Assessment of different road markings performance under different operating conditions and surfacing types

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ABSTRACT

Road markings have been identified as key component that influences road safety on the roads. Retro-reflectivity ensures that line markings are bright and - easily identified by road drivers even at night conditions. With time, the markings degrade and the reflectivity measurements also decrease. The degradation can happen either because of pavement wear, curvature or existing weather conditions.

The research aim was to monitor the performance of the road markings - under different operating conditions. Performance monitoring was conducted on different surface type, road width, geographical location and temperatures. The research utilized a vehicle-mounted retro-reflectometer.

There are various types of road markings on the market from different suppliers. Water based, solvent based and thermoplastic paints were used on the research varying the suppliers, varying the quality and/or thickness of paint applied including the quantity and quality of glass beads. The reflectivity measurements are being conducted every 6 months on the identified sections over a 50cm interval.

Initial results after 6 months indicated that with regards to the three different paint types; traffic, surface types and texture contribute significantly to reflectivity of the line markings over time. Benefits of adding more glass beads can be observed with the reflectivity measurements when compared with normal application. With regards to thermoplastics not much reflectivity is lost during the first 6 months, not much difference is observed in the initial 6 months, when using the high retro thermoplastic compared to normal thermoplastic. Some benefit was observed with reflectivity due to increasing thermoplastic application rate. Comparing the different type of paints under same operating conditions solvent based paint performed better in the first 6 months compared to water based paint.

Comparing the performance based and specified contract type, more benefits were observed with specifying increased glass beads and paint application compared to performance based contract consisting of higher premiums. There is a need to carefully look at the performance based contracts and their benefits. There is a need to understand the cost difference and benefits in increasing slightly both paint and glass bead application compared to premiums paid for performance based contracts.

1. Introduction

The road available to use by the public must be safe at any operating condition. It is the road authority's responsibility to ensure road safety in terms of either the design of the road or operating conditions. Road markings have been identified as key component that influences road safety. Markings identify the travel lanes as well as the edges of the pavement. They allow the driver to clearly distinguish where to drive. Statistics have shown a greater reduction in accidents due to improved line markings.

While road markings play a vital role in improving road safety, different range of products exists on the market. Retro-reflectivity is used to quantify the different markings available in terms of their performance. Retro-reflectivity quantifies line markings on how they reflect on the surface. Retro-reflection is the ability of the road marking to reflect light from a vehicle's headlight back to driving position of a vehicle. Luminance measures the brightness of the line markings. Both the retro-reflection and luminance are linked to performance of each road marking. Over time, the markings degrade and the reflectivity measurements decrease. The degradation can happen either because of pavement wear, curvature or existing weather conditions.

The retro-reflectivity in line markings is influenced by amount of glass beads embedded in the markings (Kopf, 2004). The effect of the glass beads and how deeply they sink into the paint affects their retro-reflectivity. If beads are embedded deeply light will not be able to reach them and if the beads do not embed far enough light is reflected poorly and beads may come loose.

Elvik (2010) stated that the use of cost benefit analysis in terms of road markings becomes controversial as the trend in the performance of the different types of materials is not well recognized. Performance based contracts come at a premium as they put more risks on the contractor as there are performance criteria that the contractor must comply with. The onus is on the contractor to ensure the line markings meet the minimum specified criteria in the contracts. Normal contracts require very strict site supervision to ensure the contractor sticks to the specifications in terms of the application of the markings, quantity and quality of glass beads.

The question that needs to be asked and be addressed is the following, which contract method is cost effective? How do agencies successfully implement performance based contracts? The premium that has to be paid for the performance based contracts, is it justifiable? When using any type of contracts what performance criteria must be considered? Is the initial reflectivity of importance on how line markings perform over time and what should be the value of each line marking type? How and when do you specify what type of paint? What operating conditions must be linked to a certain type of paint?

Few conclusions are raised by Johnson (2010) which are still relevant even today:

- There is no standard for minimum acceptable retro-reflectivity threshold
- There is lack of consistency in retro-reflectivity degradation models
- Uncertainty in the initial retro-reflectivity value

- Variation in the predicted life span of the line markings

2. Research

2.1 Mobile Reflectometer

Delta LTL-M machine was used for measuring the retro-reflected luminance R_L. The measurements were taken every 50cm to get better reliable results and reduce degree of uncertainty. Studies have been done to show that such machines margins of error are around 7-15% compared to the handheld.

