

# DURABILITY AND COST EFFECTIVENESS OF ROAD MARKING PAINT

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## 1. INTRODUCTION

Road markings may be defined as markings embedded in, or applied to, or attached to the road surface. Road markings must regulate, warn or guide the traffic and delineate the limits of the roadway or portions of the travelled way. This paper deals only with markings painted or applied to the road surface.

### 1.1 Background

Road marking is one of the most important factors in maintaining a high level of safety for road users. Road markings are low cost engineering improvements that create a safer environment and assist in achieving the road engineer-s desire for "A Forgiving Highway". Centre lines and edge lines improve road safety by reducing single vehicle accidents and head-on collisions. Road markings must supply information without diverting the driver-s attention. In order to fulfil its task, it must supply the driver with the following:

- Long-range preview information (course of the road ahead)
- Short-range preview information (lateral position and speed of the car)

It is of importance to sustain a high standard of maintenance in order to ensure the effectiveness of the existing road markings.

### 1.2 Objective of the paper

The general objective of the paper is to recommend the intervals between applications of road marking paint. The recommendations made arise out of a post-graduate research project at the University of Pretoria by de Witt (1999). An economical way must be found to make sure road markings delineate and regulate traffic in a safe manner.

### 1.3 Motivation

The purpose of road markings is to improve road safety. Road markings are necessary to guide the road user, and this guidance becomes more important during night driving and driving in unfavourable conditions, such as heavy rain and fog.

American studies by Jackson (1981) show that a reflective edge line reduces collisions by more than 10% and a reflective centre line reduces the collisions by another 10%. These two important lines resulted in a total reduction of 20% in collisions. The lowest reduction in collisions was recorded in Kansas (14%) and the highest in California (64%). A reduction in fatalities between 39% in Kansas and 78% in Michigan was reported. Research by Jackson (1981) shows a 18 to 20% reduction in collisions where effective edge lines were painted on roads with existing centre lines. An even greater reduction in collisions was observed during night time. The reductions in collisions were between 37% and 42%. Although no figure for reduction of collisions due to effective road marking was found in South Africa, the American figures mentioned above give some indication of the importance of the lines.

#### 1.4 Scope of the paper

Road marking materials will be discussed under headings:

- Types of materials.
- Skid resistance.
- Life cycle cost.

#### 1.5 Methodology

In order to obtain relative data for deterioration curves, limited experiments were undertaken. Further information was obtained during discussions with the Provincial authorities. European information was used in conjunction with South African research to obtain the technical specifications. Suppliers and contractors were also involved in obtaining data. Authorities, consultants, suppliers and contractors were asked for opinions to identify problems in the road marking business.

## 2. CONCLUSIONS OF REVIEW OF INTERNATIONAL AND LOCAL PRACTICE

Minimum retroreflectivity for road markings:

- A minimum retroreflectivity CIL (Coefficient of Illuminance) value of  $150 \text{ mcd/m}^2/\text{lx}$  (Meseberg and Seiliger, 1985) would be adequate for newly painted road markings. This value is the same as the value given in SARTSM, the South African Road Traffic Signs Manual.
- Visibility of road markings is reduced in wet conditions.

Retroreflectivity reduction of road markings:

- Thermoplastic shows a slower retroreflective-reduction rate than other road markings.
- Larger beads in road markings increase retroreflectivity and will take longer to reach the minimum value of  $150 \text{ mcd/m}^2/\text{lx}$ . as given in SARTSM, the South African Road Traffic Signs Manual.
- Water-base and solvent-base materials have approximately the same reduction rate. In choosing between these two materials a decision must be made with regard to the different costs of the two products instead of quality of material.
- Dirty markings jeopardise the retroreflectivity of the line, especially if thermoplastic is used. Lines can be cleaned from time to time instead of repainting them.

