### **Investigating and comparing different methods of line marking removal**

Lauren J. Collins

Department of Civil and Environmental Engineering

University of Auckland, Auckland, New Zealand

Abstract

This paper aims to investigate different methods of line marking removal. The purpose was to find a correlation between a roads preview distance of the line and the paint retention of the line to reduce the need for 100% removal. The water blasting methods that were tested were varying operator speed and varying water blaster pressure. The operator’s ability to achieve a required paint retained value and the impact of changes in the roads surface were also investigated. This research shows that there is a correlation between the paint retention of the line and preview distances. This correlation was determined from a small sample size and should be interpreted as an initial attempt in determining the paint retention for each preview distance established in the Line Removal Guide by the New Zealand Roadmarkers Federation. The following values were found: a preview distance of 20m results when 10% of paint retention is achieved, a preview distance of 30m results when 17% of paint retention is achieved, and a preview distance of 50m results when 30% of paint retention is achieved. It was also found that the water blaster operator can control the pressure of the water blaster easier than controlling their own speed. This shows that it is better to rely on mechanically controlled variables over the operator when changes in the removal process needs to be made. It was also shown that the operator found it difficult to achieve a target percentage of paint retained value from verbal prompts. This showed the need for pictorial references to guide the operator.

# Introduction

Although road marking removal is most common near the end of the service life of the road, it can also be needed during its service life. This can be due to road upgrades including road widening, lane re-alignment and removing temporary markings during construction. When the lines are removed it is important that the original lane does not look like the suggested travel path for road users. Due to this concern it is common for removal operators to remove 100% of the line which can scar the road surface causing the original line to remain visible. This is not only a safety concern for road users but also decreases the service life of the road.

To minimise scarring it is important to improve the road marking removal methodology. Young-Bog Ham from Korea Institute of Machinery and Materials has researched the optimal conditions for sufficient paint removal without road damage (Ham, Kwon, Noh, Han, & Kim, 2006). These are as shown.

|  |  |
| --- | --- |
| Nozzle Height | 40mm |
| Injecting Angle | 60o |
| Pressure | 1500-2000 bar |
| Rotating Velocity | 150-550 rpm |
| Velocity of Operator | 50-650 mm/s |

Table 1 Water Cutter Optimal Conditions

The tests were conducted on an asphalt specimen with a 2mm thick paint which was dried for a week before testing. The results indicated in Table 1are applicable to asphalt surfaces in a laboratory environment. These results may vary when tested on site, as the age of the paint and road surface will have an effect on the ease of removal. These results are not applicable to a chip seal surface, which is a common road surface in New Zealand, as the optimal nozzle injecting angle is 60o. This will cause the water blaster to lift the aggregate from the road surface rather than removing the paint (Ham et al., 2006; New Zealand Roadmarkers Federation Inc., 2011).

Chipseal roads vary in texture depth depending on the grade of chip and therefore the texture depth can range from less than 1mm to greater than 3mm. Issues with removing road marking from a chip seal surface are stripping of aggregate, removal of aggregate, damage to the membranes integrity and/or ghost markings (New Zealand Roadmarkers Federation Inc., 2011).

New Zealand Standards for road marking application are extensive; however line marking removal requirements are limited. The Specification for Reflectorised Pavement Marking by Transit New Zealand states that for remedial marking “no evidence of the paint shall remain after the process of paint removal has been completed” (Transit New Zealand, 2006). This is common internationally also where the National Cooperative Highway Research Program (NCHRP) mentioned that the Manual on Uniform Traffic Control Devices (MUTCD), based in the US, state that all visible traces of existing marking are to be removed or obliterated (NCHRP, 2013). This provides no constraints or guidelines for removal operators.

The Specification for High Performance Road Marking by NZTA, which is applied to roads with a traffic volume greater than 5,000 vehicles per day states a minimum requirement for skid resistance at 45 BPN, night time visibility of 150 mcd / m2 / lux (Rl), and day time visibility of 100 mcd / m2 / lux (Qd) (NZ Transport Agency, 2009a). It also states all road-marking removal shall be carried out in accordance with the Line Removal Guide by the New Zealand Roadmarkers Federation (NZRF) (NZ Transport Agency, 2009a).