2.2 Research Sections and testing plan

Routes were identified within SANRAL Southern Region Network as shown in **Table 2.2.1** of what paint types and applications were used

Variables considered for the research included the following:
- Type of paint
- Line marking age
- Quantity of glass beads
- Quality of glass beads
- Traffic
- Surface type
- Geographical location
- Marking thickness/paint application
- Cross section i.e. Surfaced/no shoulder/dual carriageway

Limitations of the research included that only thermoplastic was used from one supplier. The other paint were from four different suppliers within South Africa. The study area was only national routes in Eastern Cape. - The type of glass beads used depended on the availability locally in the country and are from one supplier.

Mobile Reflectometer tests were scheduled to be done once all markings were completed and the testing was to be done after every 6 months until the line markings were over 36 months old. The paper only focuses on results obtained from minimum of 5 months and maximum of 18 months.

Table: 2.2.1 : some of the Identified research sections with paint type and application rates applied.

Route & section	Chainages	Length of section for solvent/water based	Length of section for thermoplastic	Paint Type and Application Rates
N2-10	km 73 to km 80	None	15 km dual = 30 km	SUPPLIER A TP20-RETRO @ 1,2mm sprayed (0,34 kg/m² glass beads)
N2-11	km 0 to km 8			SUPPLIER A TP30-RETRO @ 1,2mm sprayed (0,34 kg/m² glass beads)
N2-11	km 8 to km 22,7	None	14,7 km dual = 29,4 km	SUPPLIER A TP20-RETRO @ 1,2mm sprayed (0,34 kg/m² glass beads) SUPPLIER A TP20-RETRO @ 1,6mm sprayed (0,34 kg/m² glass beads)
R75-1	km 0 to km 30	27,4 km dual + 1,6 km single = 56,5 km	None	SUPPLIER C ASP @ 0,5 lt/m² (0,8 kg/lt glass beads) SUPPLIER C WB @ 0,63 lt/m² (0,8 kg/lt glass beads)
R75-2	km 5,6 to km 48	42,4 km	None	SUPPLIER A WBP-RETRO @ 0,63 lt/m² (0,8 kg/lt glass beads) SUPPLIER A ASP-RETRO @ 0,42 lt/m² (0,8 kg/lt glass beads) SUPPLIER C WB @ 0,63 lt/m² (0,8 kg/lt glass beads)
N9-3	km 37,8 to km 59,7	None	100 km	SUPPLIER A TP20-RETRO @ 1,2mm sprayed (0,34 kg/m² glass beads)
N9-4	km 0 to km 78,1			SUPPLIER A TP20-RETRO @ 1,2mm sprayed (0,4 kg/m² glass beads)
R61-1	km 74,22 to km 147,65	73,43 km	None	SUPPLIER A ASP-RETRO @ 0,42 lt/m² (0,8 kg/lt glass beads) SUPPLIER B (ASP) @ 0,42 lt/m² (0,8 kg/lt glass beads) SUPPLIER B(i) (ASP) @ 0,42 lt/m² (0,8 kg/lt glass beads)
R63-7	km 40,23 to km 90,17 *(km 40,23 to km 69 excluded)*	7,5km + 7,5km = 15km	15 km	SUPPLIER A ASP-RETRO @ 0,5 lt/m² (0,96 kg/lt glass beads) SUPPLIER C ASP @ 0,5 lt/m² (0,96 kg/lt glass beads) SUPPLIER A TP20-RETRO @ 1,6mm sprayed (0,4 kg/m² glass beads)
R63-8	km 0 to km 23	15 km *(R63-8 km 0-7,8; R75-4 km 52-59)*	15 km *(painted R63-8 km 7,8 to 23)*	SUPPLIER A ASP-HI-RETRO @ 0,42 lt/m² (0,8 kg/lt glass beads)
R75-4	km 52 to km 59			SUPPLIER A TP20-HI-RETRO @ 1,2mm sprayed (0,34 kg/m² glass beads)
N10-4	km 60 to km 95,26	41,86 km	20 km (N10-4 km 60 to km 80)	SUPPLIER B (WB) @ 0,42 lt/m² (0,8 kg/lt glass beads *(high quality)*) - N9 & N10 km 85-95,26
R56-1	km 0 to km 16,6			SUPPLIER B (ASP) @ 0,42 lt/m² (0,8 kg/lt glass beads *(high quality)*) - N10 km
N9-6	km 93,8 to km 103,8			