Wear of road markings:

- In France and Germany (Serres, 1982) the remaining marking (percentage area covered by marking) must be 85%.
- In Sweden the wear is higher in winter due to studded tyres.
- High traffic volumes increase the wear rate.
- The wear can be accurately measured with digital photography and appropriated software.
- Wear is affected by the following:
  - Type of road marking materials.
  - Type of road surface.
  - Climatic conditions.
  - Thinning of paints.
  - Size and quality of glass beads.
  - The volume of traffic passing over the marking.

Skid resistance of road markings:

- Germany and France have minimum requirements for skid resistance of markings, namely 50 BPN (British Portable Pendulum Number).
- Thermoplastic has the highest skid resistance (higher than the road surface) and ordinary road marking paint the lowest.
- According to SABS 731-1 a skid resistance of 40 BPN after 12 months for skid resistance paint is a acceptable value.

Maintenance of road markings:

- The literature (Miglitz, 1994) showed that thermoplastics get dirty in hot climates and must be cleaned from time to time.

Road tests of road markings:

The problems experienced with field tests are as follows:

- It is a long process (up to four years). The German accelerated tests (Harhopf and Seliger, 1990) are costly but accelerated tests can be done.
- Survey personnel are in danger from vehicles travelling at high speed.
- Disruption of traffic flow.
- Usually experimental lines are painted transverse and not longitudinal. It is difficult to get the same results with transverse lines as with longitudinal lines as painted in practice.
- Determination of the position where the wheels crossed the markings.

Visibility at night on wet roads:

- Normal reflective lines (ordinary road marking paint) lose their visibility during wet, nighttime conditions (Blaauw and Padmos, 1982).
- Thermoplastic lines are more visible than ordinary road marking paint during wet, nighttime conditions (Dejuiffe, 1990).
- Profiled markings have a better visibility in wet weather than ordinary road marking paint (Meseberg, 1990).
- Although bead retention of larger beads is difficult larger beads (larger than one mm) increase the visibility in wet conditions (Dejuiffe, 1990).

### **3. ROAD MARKING MATERIALS**

#### **3.1 Types of road marking materials**

##### **3.1.1 Introduction**

In order to determine the frequency of application of road markings it is important to consider different road marking materials and some of their characteristics. The most viable road marking material would be the one with the lowest cost that leads to the safest environment. It is difficult, even where possible, to relate reductions in collisions to a specific road marking material. Therefore, it is necessary to consider the following points in choosing the material:

- Low initial cost.
- Good day-visibility (dry and wet conditions).
- Good night-visibility (dry and wet conditions).
- Adequate skid resistance.
- Applied with minimum traffic interference.
- Rapid drying time.
- Low rate of wear.

Modern materials on the market usually satisfy the functional specifications of SABS. This leaves the choice between initial cost and long life with the better functional aspects, such as visibility and durability, of the more expensive material. The different materials that were investigated are the following:

- Solvent-borne paints.
- Thermoplastics
- Non-skid paints
- Preformed road marking tapes
- Adhesive tape markings
- Cold plastic

### 3.1.2 Solvent-borne Paints

Ordinary solvent-borne paints are readily available in South Africa. Equipment used by the major contractors is up to standard and they can perform a reasonable quantity of work per day.

According to Havell, (1983) ordinary paint has the following shortcomings:

- It is not retro-reflective.
- It is applied as a thin film.
- It is slippery.

The retroreflectivity can be improved by adding glass beads, which is common practice in South Africa on rural roads; less so on urban streets. Ordinary paints without glass beads are used in parking lots and other applications that do not need to give long and medium-distance information to the driver. According to Coetzee, (1989) "practical experience has shown that paint markings applied on fresh bituminous surfaces have a shorter life than those applied after the volatiles in the bitumen have had time to evaporate. No information could be found for paint applied to concrete surfaces, but it is possible that the presence of a curing compound on newly-constructed concrete may have an adverse effect on the adhesion between the paint film and the road surface". SABS 731-1 gives the concrete road precaution of less than one month.

