN and 0.9GN at six months as no data outside this range was used in this study. It should be noted that these prediction envelopes are based on sites that contain a large range of variables and assume a linear relation. These

predictions should only be used with GripTester data that has been collected in summer months (April to October).

A comparison of aggregate sources showed that certain sources provide higher low-speed skid resistance than others at six months and this did not follow a trend with higher PSV values. On many of these sites it is possible that the binder has not been removed from the aggregate surface and other factors such as macro texture, aggregate shape and other materials (general detritus) may influence the level of friction measured. Figures from chapters 3.4 and 3.6 show that smaller aggregate sizes are more liable to provide high low-speed skid resistance, this is likely due to an increase in contact between surface course and tyre. Aggregate size is also seen to influence results at a later stage i.e. after two years. As well as providing enhanced friction, smaller aggregate sizes are also believed to provide better durability under higher stress (McHale and Martin, 2017).

Analysis was also carried out between six month GNs and traffic level and Site Class. It was observed that at six months neither traffic levels or Site Category influenced results on either TS2010 or Clause 942. This could be an effect of early life and that accelerated polishing from increased traffic (both commercial and all types) on higher stress sites has not yet occurred. Alternatively, the lack of variation in Site Classes could be due to how certain sites are categorised as opposed to the level of stress they receive, e.g. a lane next to a decelerating lane leading up to a junction still requires high friction but is less likely to be subjected to high stress as the decelerating lane will be taking most of the braking of vehicles.

A review of the average GNs against the contractual 6 month minimum level for TS2010 showed that no TS2010 sites fell below this limit. Although there is no contractual level for Clause 942 surface courses a comparison was made against the TS2010 contractual level for research purposes. This showed that only one of the 119 Clause 942 sites fell below the contractual level. It occurred on a Site Class 3 site, and relates to 0.9% of Clause 942 sites falling below TS2010 contractual levels.