				80-85 & R56 SUPPLIER A TP20-RETRO @ 1,2mm sprayed (0,34 kg/m² glass beads) - N10 km 60-80
N2-19	km -3,6 to km 25,6	None	45 km (12,8 km single; 3,0 km dual; 26,2 km single)	SUPPLIER A TP20-HI-RETRO @ 1,2mm sprayed (0,34 kg/m² glass beads) - R61
R61-7	km 39 to km 51,8			SUPPLIER A TP20-HI-RETRO @ 2,4mm screed/extrude (0,34 kg/m²-glass beads) - N2
N2-16	km 60,9 to km 80,3	None	50 km (Start at change in surfacing at N2-17 ± km 15,6 and do 35km south on N2)	SUPPLIER A TP20-RETRO @ 1,2mm sprayed (0,34 kg/m² glass beads) - R63
N2-17	km 0 to km 15.6			SUPPLIER A TP20-RETRO @ 1,6mm sprayed (0,34 kg/m² glass beads) - N2
R63-16	km 30,45 to km 45,45			
R72-1	km 15 to km 45	30 km (R72-2)	30 km (R72-1)	SUPPLIER A TP20-RETRO @ 1,2mm sprayed (0,34 kg/m² glass beads) SUPPLIER A TP20-RETRO @ 1,6mm sprayed (0,34 kg/m² glass beads)
R72-2	km 19.2 to km 49,2			SUPPLIER B (WB) @ 0,42 lt/m² (0,8 kg/lt glass beads) SUPPLIER B (ASP) @ 0,42 lt/m² (0,8 kg/lt glass beads)

3. Results

Correlations were done for every test sections done between handheld and mobile reflectometer as seen on **Figure 3.1** below.
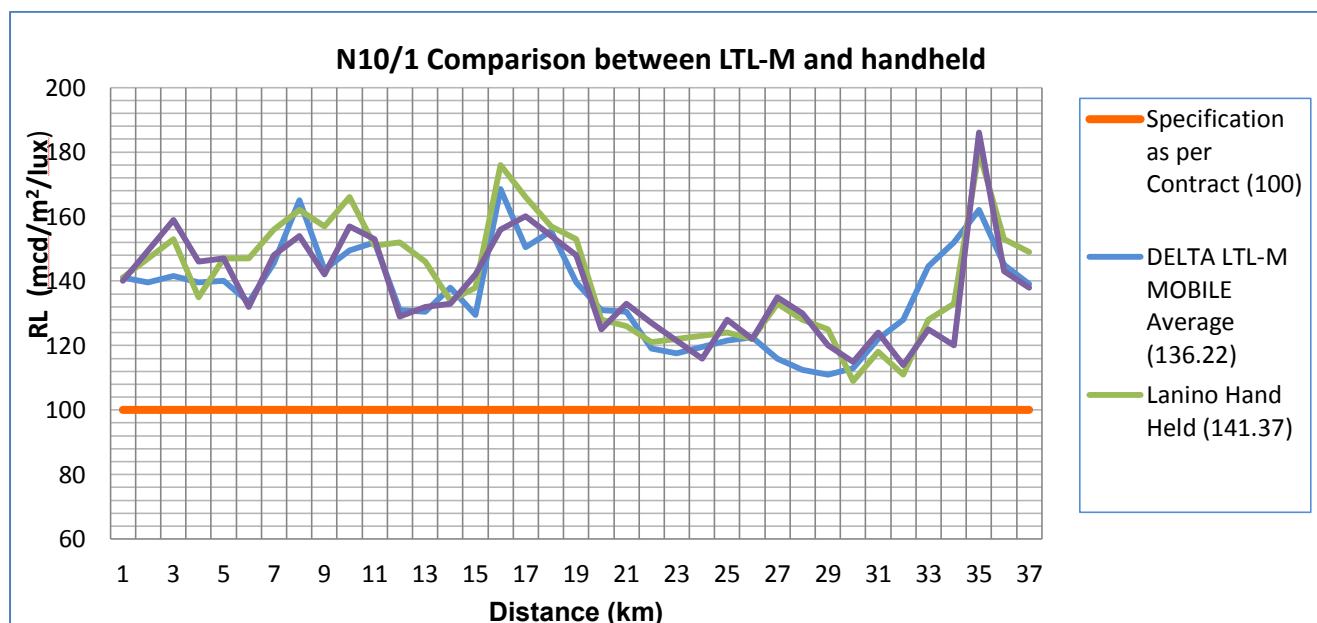