Lines painted earlier than three months after construction show a change in colour from white or yellow to brown as a result of the high content of volatiles present in the surface. The dilemma is that a new surface cannot be left without road markings for two to three months. Usually the Client concerned with a newly constructed road wants the road painted immediately after construction of the road for safety reasons. Temporary markings (decrease the application rate of the line) cost approximately the same as permanent markings. Other forms of temporary markings, such as preformed road marking tapes are more expensive than ordinary road marking paint. SABS 731-1 indicated a life-span of less than six months for such markings. Therefore it is good practice to paint the road with ordinary solvent born paint and repaint it after twelve months instead of painting it with temporary paint and repaint it after six months.

### 3.1.3 Thermoplastics

Thermoplastics can either be sprayed (spray plastic) or applied as a screed. Warning and regulatory markings, such as direction arrows, are applied as a screed, whereas a line is usually sprayed as a thin (1,5 mm) film. For thick lines (two to three mm) the material can be extruded from a flat nozzle close to the road surface or sprayed twice.

As the glass beads in fresh material are covered with pigment and resin, a surface application of glass beads is necessary to obtain initial retro-reflection. In time the line becomes polished and the glass beads that were covered with pigment and resin are worn clean and work effectively.

The major advantage of thermoplastic is the fast drying time. Minutes after application the road surface may be opened to traffic. Thermoplastic material is not influenced (no change in colour was observed during the investigation) by the volatiles in bitumen surfaces. Therefore it is not necessary to respray the line after application as in the case of ordinary road paints.

### 3.1.4 Non-skid Paints

Non-skid paints are not often used in South Africa. They have been used in Australia and Germany to some extent.

### 3.1.5 Other Road Marking Materials

Other road marking materials that are available are as follows:

– *Preformed road marking tapes*

Ease of application and high durability are their main characteristics. According to Havell, (1983) the major limitation of preformed tape is, however its cost. Although on temporary diversions, the ease of laying and the relatively low cost of removal may be attractive for temporary diversions. The cost of preformed tapes in South Africa is about 20 times that of ordinary road paint, and can only really be justified for short lengths such as stop and other transverse lines subjected to heavy wear.

– *Adhesive tape markings*

The main advantage of adhesive tape markings is their ease of application and their durability. However, they are very expensive and rarely used in South Africa.

– *Cold plastic*

Cold plastic is a double-component road marking material. Unlike thermoplastic no application of heat is necessary (it is a catalytic reaction). It is the most durable marking material but is very expensive. The material is excellent for use in countries with low temperatures. Due to South Africa's hot climate the use of cold plastic is not cost effective.

The following paints fall under other road markings, but are only worth mentioning because of their extremely high costs. :

- Epoxy paints
- Epoflex thermoplastics
- Field-reacted materials

## 3.2 Skid resistance

The skid resistance of road markings is important especially for motorcyclists in urban areas. The high percentage of area that is covered with road markings ahead of intersections is extremely dangerous for motorcyclists if the skid resistance is not up to standard. After monitoring 49 road markings for approximately a year Havell (1983) found the following:

- Repainted ordinary paint has a low skid resistance for a long period, until the paint finally wears to expose the road surface. The skid resistance values are much lower than the skid resistance of the road surface. As the paint wears and the aggregate of the road surface becomes exposed slightly higher values were recorded.
- The first application of ordinary paint leads to initial low skid resistance which quickly improves because of wear. Repainting is required within four to six months whereupon the skid resistance falls to that of a typical repainted line. The effect is most marked when a new road surface is painted for the first time.
- "Non-skid" paints maintain a much better skid resistance of between 60 and 90 per cent of the road surface value. Repainting with "non-skid" paint will therefore not affect the skid resistance as it does with ordinary paint. Although still lower than the road surface, higher skid resistance values than ordinary road marking paints were recorded.

- Thermoplastic road markings have, at all times, a higher skid resistance than even the "non-skid" paints. Except for a short period when first applied, the skid-resistance of thermoplastics exceeds that of all normal roads. These markings are therefore the only ones which can truly be described as non-skid.