The NZRF Line Removal Guide has more extensive information on line marking removal. This guide addresses the need for removal to be undertaken with the purpose to reduce scarring to minimise road user confusion.

They have done this by providing a guide on the removal methodology, and also a table showing the ideal removal method based on the paint and road type, This states that for paint marking on a chipseal surface that either high pressure water blasting or abrasive blasting should be used. They have also provided a suggested standard where they have established the required preview distances for line marking that correspond to the posted speed environment. This is shown in Table 2.

Table 2 shows that the higher the posted speed limit is the greater the preview distance can be. This means that less paint will need to be removed reducing the need for 100% removal to be undertaken. It also shows that the centre lines and lane dividers require a shorter preview distance as they are more critical to correct lane positioning. By providing a preview distance for each speed environment the need for 100% removal is minimised, thereby reducing the risk of scarring and damage to the pavement.

The advantage of this table is that it provides operators with direction on how to remove markings correctly.

However there are no guidelines on how to practically achieve the required preview distance during removal. A suggested way of achieving this is to create pictorial references of the required percentage retained for each speed environment (New Zealand Roadmarkers Federation Inc., 2011).

|  |  |  |  |
| --- | --- | --- | --- |
| **Line Type**  | **Posted Speed Limit (kph)** | **Viewing Direction** | **Viewing Point Distance (m)** |
| Edgeline  | Above 70 | With travel | 50 |
| Centre Line and Lane Lines  | Above 70 | Both | 30 |
| Centre Line and Lane Lines – Divided carriageways  | Above 70 | With travel | 30 |
| Edgeline  | Below 70 | With travel | 20 |
| Centre Line and Lane Lines  | Below 70 | Both | 20 |
| Centre Line and Lane Lines – Divided carriageways  | Below 70 | With travel | 20 |
| Intersection Markings  | Rural | With travel | 10 |
| Intersection Markings  | Urban | Both | 10 |

Table 2 Preview distance table from the NZRF Line Removal Guide

# Objectives

The purpose of the project was to investigate different methods of line marking removal to reduce road damage and to improve road user safety through reduced road scarring (known as ghost markings).

The different methods tested were based on the NZRF Line Removal Guide to find a paint retention value to match the corresponding preview distances. The method of paint removal selected was water blasting as it is one of the more common methods of removal, and also one of the recommended paint removal methods for chip seal surfaces (New Zealand Roadmarkers Federation Inc., 2011).

The main objective was to find a correlation between the paint retention and the preview distance of the line, to provide a more useful measure of line marking removal to the industry. Another objective was to assess the operator’s ability at controlling the water blaster to gather an understanding of what constraints they have. This would be accompanied with additional road surface tests to assess changes in the roads texture and visibility.

# Methodology

The site chosen was at Princes Street East, Otahuhu, Auckland. The site had a grade 3 and 6 chipseal surface with one layer of paint from a recent reseal which is less than a year old. A chipseal site was chosen as it is one of the more common pavement types in New Zealand, and is also more inclined to undergo damage from removal.

One side of the road was used and was divided into 3 sections which consisted of six 3m lines in each section. Each section catered to a different type of removal method. Section One was used to assess varying water blaster pressure with a constant operator speed. Section Two was used to assess varying operator speed with a constant pressure. Section Three was used as a tool to gauge how easy it was for the operator to achieve a target percentage of paint retained.

During removal over all three sections, the nozzle height and calibration were kept the same, as well as the water blasting equipment and operator. Section One with varying pressure, ranged from 15kPsi to 40kPsi and was achieved with an operator pass of 10s. Section 2 with varying operator pass speed, had time periods which ranged from 10s to 35s and a constant pressure of 20kPsi. Though the third section had no constraints on pressure and speed, this was done last to help the operator make an educated guess on what they thought would work best.