Figure 3.1: Correlation between handheld reflectometer and Delta LTL-M on one of the research sections

Benefits can be observed in applying high quality thermoplastic paint over same surface, environment and traffic (RS3) as seen in **Figure 3.2** below. The research section RS3 age of markings is 16 months over an asphalt section. Traffic is less than 3000ADT and thermoplastic quality was varied. Benefits can be observed with higher reflectivity values of high quality thermoplastic.
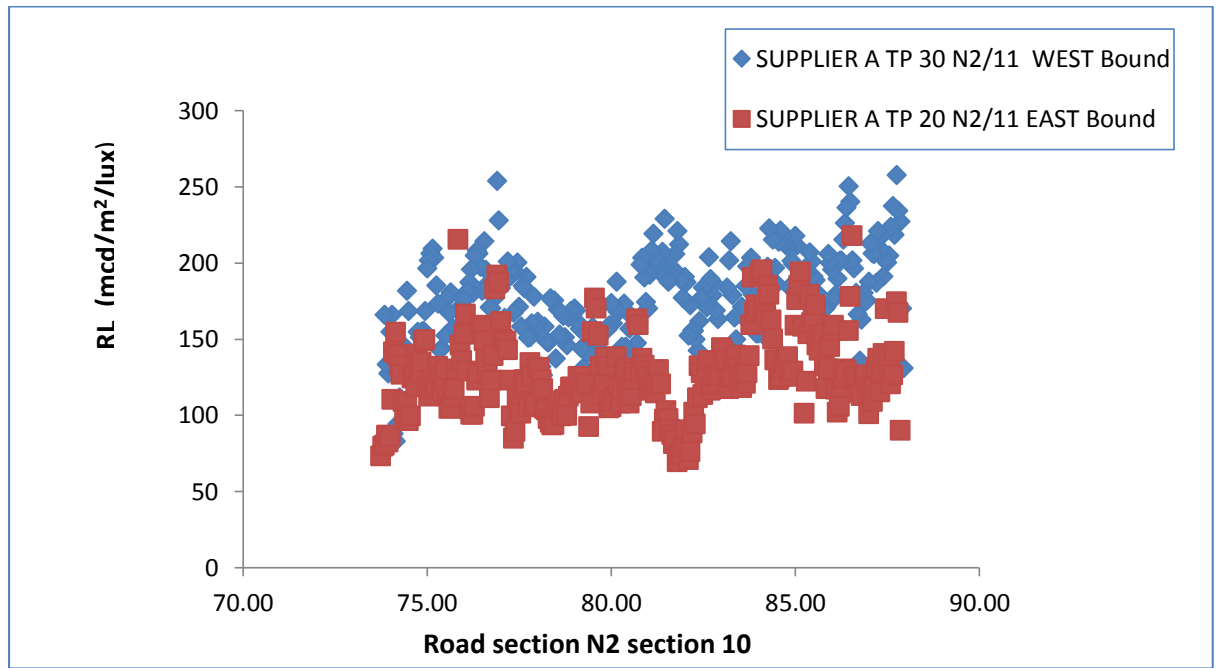

Figure 3.2: Reflectivity results for different types of thermoplastic applied over same environment and traffic.