### 3.3 Life cycle cost

Comparisons between various types of road marking materials cannot be made on the cost and amount of materials alone and other factors must be considered as well. The following factors influence the price in such a way that it is necessary to look at the actual payment that is made by the authorities to the road marking contractors. These factors are:

- Overheads.
- Labour.
- Lay out.
- Location.
- Transport.
- Life.

It is important to bear the following points in mind when a comparison is made between the cost of lines:

- Prices for the painted continuous and intermittent lines per metre are approximately the same. The price to paint a continuous line of 12 metres is the same as three four-metre lines with gaps (eight metres) in between. The cost of painting a length of road with intermittent lines is much less than with a continuous line.
- Cost per linear metre is closely related to the width of the line (application-specifications are given in litres per square metre).
- Yellow lines are slightly more expensive than white lines.
- Cost must be compared over a couple of years. The comparison must be for at least as long as the lifetime of the line that lasts the longest.
- Low initial cost has a significant influence on the decision whether to use the cheaper product with a short lifespan or the more expensive product with a long lifespan. This may occur when authorities attempt to achieve as much as possible with limited funds within annual budgets.

In order to compare the annual cost of materials (i.e. initial cost and maintenance cost) it is important to determine the expected lifetime of the various road marking materials. This is a difficult task because of the following variable factors:

- The quality of the material. Although SABS 731-1987 gives specifications for the paint and CKS 192 for the glass beads, different contractors use different products with variations in quality. The quality of the beads is extremely important in order to achieve adequate retro-reflectivity.
- The thickness of the marking. Specifications are given for the quantity measurement of litres per square metre but there have been complaints in the past that the correct amount of paint was not applied. It is very difficult to monitor the paint thickness. A small adjustment in the operating speed of the machine can make the difference between too thin a layer of paint and the correct thickness.
- The volume of traffic passing over the marking. Heavy vehicles in South Africa tend to drive on the shoulder of the roads. The yellow edge line is crossed frequently and the white middle line is rarely crossed. The overall intensity of the traffic on the road also contributes to the wearing of the line.

- Type of surface. Dale, (1988) indicated that paint on Asphalt concrete last about 1.15 years and paint on Portlant Cement Concrete lasted about 0.75 years. Observations made by the author indicate that marking materials last longer on a bituminous surface than on a concrete road. Traffic passing over lines polishes the tops of stones. Therefore, the texture is of importance.
- The workmanship and weather during the application of the markings. Application of materials such as thermoplastic needs an experienced team. Incorrect application can lead to colour variations. The thermoplastic change colour when heated higher than specified.
- There is limited specifications indicating when a marking is approaching the end of its life-span.

### 3.5 Paint versus thermoplastic

The following were concluded on this topic:

- The cost of thermoplastic is three to four times more expensive than that of ordinary road marking paint.
- Observations made during the study (sections on the N12 near Alberton) showed that the life expectancy of thermoplastic is four to five times longer, than ordinary road marking paint, i.e. eight to ten years instead of two to three years.

## 4 MAINTENANCE

### 4.1 General

One of the functions of markings is to put Road Traffic Act regulations into effect and their legal status may be affected by undue wear or damage. After a period of time the performances of road markings begin to deteriorate. This deterioration may be due to the following:

- Normal wear and tear or damage.
- Spread due to movement of the road surface or plasticity of the material.
- Loss of colour.
- Reduction of skid resistance.
- Reduction of retro reflective properties.

Road markings must be inspected regularly to determine if they comply with specification. Due to safety reasons all inspections shall be carried out in daylight conditions except retro reflectivity inspections when the necessary apparatus to measure the retroreflectivity in daylight is not available. Above-mentioned inspections must be done as specified in SABS - 731.

A discussion of the results from the test site is included in Annexure A.

### 4.2 Opinion of authorities

Regional Engineers and their assistants of the Department of Transport (RSA) as well as Engineers from the Provincial Authorities were asked what the frequency of applications should be in their opinion. Note that these questions was asked in 1994 and that CSRA was still used and not COLTO. The answer to this question was surprisingly similar, namely between 18 and 24 months. The following comments were offered with their answers:

- The frequency of applications is unfortunately not determined by the condition of the line but rather by budget constraints.
- They prefer the use of thermoplastic to paint. This material may last up to ten years. The initial cost is however much higher than paint.
- They are not convinced that the application rate applied by the paint contractors is always as specified by CSRA or SABS 731.