The road surface was also tested for changes in road visibility and road texture. Luminance, retroreflectivity and texture depth was found to assess the changes in visibility of the line, and the texture depth and skid resistance was found to assess the changes in the texture of the line.

## Paint Retained

To assess the lines paint retention, pictorial references needed to be analysed. To do this, photos of the line marking were implemented in three locations along each 3m line. This was then repeated post removal. The photos were taken on a damp road surface at a constant height and shaded with an umbrella. These photos were then analysed through the Zehntner application provided through the Zehntner website. This application has a manually adjustable detection level which can dramatically change the results of how much paint is measured as retained. To minimise the impact of this variable, the detection level was set between 149 and 151 for each photo.

## Texture

Before site testing could be implemented, a new way of determining the macro texture of the line was developed. The current standard for testing the macro texture of the road involves spreading 45ml of sand into a circle and determining the diameter which is used to calculate the texture depth (Transit New Zealand, 1981). This had to be modified to cater for the restricted width of the line marking by designing a Modified Sand Circle (MSC), the underside is depicted in Figure 1 below.



Figure 1 Modified Sand Circle

The sand was spread along the length of the line within the restricted 80mm width. The sponge on either side of the template was firm enough to not reduce the 80mm width, but soft enough to help prevent a sufficient amount of loose sand from escaping. The material was flexible enough to mould to the road surface and was weighted with a constant weight. The measured length of the sand was used to calculate the texture depth with the equation:

$$D=\frac{4500}{80 x L}$$

Prior to using the MSC during the actual testing, this test was validated by implementing sand circle tests and MSC tests at the same location, over different surface textures. Figure 2 shows that a correlated relationship can be drawn and the test was appropriate for use on site.

Figure 2 Relationship between Sand Circle test and Modified Sand Circle

# Results and Discussion

When evaluating the results there were three main areas to assess: The operators ability at controlling the water blaster, if there is a correlation between the percentage of paint retained and preview distance, and finally how the removal of the paint line changed the road surface.

## Operators Control

By comparing the percentage of paint retained values to the changing variables, two graphs were obtained, shown in Figure 3 and Figure 4

Figure 3 Paint retention of the line with varying pressure

Figure 4 Paint retention of the line with varying time period

From this, it is clear that removing the line using a varying pressure produced a steady decrease in percentage of paint retained, whereas removing the line with varying time period produced an inconsistent change in percentage of paint retained. Hence, it can be established that the operator has less control over the amount of paint removed when they had to vary their speed. This may be due to the change in pressure being machine operated whereas changing the operator speed was open to interpretation by the operator. When the operator had to change tempos they found it hard to reach the required time period and found that they stayed on certain sections of the line longer than others to achieve the required time period. This test was undertaken once and therefore the operator only had one attempt at each time period which may have affected the results. More tests for each time period may be able to reflect the control more accurately.

When the operator was given a target percentage of paint retained to achieve, their results were varied as shown in Figure 5

Figure 5 Paint retention of the line corresponding to the goal paint retention

From this, it is clear that the operator found it hard to achieve the target. However there were other factors which may have affected this. The line being used varies in percentage retained pre-removal, and therefore may confuse the operator when trying to achieve the target. Also, due to the percentage retained values having an adjustable detection level, the readings may not reflect the operator’s view of the percentage retained value. It is unknown whether the detection level can be scaled, though if it is scalable then the true graph would still be linear if the operator reached each target.

This was then assessed in another way. Since the paint on the road had low visibility initially, it may be assumed that the operator may be trying to achieve a percentage retained value based on the initial paint markings being 100%. As shown in Figure 6 the operator achieved 20% retention, 30% retention and 40% retention reasonably well. However when the operator tried to not remove as much of the paint, the values became more inconsistent.

Figure 6 Paint retention percentages when initial markings are treated as 100% retained.

From this it can be established that the operator found it hard to achieve the target paint retention percentage accurately through verbal prompts especially when less paint needs to be removed. This validates that additional guidance is needed to assist the operator in achieving a target paint retention percentage. Due to the low visibility of the line initially, it would be more difficult to achieve the same paint retention values on roads with higher visibility. This is shown in Figure 6 where the achieved values were less consistent where a target of 50% paint retention, or higher, was requested.