Influence of surface type can be observed with the reflectivity results under same environment and traffic as seen in figure 3.3 below and comparing it with Figure 3.2 above. Road surface is a 20/7/7mm split seal. The road is within same vicinity as section 10 with similar traffic. The age of markings is also 16 months. Figure below shows not much benefit of applying thicker paint marking application and not increasing the beads quantity or quality.
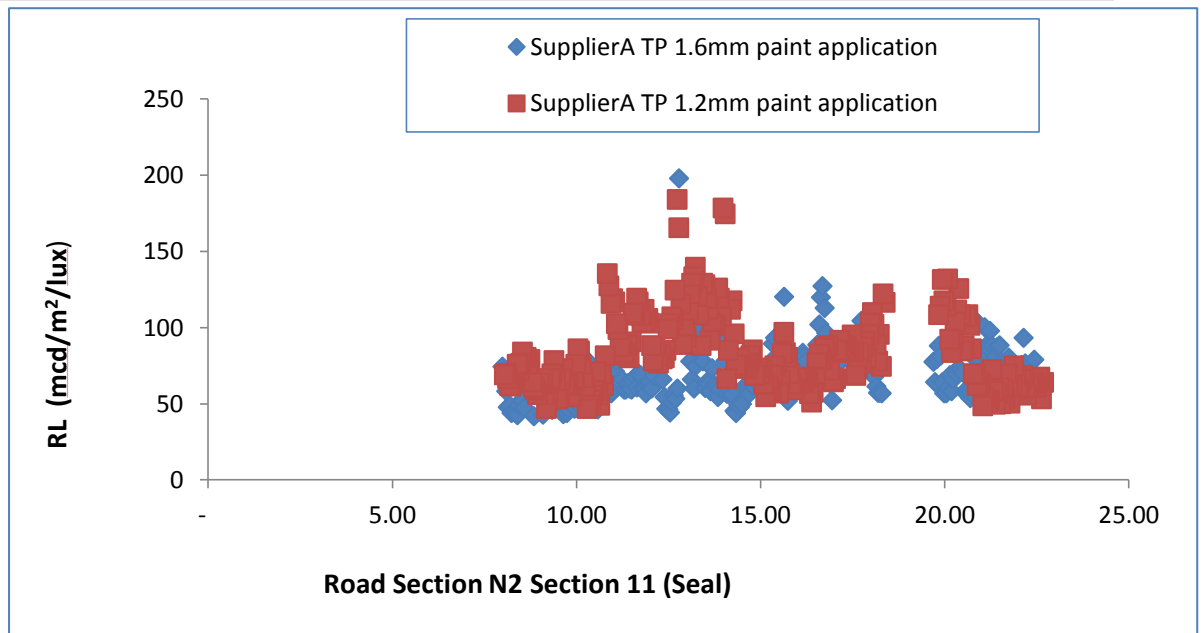
Figure 3.3: Reflectivity results varying thermoplastic application rate over same environment and traffic.

When varying paint type, supplier and application rates (RS6) under same environment and surface type same performance is observed from the two different suppliers of the same water based paint. Age of the lines was 5 months. Benefits of increasing glass beads quantity is observed with the reflectivity results as seen below.
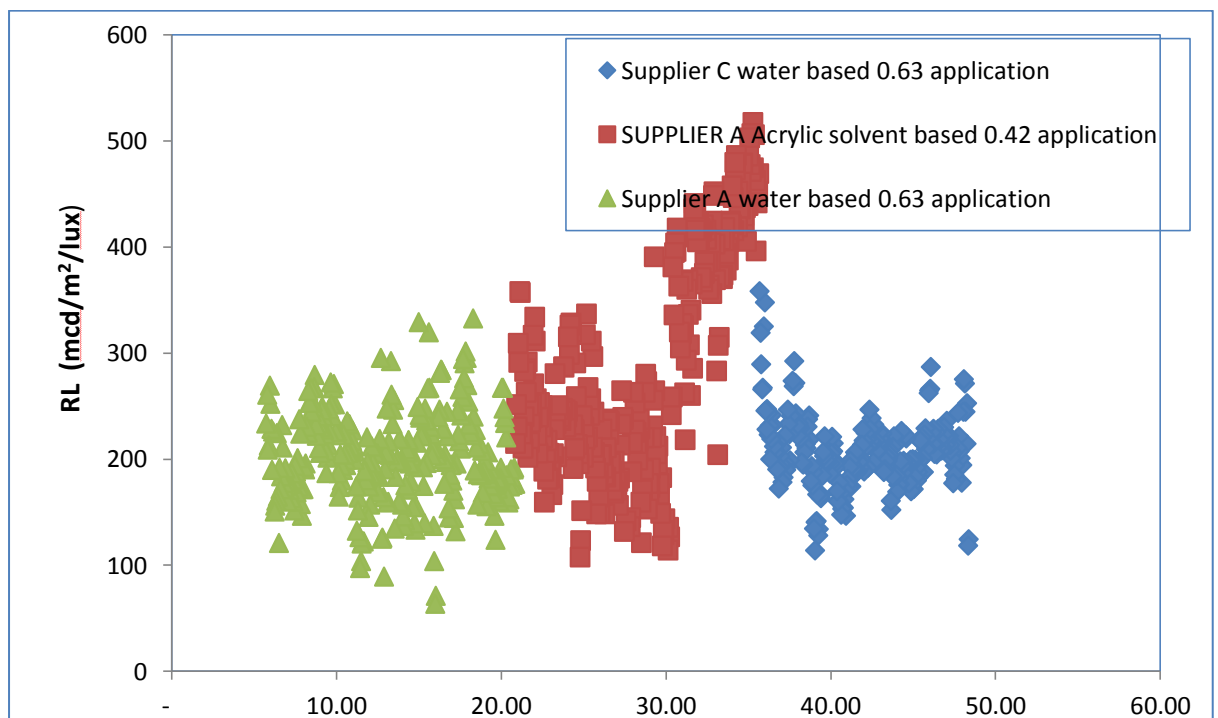