- Road markings must fit in with other maintenance systems.
- The painting of a newly constructed bituminous road must be done at least three months after construction. If the road is painted directly after construction it must be repainted before the construction maintenance period expires.
- It would be good practice to repaint a new road after 12 months in order to ensure a substantial paint base.

## 5 CONCLUSIONS AND RECOMMENDATIONS

The general objective of the paper was to recommend the intervals between applications of road marking paint. Authorities may use recommendations made in this paper until the South African National Roads Agency's Management System for Road Markings is in place.

### 5.1 Conclusions

The following conclusions are made:

- Although thermoplastic material is initially three to four times more expensive than ordinary road marking paint, it was found to last up to five times longer than ordinary road marking paint.
- Another advantage of thermoplastics is that they can be applied on bituminous roads directly after construction.
- Thermoplastics are the only products that have a higher skid resistance factor than the road surface itself.
- Thermoplastics have a drying time of approximately two minutes, which is much quicker than the fifteen minutes of ordinary road marking paint.
- Ordinary road marking paint is by far the most common product used in South Africa. Correctly applied, it will last for 18 to 24 months.
- Ordinary road marking paint does not react well to the volatiles in newly constructed bituminous roads.
- Non-skid paints are not cost effective and do not perform as a non-skid material as their skid resistance is still lower than that of the road.
- Preformed road marking tapes and adhesive tape markings are very expensive and rarely used in South Africa.

### 5.2 RECOMMENDATIONS

The following recommendations are made:

- Use thermoplastic materials on newly constructed roads rather than ordinary road marking paints.
- Use thermoplastic materials, if the budget allows for it, for maintenance of road markings rather than ordinary road marking paints.
- If ordinary road marking paint is used on newly constructed bituminous roads it must be painted at least three months after construction or, if painted immediately after construction, it must be repainted before the maintenance period expires.
- In addition of controlling the end product as described in SABS 731-1 the application rates of paint and glass beads must be strictly controlled.
- On newly constructed roads the controlling person must do quality control on the road marking process.
- It is worthwhile to control the application rate on maintenance painting as well.
- If ordinary road marking paint is used, the line should be repainted every 18 to 24 months.
- Although the time-envelope for repainting of ordinary solvent-borne is 18 to 24 months, no line must be left unpainted for more than three years.



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## ANNEXURE A

### DISCUSSION OF DATA OBTAINED FROM TEST SITES.

Data obtained during the study at the various test sites will be discussed briefly. Retroreflectivity measurements were conducted using a retro reflector apparatus supplied by National Highway Markings. Test sites next to existing CTO (Comprehensive Traffic Observations) stations were pointed out by the Department of Transport.

#### 1 Test site 1

Location: N 12, Comores, Northbound next to CTO Station No 134.  
Annual av daily traffic: No data found.  
Product: Thermoplastic, white and yellow line.  
Measurement: 10 measurements on the line next to the station were taken. The average and standard deviation of these measurements in mini candelas/m<sup>2</sup> /lux are indicated in Table 1

Table 1 Retro reflectivity of test site 1.

Yellow line:

Date:	94/09/06	94/09/13	94/11/21
Avg.:	153.6	161.3	150.2
Std dev:	9.6	10.9	9.6

White line:

Date:	94/09/06	94/09/13	94/11/21
Avg.:	259.5	269.4	263.4
Std dev:	11.5	8.3	9.7

Discussion: This site was used to determine the influence of traffic on newly painted thermoplastic. An assumption was made that the retro reflectivity of thermoplastic increases slightly in the first month after implementation. This test section indicated that traffic has a polishing affect on thermoplastic. At the time of the experiments this was the only site where thermoplastic was newly applied.

