Skid Resistance and Pavement Marking Materials

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ABSTRACT

In the roadmarking industry, the introduction of performance based contracts moved the focus from inputs to outcomes, with an emphasis on meeting the delineation needs of the driver, while at the same time using marking systems that did not create a hazard. Among the performance criteria is a requirement for markings to meet minimum skid resistance levels.

This paper looks at the performance criteria and contrasts the requirements in New Zealand with those in Australia and those called up in European Standards.

We look at the way contractors are measuring and reporting against the standards set out in New Zealand RCA contracts.

Ongoing materials testing has identified skid resistance profiles for the variety of marking systems that are used in the pavement marking industry. The road surface texture – whether smooth or coarse textured - has a significant impact on skid resistance for thin film marking, however with those marking systems with greater film builds this is of less significance. We look at typical skid resistance performance of the range of marking systems, highlight risk areas, and talk about ways that skid resistance can be improved.

The Transit NZ pavement marking P/20 performance based specification is currently being reviewed. The paper proposes revised test requirements based on the experience of the past eight years.

1. INTRODUCTION

Horizontal pavement marking materials are applied to road surfaces to provide guidance for the travelling public. The application of road marking materials generally results in a localised reduction in skid resistance to the pavement. The different friction on the pavement marking and the adjacent pavement surface may create a potential hazard, in particular for motorcyclists, cyclists and pedestrians.
The management systems for effective pavement marking in relation to skid resistance are quite different from that of the road surface. With the road surface, the loss of skid resistance often determines the end of the surface life, however with marking systems the loss of visibility - day or night, should determine the end of the markings life. The skid resistance needs to be maintained above a safe level throughout the markings life.

2. SOME HISTORY

In New Zealand until around 10 years ago, the majority of pavement markings were carried out using low quality solvent paint. There was limited reflectorised markings (An early 1990's survey by Transit NZ reported only around 14% of the State Highway was reflectorised for night time visibility). Typical remark cycles were 6 monthly, and in many locations markings did not provide effective delineation for much of that time.

A number of factors worked together to bring about a quantum improvement in marking systems:

- Manufacturers invested in research and development for better products.
- Internationally better formulations such as chlorinated rubber modified solvent paint and waterbourne paints were developed.
- Long life marking systems such as thermoplastics and cold applied plastics were supported by RCA's
- Transit NZ substantially increased their expectations with products, and revised their materials specifications
- NZRF sponsored conferences highlighted the improvements that were being delivered in Australia and further afield.

By the mid 1990's, the industry was addressing the prospect of performance based contracting. The change was from a method based contracts approach, to one that focused on outputs – the visibility and information needs of motorists. And at the same time avoiding creating hazards through too frequent remark, or the use of marking systems that did not meet skid resistance requirements.

3. CURRENT SITUATION IN NEW ZEALAND

The issue of skid resistance of pavement marking materials is addressed through the Transit New Zealand specification for materials, and the specifications for method based application and performance based contracts.

3.1 TRANSIT NZ M/7 SPECIFICATION FOR ROADMARKING PAINT

> ***8.6 Skid resistance***
> *When tested in accordance with appendix B of this specification (using the British Pendulum tester and following the procedure outlined in TRL*

Roadnote 27) no less than seven days after application the skid resistance on an unbeaded test plate shall be not less than 30 BPN.
As an alternative the skid resistance when tested on a beaded test plate, shall not be less than 30 BPN for approval as "reflectorised only" marking

3.2 TRANSIT NZ M/20 SPECIFICATION FOR LONG-LIFE ROADMARKING MATERIALS

3.2 Skid resistance

When tested in the wheelpath in accordance with Roadnote 27 of Transport Road Research Laboratory at 1 hour after application and any time thereafter, the skid resistance on a test line shall be not less than 50 BPN and no greater than 65 BPN.

3.3 TRANSIT NZ P/22 SPECIFICATION FOR REFLECTORISED ROADMARKING

14 Skid resistance

The skid resistance of the marking shall be as shown below. Initial measurements, taken between one hour and one week after application, shall comply with the following:

- *45 BPN or greater for markings with a dry film thickness of less than 0.9mm (eg paint); or*
- *Greater than 50BPN but less than 65 BPN for markings with a dry film thickness of 0.9mm or greater (e.g. thermoplastic or long life materials)*

Skid resistance shall be measured in accordance with Transit NZ specification TNZ P/20.
(Additional aggregate may need to be added to achieve these values).