Figure 3.4: Reflectivity results for different types of paint from different suppliers and application rates.

More benefits of increasing and utilising high quality glassbeads can be observed in Figure 3.5 below. Thermoplastic paint is 18 months old and both solvent and water based 11 months. The paints were applied at normal paint application but increasing the beads to 0.8 kg/m² instead of 0.34 kg/m².
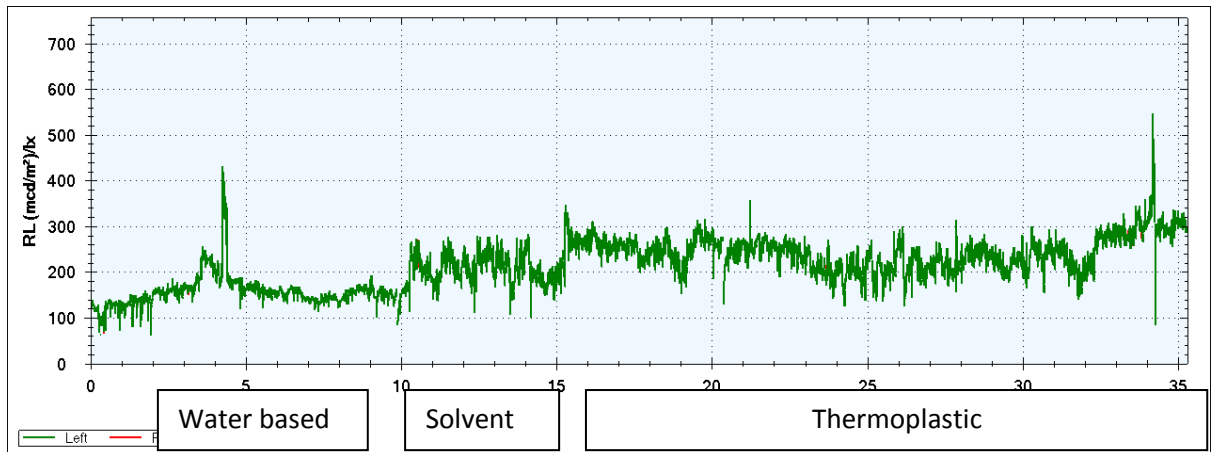
Figure 3.5: Reflectivity results indicating benefits of increasing glass beads quantity and quality for water based and solvent based paint.

With regards to comparing reflectivity results for specified application rates and performance based sections not much benefit can be observed for the premiums paid for performance based contract. The results indicate that higher reflectivity values can be obtained by increasing the beads quality and quantity for either water or solvent based type especially for majority of South African Network which is seals and not asphalt. The contractors appear to aim for the initial specified reflectivity. Their methodology is based merely on experience and not quantified anywhere.