## Preview Distance

The preview distance for each line was measured in the morning where the light was in front of the viewer and when shadowing on the road would not occur. One person viewed the line at the driver’s height of 1.2m, while another person stood on the section of line being assessed. The viewer assessed the road in the same direction the operator removed the paint for consistency. The preview distance noted was when the viewer could no longer see the section of line, or when it sufficiently merged with the road surface.

The values obtained for each section was varied and showed no relationship between paint retention and preview distance. As shown in Figure 7

Figure 7 Relationship between preview distance and paint retention of the line

The variability may be due to the sections length only being 3m. Although 3m is a sufficient length to test on, when evaluating the line from further away, less of the line becomes visible. This limits the observation area and increases the difficulty for the viewer to separate the surrounding markings from the marking that is being assessed.

Another factor to be considered is that the viewer found it hard to establish when the markings disappeared. When evaluating the line it was found that lines do not suddenly become invisible, instead they become less visible with distance. Due to this, the viewer had to use their own judgement on what the preview distance of each line was. This leads to human error which can be greater when the paint retention values vary inconsistently.

Due to the inconsistency in data from Figure 3 and Figure 4 it was assumed that the preview distances would be less consistent when assessing those areas due to the fluctuation in the paint retention values. It was assumed that the values for the section that varied pressure would have less judgment error. Thereby, when the preview distance was assessed against the paint retention values along Section One, a sufficient relationship was drawn as shown in Figure 8.

Figure 8 Relationship between preview distance and paint retention of the line along Section One

Although the R2 value of 0.8065 is not very high for statistical analysis, due to the low number of values plotted and the human error involved, the relationship was deemed sufficient to explain the correlation between the preview distance and paint retention. Hence a paint retention value for each required preview distance was established using the equation in Figure 8 shown in Table 3

|  |  |
| --- | --- |
| Preview Distance | Paint retention % |
| 20m | 10 |
| 30m | 17 |
| 50m | 30 |

Table 3 Paint retention of the line for the preview distances given in the Line Removal Guide

Due to the variability in judgement and the small sample size, the paint retained percentages established should be seen as initial values. These values only apply when using the Zehntner application with a detection level of 149-151.

Due to this, pictorial references are shown below to help describe what each paint retention percentage would look like.



Figure 9 10% paint retention for a 20m preview distance



Figure 10 17% paint retention for a 30m preview distance



Figure 11 30% paint retention for a 50m preview distance

## Additional Tests

Additional tests were conducted to assess changes in visibility and texture of the line marking. This was done by determining the retroreflectivity, luminance, skid resistance and texture depth of the line markings before and after removal, as well as the road surface adjacent to the markings. When the results were evaluated together it was difficult to see any pattern. Due to this, Section One was used to demonstrate the findings as it had a consistent increase in removal along the line.

### Retroreflectivity and Luminance Tests

Ghost markings are most visible during wet, night time conditions and therefore it is important to assess both day time and night time visibility of the line markings. To assess this, a Retroreflectometer was used. The Retroreflectometer gives readings for luminance and retroreflectivity which assess the day time and night time visibility respectively. The machine determines the retroreflectivity of the road by producing a light at an angle of 88.76o which mimics a car’s headlights hitting the line marking from 30 m away (NZ Transport Agency, 2009b).

The line marking was assessed both before and after removal and the following results are shown in Figure 12 and Figure 13.

Figure 12 Change in night time visibility along Section One

Figure 13 Change in Day Time Visibility along Section One

This shows that the initial line markings visibility was so low that they did not ever meet the minimum requirements stated in the specification for High Performance Road Marking, which were 150 mcd / m2 / lux and 100 mcd / m2 / lux for retroreflectivity and luminance respectively. Thus, it was established that line marking removal would be able to remove the paint (and reduce reflectivity) to a satisfactory level without extensive damage caused.

It can also be assumed that a road which meets the minimum standards for line marking would result in greater scarring to achieve similar percentage retained values.