3.4 TRANSIT NZ P/20 SPECIFICATION FOR REFLECTORISED ROADMARKING

2.4 Skid Resistance

The skid resistance shall be either:
(a) 45 BPN or greater for markings with a dry film thickness of less than 0.9 mm (e.g. paint); or
(b) 50 BPN or greater for markings with a dry film thickness of 0.9 mm or greater (e.g. thermoplastic or long life materials); or
(c) the value specified with the contract (in BPN).

At each test site the above skid resistance values of either (a) and (b) above as appropriate must be exceeded 4 out of every 5 test results. The method of measurement shall be as set out according to method C of the Appendix 2 to this specification.

<u>TEST METHOD C : MEASUREMENT OF SKID RESISTANCE</u>

Skid resistance is to be by measurement with the British Pendulum Tester, used in accordance with TRRL Roadnote No. 27. The test instrument is to be in current calibration and is to be operated by experienced personnel (who *have had a minimum 4 hours of formal training from a recognised testing agency).*

Testing shall be at five positions spaced at 10 m intervals within the monitoring site. Four out of five readings shall be greater than the required values.

Mobile instruments can be used but contractors need to substantiate correlations between mobile instrument values and values obtained with the BPT. In addition the contractor must be able to demonstrate sufficient control over the mobile instrument so that there is, at most, only a very small risk of spurious data such as measurements where there is contact with the unmarked pavement being included within the data.

4. CURRENT SITUATION - INTERNATIONAL

4.1 RTA, NEW SOUTH WALES, AUSTRALIA

The RTA have developed a condition rating for pavement marking from Condition 1 (new) to Condition 5 (missing, dangerous, immediate replacement)
Conditions 1,2 and 3 are considered to be satisfactory.
Skid resistance values in Condition 1 and 2 are above 45 BPN
Skid resistance value in Condition 3 (limited life, functional) is rated at less than 45 BPN

There appears to be considerable reluctance to specify minimum values across any rating category because of the risk of litigation if markings are found to not comply, where they may have contributed to an accident, with property damage or personal injury.

4.2 EUROPE - EN1436 ROAD MARKING MATERIALS – ROAD MARKING PERFORMANCE FOR ROAD USERS

4.5 Skid resistance

The skid resistance value, expressed in SRT units, shall conform to table 7. The skid resistance shall be measured in accordance with annex D (British pendulum operated in accordance with TRL Road Note no. 27)

Table 7. Classes of skid resiatance

Class	*Minimum SRT value*
S0	*No requirement*
S1	*SRT ≥ 45*
S2	*SRT ≥ 50*
S3	*SRT ≥ 55*
S4	*SRT ≥ 60*
S5	*SRT ≥ 65*

5. MEASUREMENT OF SKID RESISTANCE FOR PAVEMENT MARKINGS

There are a variety of instruments that are used for testing the skid resistance of roadmarking materials.
The British Pendulum is a static instrument with its rubber slider swinging over a wetted surface. Other instruments such as the Griptester and the T2Go instrument are active testers, where the measurement instrument moves along the roadway, and there is measurement from a contact point.

5.1 BRITISH PENDULUM TESTER (*Dravitzki, Potter 2002*)

- There are around 22 instruments in New Zealand.
- The BPT is most often used for site investigations, as a research tool and for testing at accident sites.
- It has the advantages of being:
    - Lightweight and portable
    - Quick and easy to set up on site
    - Can be used on an uphill or down slope up to 1 in 10
    - Testing can be carried out in the direction that the markings are trafficked
    - These are direct readings rather than complicated calculations
- It has the disadvantage of having:
    - A small test area meaning that if the surface is variable more tests are needed to get a stable average
    - Measurements need to be carried out under TTM closure which can be expensive
    - It is affected by moderate/strong wind and rain
    - It requires a trained operator
    - It is a delicate instrument – less strong than it appears
    - Requires annual calibration and attention to the rubber slider.
    - It is an expensive instrument to purchase and maintain

5.2 GRIPTESTER *(Dravitzki, Potter 2002)*

- The Griptester when used for measuring pavement markings has the following advantages:
    - Continuous lengths of roadmarkings can be measured in one pass
    - If used in tow mode traffic control may be limited to the use of a pilot vehicle and/or attenuators
    - Easy to repeat runs
- The Griptester has the following disadvantages
    - Camber tends to drag the wheel off an edge or centre line
    - There are measurement inconsistencies when going around corners
    - RPM's interfere with centre line measurements and bounce the tester
    - It is hard to use in push mode on anything but a level surface
    - The push mode requires full TTM closure which can be expensive
    - Requires a skilled operator
    - Requires frequent calibration
    - Must be tested on a dry road surface