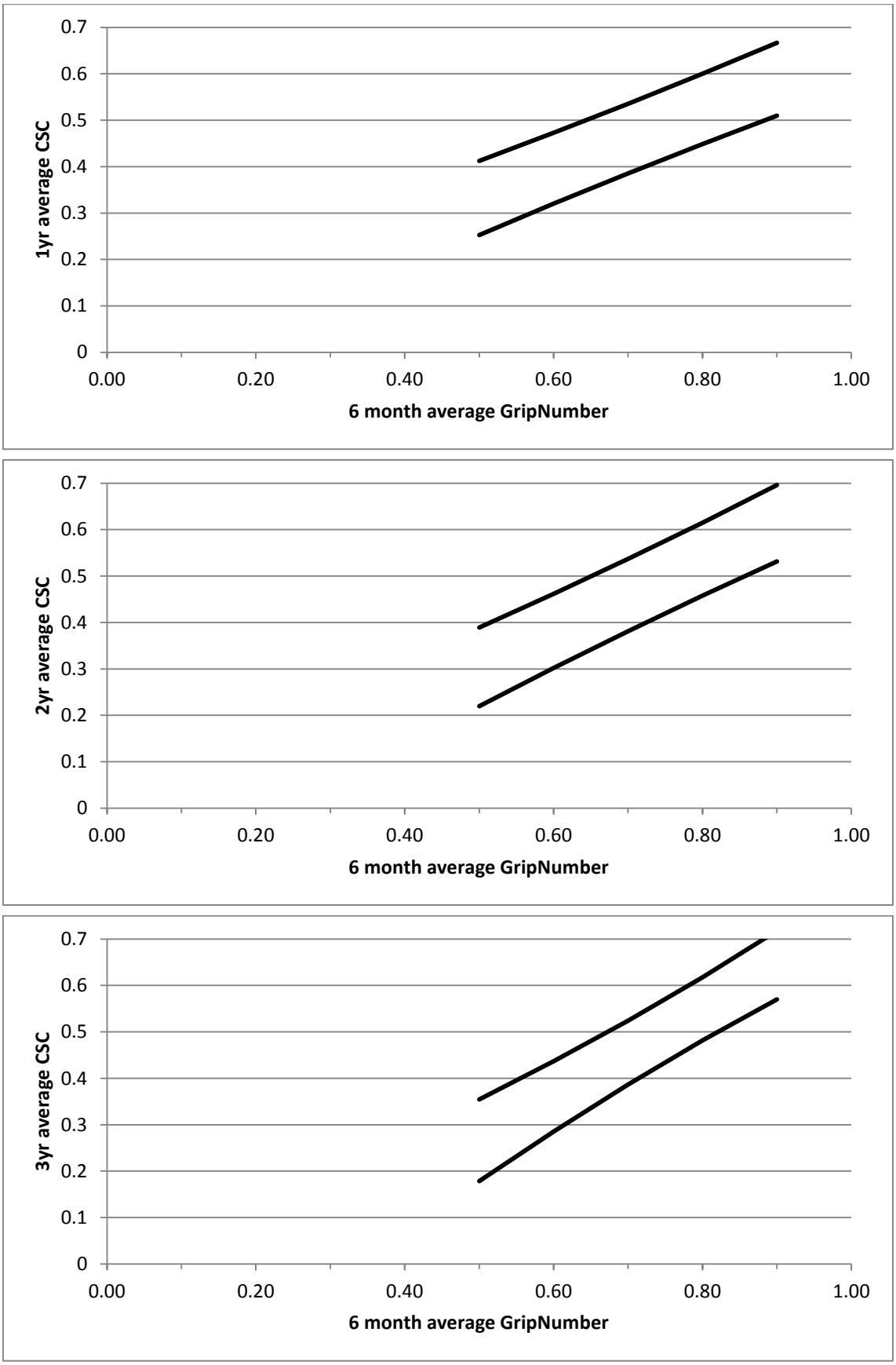

Figure 4-1: Prediction of future CSC based on six month GripNumber

5 Findings

Based on the data collected within this study the following findings are made:

- GripTester results were observed to be higher during winter months (November – March).
- Six month GripTester results taken on TS2010 surface course show a broad relation to SCRIM results taken when the material is between one and three years old.
- Six month GripTester results show no relation to SCRIM results on Clause 942 materials.
- No TS2010 sites fell below the TS2010 contractual levels and only one Clause 942 site fell below the TS2010 contractual levels.
- No relations were established between six month GripTester results and PSV.
- Smaller aggregate sizes provided higher levels of skid resistance, although this was based on a limited data set.
- No relations could be established between six month GripTester results and traffic levels and Site Class Categories.

6 Recommendations

Based on the data collected within this study the following recommendations are made:

- For compliance purposes, consideration should be given to restricting the time of testing for GripTesters, i.e. surveys should be taken between April and October.
- The benefit of using GripTesters to routinely survey Clause 942 surface courses should be reviewed.
- Additional analysis to include the 2018 SCRIM survey data could provide confidence in establishing a relation between six month GripNumbers and future CSC results and its potential to be used as a predictive tool.
- The increased use of smaller aggregates sizes to enhance the skid-resistance properties of surface courses should be considered.

Acknowledgments

The work described in this report was carried out in the Science and Engineering Group of Transport Research Laboratories. The author is grateful to Michael McHale who carried out the technical review and auditing of this report. The author would also like to acknowledge the invaluable assistance of Andrew Ferguson of Transport Scotland for his involvement in matching GripTester data with data from IRIS.

References

Highways England, Transport Scotland, Welsh Assembly Government and The Department for Regional Development Northern Ireland (2015). *Design Manual for Roads and Bridges*, Volume 7: Pavement Design and Maintenance, Section 3: Pavement maintenance assessment, Part 1: HD28/15 Skidding Resistance. London: The stationary Office**.**

Manual of contract Documents for Highway Works. *Volume 1: Specification for highway works (MCHW 1).* London: The Stationary Office.

McHale MJ and Martin LA (2017). *PPR821. Scottish Inspection Panel 2016.* Crowthorne: TRL Limited.

TSIA No. 35 (2015). *Transport Scotland Interim Amendment No. 35,* TS2010 Surface Course Specification and Guidance. Glasgow: Buchanan House.

An analysis of early-life skid resistance of SMAs on the Scottish trunk road network

The GripTester skid resistance measuring device has been used extensively on the Scottish trunk road network following the introduction of Transport Scotland's new standard surfacing (TS2010). This report details the analysis carried out on measurements collected between 2014 and 2016 on both TS2010 and other thin surface course systems at a nominal material age of six months. Comparisons are made against road characteristics including material type, Site Categories, traffic levels and subsequent SCRIM surveys. Recommendations are made based on the findings of this study and include restricting GripTester surveying to summer months and to develop the use six month GripTester as a potential predictive tool. for future SCRIM surveys.

Other titles from this subject area

TRL670	New surface course specification for Scotland. M J McHale, I Carswell and P Roe. 2011
PPR825	High speed friction assessment of TS2010. P D Sanders, M McHale, L A Martin and D Leal. 2017
PPR497	GripTester trial- October 2009 Including SCRIM comparison. A Dunford. 2010.
PPR821	Scottish Inspection Panel Report 2016. M McHale and L A Martin. 2017

TRL
Crowthorne House, Nine Mile Ride,
Wokingham, Berkshire, RG40 3GA,
United Kingdom
T: +44 (0) 1344 773131
F: +44 (0) 1344 770356
E: enquiries@trl.co.uk
W: www.trl.co.uk

ISSN 2514-9652

ISBN 978-1-912433-82-7

PPR893