### British Pendulum Test

To assess the skid resistance of the road the British Pendulum Test (BPT) was used. The test was implemented once along each 3m line and once next to the 3m line. The BPT was swung 5 times in the same area and the average was found. One section along the 3m line was chosen due to chipseal roads having an uneven surface. This caused difficulties in finding areas where obtruding aggregate would not obstruct the BPT’s swinging arm. The results are shown in Figure 14 for Section One.

Figure 14 Skid Resistance along Section One

This shows that the skid resistance of the line was very similar to the skid resistance of the road; however after the marking was removed the skid resistance was much greater. Although this shows that removing the marking still meets the required minimum standards of 45 BPN, it also shows that the road surface and the removed markings have a greater change in skid resistance. This can be a safety concern for road users when they drive over the markings as the change in skid resistance may reduce vehicle control. Though it is unclear on how great the difference in skid resistance needs to be before this becomes a safety concern.

### Modified Sand Circle Test

Another test used to assess the macro texture of the road was the Modified Sand Circle Test (MSC). The macro texture affects the skid resistance and visibility of the road. This was carried out in the middle of the 3m line as well as on the road next to the line. The results are as shown in Figure 15 for Section One.

Figure 15 Change in Texture Depth along Section One

This shows that the road and the markings initially have a great difference in texture depth due to the paint covering the voids in between the chip seal. When the removal pressures are low, the texture depth is still lower than the road. This is due to the paint being removed between the voids in the chipseal allowing the markings to more closely represent the texture depth of the road surface.

Once the pressure becomes so great, the texture depth starts to exceed that of the road surface. This shows that the high pressure stops removing the paint from the chip seal and instead begins to blast of the aggregate from the road surface which damages the road.

In this instance it begins to occur at 30kPsi, however this may not be the case if this was repeated, as the road surface initially varied in macro texture and the chipseal road was unevenly compacted which will affect the results.

# Conclusions

In conclusion, this research shows that there is a correlation between road preview distances and paint retention on the road. From this, initial values of paint retention for each preview distance from the Line Removal Guide can be found. These values will have a large margin of error and therefore additional tests may show variability in their results. The research also showed that the operator found it hard to achieve the required percentage retained values from verbal prompts. This validates the need for pictorial references for operators to use during removal.

It was also found that the operator had more control of removal when variables were changed mechanically rather than manually. This shows that when undergoing removal, it is better to control the water blaster through mechanical processes rather than through the operator.

The additional tests showed that the line marking on site had a low day time and night time visibility and therefore damage to the road would not be as significant in comparison to a more common chip seal site where the paint would be layered and aged. The skid resistance of the line marking was greater than the road after removal; however it is unclear whether the difference in skid resistance of the marking is great enough to be of a safety concern. Finally the change in texture depth of the road showed that the water blaster removed the paint within the chip seal voids at lower speeds, but eventually the water blaster began to remove the aggregate off the road as the pressure increased. This showed that lower pressures were more effective at paint removal.

# Recommendations for Further Research

The results found have high variability due to the condition of the chip seal road and paint, the measuring application for the paint retained, and the limited length of each removal area.

To further improve this research it is recommended that tests should be carried out on other chip seal roads with multiple layers of paint. Due to the recent reseal of the road used, it was found that the road surface was not well compacted and therefore aggregate was looser in some areas than others. This reseal also meant that the paint was thin and did not meet the minimum requirements for visibility. By retesting on layered paint and a well compacted road surface, the results would better describe road damage from removal as this will reflect a more common road surface.

Due to the adjustable detection level on the Zehntner application, the results from this research may not reflect the true paint retention of the road. It is advised that paint retention of the line should be analysed to find the true paint retention of the line.

Since it is easier to control mechanically changed variables, further testing should be undertaken where the speed along the line can be controlled mechanically. This should also be tested for other mechanically controlled variables including nozzle head height and configuration.

Due to the high variability in recording preview distances for each paint retained value, it is important that more testing is done to validate the relationship. This should lead to pictorial references for water blasting operators to use as a guide.

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