#### 2 Test site 2

Location: N 3/6, Van Reenen next to CTO Station No 003.  
Annual av daily traffic: 7 500.  
Product: Road marking paint, yellow line.  
Measurement: 10 measurements next to the station were taken. The average and standard deviation of these measurements in mcd/m<sup>2</sup>/lx are indicated in Table 2.

Table 2 Retro reflectivity of test site 2.

Yellow line:

Date:	93/04	94/09/01	94/11/18	95/07/24	95/11/21
Avg.:	Fresh application	104	87.5	74.0	79.3
Std dev:	Fresh application	12.6	10.3	10.3	16

Discussion: This line was painted in April 1993 according to the Natal Roads Department. In September 1994, seventeen months after application of the line, it was below the acceptable levels for old materials (100 mcd/m<sup>2</sup>/lx) according to SARTSM. Another two months later the line appeared to have deteriorated rapidly. The high standard deviation of the last measurements is an indication of the poor reliability of these measurements. At this stage of the experiment there was not much of the original line left. The line was practically destroyed. This line should have been repainted approximately 18 months after the previous application.

3 Test site 3

Location: N 3 section 5, Heavytree next to CTO Station No-s 604 and 601.  
 Annual av daily traffic: 9 800.  
 Product: Road marking paint, yellow line.  
 Measurement: 10 measurements next to the station were taken. Unfortunately this information was rendered useless due to a fog spray that was applied after the first measurements.

4 Test site 4

Location: N 3 section 1, Mariannahill next to CTO Station No 377.  
 Annual av daily traffic: 22 500.  
 Product: Road marking paint, yellow line  
 Measurement: 10 measurements next to the station were taken. Unfortunately this information was rendered useless due to rubber on the yellow line that was caused by slow-moving heavy vehicles accelerating from the toll plaza during the experiment.

5 Test site 5

Location: N 2 section 26, Tongaat Plaza next to CTO Station No 467.  
 Annual average daily traffic: 8 500.  
 Product: Road marking paint, yellow line  
 Measurement: 10 measurements next to the station were taken. The average and standard deviation of these measurements in mcd/m<sup>2</sup>/lx are indicated in Table3

Table 3 Retro reflectivity of test site 5.

Yellow line:

Date:	94/02	94/09/01	94/11/18	95/07/24	95/11/21
Avg.:	Fresh application	174.9	171.3	138.9	109.3
Std dev:	Fresh application	10.4	16.6	24.3	7.8

Discussion: This line was painted in February 1994 according to the Natal Roads Department. In November 1995, 21 months after application of the line, there were still acceptable levels for newly applied materials (100) according to SARTSM. Three months later (February 1996) the line was inspected visually and was due for a repainting to the opinion of the first author. At this stage of the experiment there was not much of the original line left. The line was practically destroyed. This line should have been repainted approximately 24 months after the previous application.

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## Curriculum Vitae

Name of firm : Windhoek Consulting Engineers  
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## Key Experience

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Riaan de Witt joined the Department of Transport (RSA) in the Maintenance Management Systems Division after obtaining his B Eng. Degree; at which time he also enrolled for B Eng. (Hons). He completed his Honours Degree in 1994.

In 1994 he joined the Transvaal Regional Office where he assisted the Regional Engineer in transportation engineering and construction related projects.

He was appointed as Resident Engineer at the end of 1995 on a 130 km (11 bridges) construction project, responsible for all construction supervision.

In September 1996 he joined Windhoek Consulting Engineers and was appointed as Assistant Resident Engineer on the construction of the Ogongo-Oshakati concrete canal.

In January 1997 he was appointed as Resident Engineer on the Asphalt Rehabilitation of the 120 km bituminous surfaced road between Otjiwarongo and Otavi.

In June 1998 he was transferred to Eenhana as Resident Engineer for the Construction of the 73 km Main Road 110 between Onuno and Elundu. He completed his Master's Degree in Transportation Engineering in 1999.

In January 2000 he joined the Windhoek office as Engineer in the Transportation Division. He is responsible for various design projects as well as contract management.