6. SKID RESISTANCE MEASUREMENT BEING CARRIED OUT IN NEW ZEALAND

6.1 LTSA RSS 10

The LTSA RSS 10 survey of skid resistance, 1999 included a question on skid resistance of pavement markings.
The RSS survey included 31 RCA's – 28 territorial local authorities and 3 regional offices of Transit New Zealand.
Question 11 asked; Does your authority have a policy on skid resistance of road markings? If so what is the policy and what minimum value of skid resistance is specified.

Sixteen (52%) RCA'authorites had a policy on skid resistance of roadmarkings naming TNZ M/7 1998 Specification for Road Marking Paint. (30 BPN) Of the other RCA's, fourteen had no policy, and one was unsure.

6.2 LTSA RSS 22

The LTSA RSS 22 survey of road markings, 2003/2004 included a question on skid resistance.
The RSS survey included 33 RCA's – 29 territorial local authorities and 4 regional offices of Transit New Zealand.
Seven of the contracts included Transit NZ P/20 type specification requirements (see the performance criteria above)
Question 13 asked; Do you have tests to determine the skid resistance of your markings? If yes, what programme do you have for this?

Thirty (91%) of the RCA's said they do not undertake skid resistance tests of their road markings
3 (9%) reported undertaking skid resistance tests for road markings. 1 had undertaken British Pendulum tests near the start of the contract term and had not repeated them because they demonstrated compliance considerably exceeding requirements. Another noted they were part of P/20, and the third did not give any details of the tests they had carried out, or when they were undertaken.

7. SKID RESISTANCE OF PAVEMENT MARKING SYSTEMS

There have been several projects looking at expected skid resistance from various marking systems.

7.1 *Richards 1997* reported that pavements in South Australia have an average skid resistance of 52 BPN. Solvent roadmarking paint, in its un-reflectorised form, produces skid resistance levels of 18 to 30 BPN when freshly applied. The skid resistance only increases when the pavement is exposed through wear. Surface applied Type B (drop-on) beads (300gsm into 400um WFT) improved skid resistance to 40 BPN.

7.2 *Thew, Dabic 1999* looked at skid resistance of paint marking systems and the adjacent pavement surface, with measurements using the British pendulum tester. Applications of waterbourne at 200um DFT and Type C (intermix) glass beads showed values between 9 and 13 BPN's lower than the associated road surface.

These readings included the following road surface types:

	BPN road surface	BPN marking
Grade 5	75	62
Grade 3/5	79	70
Grade 3	63	54
Flushed	55	46
Grade 4	73	60

Readings on alkyd markings also gave lower readings than the adjacent surface, but the differences were19-22 BPN's.
The authors concluded; *Since our testing, we believe that the difference between the seal and line readings was not the significant factor. The skid resistance is more reliant on the surface condition.*

With paint marking systems, the skid resistance of the marking will be dependent on the interaction of a number of variables:

- Surface, whether smooth or aggregate textured
- Skid resistance of the surface
- The type of binder (paint) that is used – generally the higher the solids content the better the skid resistant properties
- Application rate of the binder, and whether there has been a build up of paint through remarking
- The glass beads that are used – generally skid resistance is improved with the application of Type B/C (drop-on and intermix) beads and reduced through the application of Type D (large) beads.
- The application process – beads that have either sunk into the binder, or which are under-embedded may have a significant affect on skid resistance.
- Contaminants on the surface such as oil or mud may have a significant impact on skid resistance.

7.3 The draft of 4049.3 Waterbourne Paint provides some information in its section headed *Guidance on the use and application of waterbourne pavement marking paint*;

B7 SKID RESISTANCE

The pavement surface itself provides adhesion for the road user in all conditions because of its macrotexture and its microtexture. Microtexture is the fine texture which can be felt by running a finger over the stones, and determines the level of skid resistance. The macrotexture is the surface texture which is obvious to the eye, typically 5 to 20 mm, which determines how rapidly the skid resistance drops with an increase in vehicle speed, particularly in wet conditions. .