The figure below shows a comparison of reflectivity values for water based type for performance and specified sections. Again benefits of increasing quantity and quality of glass beads are observed. Performance based lines are 18 months old and specified lines are 12 months old with 0.8 kg/m² high quality glass beads applied.
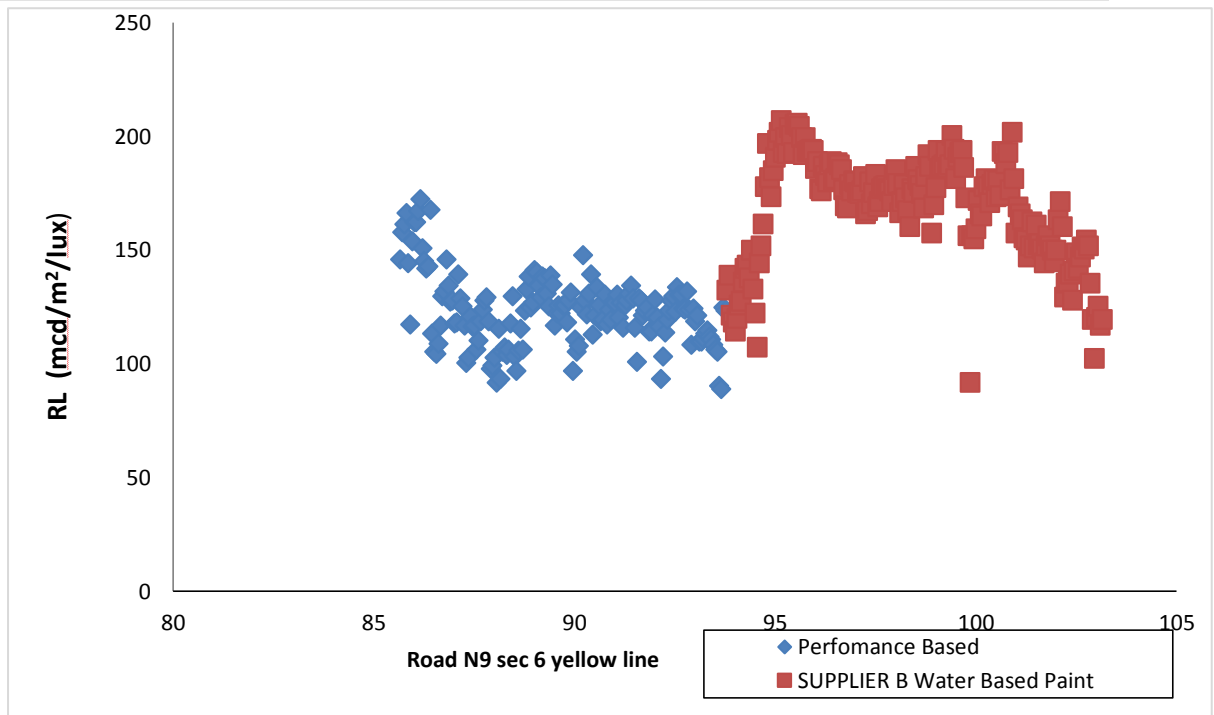
Figure 3.6: Reflectivity results indicating benefits of increasing glass beads quantity and quality for water based paint and comparing with performance based reflectivity results.