Unbeaded pavement marking paint fills in the microtexture of the pavement, resulting in a localized reduction in skid resistance. The reduced skid resistance, together with the resultant differential with the adjoining pavement, can create a hazard for road users, particularly in areas requiring braking and/or directional changes. This characteristic must be borne in mind when specifying pavement marking paint in areas such as intersections.

Whilst the addition of drop-on glass beads to pavement marking paint may increase the skid resistance, typically from 25-30 BPN to 35-38 BPN, testing has shown that levels above 45 BPN are desirable for motorcyclists. Where skid resistance is *considered to be a critical performance parameter, pavement marking paint should be modified by the pre-mix or drop-on addition of suitable angular aggregates. The advice of material suppliers should be sought where skid resistance is a key performance requirement.*

7.4 The draft version of EN1436 also includes notes highlighting the variable impacting on skid resistance;

4.5 Slip/skid resistance

Unless inappropriate in view of the road marking surface, the slip/skid resistance shall be measured by means of the pendulum test value PTV according to EN 13036-4 using a wide slider and a CEN slider rubber, and shall conform to Table 7.

The pendulum test value PTV is inappropriate for some structured road markings, refer to 3.7. For those cases, other measures of slip/skid resistance normally show satisfactory values. Other measures of slip/skid resistance may be used provided that they are relevant and that the test methods show acceptable repeatability and reproducibility.

NOTE 1 The "International PIARC experiment to compare and harmonize texture and skid resistance measurements", PIARC - 01.04T - 1995, gives information about different skid resistance test methods and equipment, as well as their repeatability and correlation to PTV.

NOTE 2 Skid/slip resistance is a property of a road marking surface to maintain the adhesion of a vehicle tyre and pedestrian footwear, it can be enhanced by adding anti-skid aggregates but with a substantial negative effect on retroreflective properties.

NOTE 3

There are numerous factors which contribute to skid resistance of road markings in use, including:

- *tyre pressure, contact area, tread pattern,*
- *wheel alignment,*
- *rubber composition of the tyre or sole,*
- *micro- and macrotexture of the road surface in relation to the film thickness of the road marking (it is the main factor when the film thickness is less than 0.6 mm),*
- *frictional characteristics of the surface,*
- *vehicle speed,*
- *weather conditions, ie. wet/dry/icy,*

therefore, skid/slip resistance is not a constant but varies with climate and traffic and the effect of these on the characteristics of the surface material itself and, consequently, its evaluation incorporates a high degree of uncertainty.

NOTE 4 In the case that "in situ" inspections are requested (taking into account its high degree of incertitude), other equipment more practical and safer than the pendulum presents advantages.

In the case of high film build materials – thermoplastic and cold applied plastic, the materials skid resistance is generally less related to the pavement surface since the marking creates its own texture. It is critical that formulations are used that will provide adequate skid resistance. With thermoplastic the application of angular material may be required to achieve adequate initial skid resistance numbers.
In any case, with both thermoplastic and cold applied plastic marking systems there is a tendancy for the skid resistance to move up and down throughout its life depending on the wearing surface that is exposed at the time of testing.

8. IMPROVING SKID RESISTANCE OF PAVEMENT MARKING SYSTEMS

Improvement in the skid resistance of marking materials can be made through the introduction of angular material into the marking system.
These can either be dropped onto the marking system, or may be introduced through a premix process.
NZRF HSE Guide Section 8 Roadmarking Materials.

8.1 QUARTZ ANGULAR MATERIAL

- Crushed high purity quartz.
- Quartz angular material is intended for surface application to a wet /unset film of pavement marking material to provide or enhance the skid resistance properties of that marking.

8.2 SILICA FRICTION MATERIAL

- Silica sand
- Note: difficulty with sand is that it may be formed by a variety of materials and its characteristics may vary dramatically.

8.3 CORUNDUM ANGULAR MATERIAL

8.4 NOTES ON ALL ANGULAR MATERIAL.

- Can be used with all types of roadmarking materials.
- Machine application is recommended.
- Application equipment needs to be matched to application speed and desired skid resistance
- Rates of 200 to 275 gm/m^2 are considered appropriate for many materials/substrates to achieve skid resistance values similar to common road surfaces.
- If angular material is required to be applied in conjunction with the beads, it is recommended that the angular material is applied separately immediately before the application of the glass. Mixing prior to application is not recommended. Material needs to be matched to bead size. An application rate of 1 part angular material to 2 parts beads may be found to be sufficient.
- Trafficking of the markings must not occur until material is sufficiently dry enough to retain beads. Dry through times will vary significantly with materials and film builds.
- Over application may reduce effectiveness of marking through dirt entrapment and shadowing of surrounding beads.

Richards 1997 concluded that the application of angular material into paint marking systems with drop-on bead, increased the life of the marking, but it had virtually no affect on the skid resistance. The beaded line measured 40 BPN, when applications of between 60 gsm and up to 150 gsm of angular material were added this, only increased the skid resistance by 2 BPN's.

Carnaby 2002 reported on an ongoing testing programme mostly focused on big bead installations. The research challenged the objective of providing skid resistance as well as providing good day/night and wet night visibility of markings.

To provide the anticipated levels of skid resistance, usually requires a surface application of angular particles. These angular particles may create shadows over the surface applied glass beads and render the line invisible during night conditions. The challenge has been to find a balance between angular and spherical surface applied particles, in size, quality, quantity, ratio and method of application, that can provide durable cost effective horizontal pavement markings with excellent dry night delineation, excellent wet night delineation and a high level of skid resistance.

Testing included paint, preformed thermoplastic, and cold applied plastic marking systems.

The paint marking system involving the installation of 300 DFT waterbourne, 400 gsm large beads and 200 gsm of crushed quartz., Trial results are reported in test AU008 which looked at a variety of different angular material and adhesive coatings on the beads. At 20 Months and after 1.8 million lane vehicles the retroreflectivity levels of three of the best performing paint markings varied between 269 mcd and 395 mcd, with skid resistance between 44 BPN and 53 BPN

The preformed thermoplastic was tested with adhesive coated and non coated beads and with surface applied quartz. Trial results are reported in test AU011. The wear characteristic of thermoplastic means that there is movement both up and down over the 20 months, of both the skid resistance and retroreflectivity values. Skid resistance values vary between 40 and 57 over the trial period. There is an observed improvement in skid resistance as glass beads are dislodged, and a corresponding decrease in retroreflectivity.

The cold applied plastic trialling is reported in AU014. A wide variety of sites were marked and the application involved a variety of bead sizes and adhesive coating. The main finding of this testing was the importance of adhesive coatings to get bead retention. Retroreflectivity numbers tended to increase through the trial duration as skid resistance numbers tracked downwards, from a high of 68 BPN to 38 BPN as the range of starting values.

Bob Carnaby's emphasis is on improved marking systems and application processes, he summarises some of the main design and process findings of the test programme;

In much of Potters field testing it is becoming obvious that, for longitudinal roadmarking applications, it is important that;

- *angular particles be of a cubic shape,*
- *be of a toughness of at least Mohs 6,*
- *match the particle size of the glass beads,*
- *be applied at a ratio of 1 part angular to 2 parts glass beads,*
- *should not exceed 275g/m2 angular to 550g/m2 of glass beads,*

- *should not be applied at an application rate of less than 200g/m2 of angular to 400g/m2 of glass beads,*
- *should have angular material applied first and followed immediately by an application of glass beads, and,*
- *most importantly, only quality products should be used.*

7. CONCLUSION

Proposed standard for pavement marking

At present the standard set for pavement markings is set out in Transit NZ P/22 for method based contracts and Transit NZ P/20 for performance based contracts.
The standard is consistent between the two specifications, however in the case of P/22 it is reliant on materials that have been tested to M/7 with their plate/on-road requirement of 30BPN.

Reasonable levels of skid resistance are required where there are road users who are susceptible to varying levels of skid resistance. Motorcycles, cycles and pedestrians are affected by dramatic changes in skid resistance of surfaces.
Skid resistance levels of 45BPN are probably appropriate in pedestrian contact locations and for most transverse markings, including limit lines, letter and symbols associated with intersections. This should also apply to cycle facility installations.
Away from these situations, and including most longitudinal markings a level of 40 BPN is suggested. This would better allow a focus on retroreflectivity including wet night retroreflectivity.

Intervention through using angular material can be minimised by setting lower skid resistance values in locations where skid resistance is not critical.

A key issue here is design rather than intervention. Markings systems that meet requirements should be either specified or designed for their location.

This understanding should be determined at the development stage and formulated into the manufacturing and application process. Observations and testing after application should then be carried out to confirm that the product applied is performing in accordance with its design. In the case of high film build materials ongoing testing will confirm expected long term skid resistance is occurring.

References:

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