Similar trend is observed on **Figure 3.7** where again not much higher values are observed from performance based contract compared with varying the water based paint and beads application rate. Here the performance based lines are 6 months and rest 8 months old.
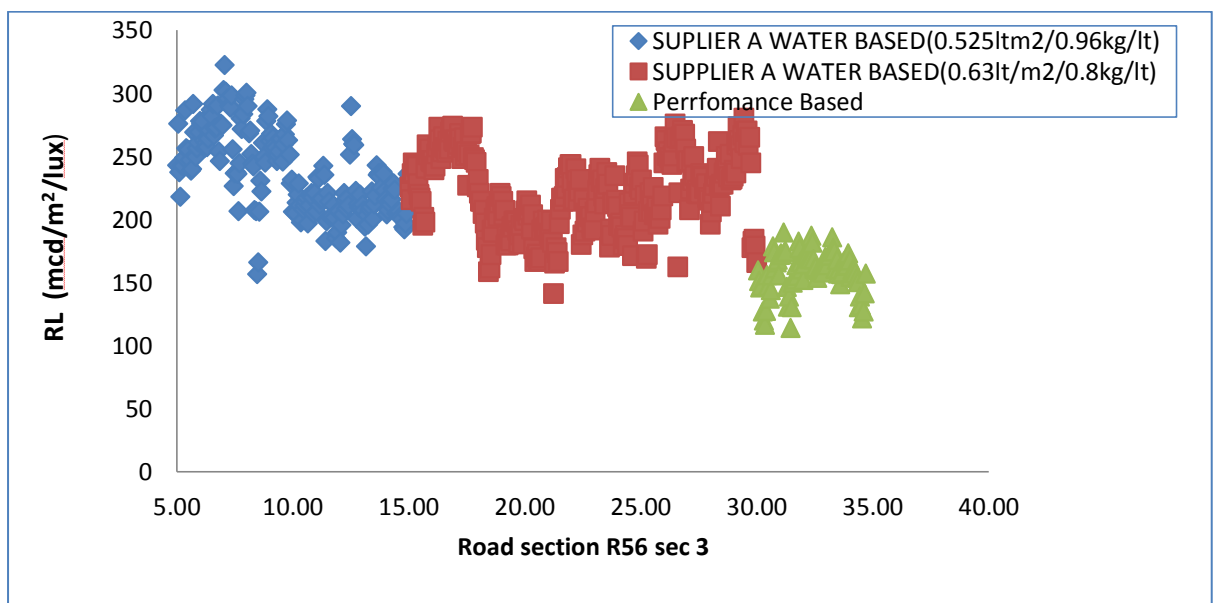

Figure 3.7: Reflectivity results indicating benefits of increasing glass beads quantity and quality for water based paint and comparing with performance based section on R56 section 3.

4. Discussions

In varying or increasing the paint and beads applications or thickness, one needs to find the balance so the beads cannot be affected by how they are embedded within the paint. This can be observed in Figure 3.2 and Figure 3.7 where increasing the paint application didn't necessarily result in higher reflectivity values.

The initial reflectivity value of the paint varies depending on surface type and age, traffic and the location. Future researches will need to work on the range or minimum specified values for the initial measurement.

In terms of contract type, there is a need to compare the premium paid to the cost of varying the paint and glass bead applications. Higher values were observed on the markings with varying the applications which will then have a positive influence on their long term performance.

The degradation models will need to first identify what paint application rates to vary and how to vary the application rates for the best results.

5. Conclusions

The following conclusions are drawn from the results analysed:

1. For thermoplastics the influence of increasing paint and glass bead application can be observed over time and not the first initial months as the beads are embedded within the paint.
2. Water based paint appears to have more benefits when increasing their application rate with glass beads quality and quantity than solvent based paint.
3. Traffic and age of lines appear to have more influence on the reflectivity values of the lines.
4. Benefits of increasing quality and quantity of glass beads observed in all paint types
5. Paint thickness and glass bead quantity influence the initial values of the lines
6. More benefits observed in increasing the glass bead quality and quantity on water based paint.
7. Not much difference is observed in varying the paint and glass beads on thermoplastic in the initial months over same environment and surface type.
8. More benefit is observed after 12 months or more with thermoplastic paint type.
9. Reflectivity values decrease more on seal surface than on asphalt surface
10. Solvent paint performed better than water based paint over time
11. Not much difference from the 2 of the 4 used suppliers on the performance of both water based and solvent based type.

12. Premiums paid over performance based contract need to be further looked at especially in terms of long term performance and the minimum initial threshold for reflectivity value

6. Recommendations

Based on the findings of the research the future work studies are recommended:

1. Correlate texture measurements of different surfacing with the retroreflective measurements
2. Investigate influence of line marking placement direction on the retro reflectivity
3. Investigate the influence of environmental effect on pavement markings
4. Investigate retro-reflectivity of different markings in wet conditions
5. Investigate the influence of existing line markings type on the adhesion of the new line marking and its initial retro-reflectitivity
6. Investigate the influence of surface type, age of surface, environment and traffic on what performs better between solvent and water based paint.

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