FOR SAFETY'S SAKE, LET'S DO ROAD MARKING QUALITY CONTROL

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1. INTRODUCTION

1.1 Road Markings

Road markings are generally used on all surfaced South African roads and streets except the lowest order residential streets. Drivers have become so accustomed to road markings that they tend to react to these without really thinking. This may be because road markings are the only road signs that are virtually in constant view of the driver. If the driver of a vehicle doesn't look directly at the road markings they still remain in his peripheral vision whenever he ventures on the road. Under favourable conditions road markings can therefore convey information to the driver on a continuous basis by day and by night.

The unfortunate truth is that the conditions under which road markings need to be viewed are very often far from favourable. This can be the result of an unfavourable position of the sun relative to the marking or the driver, the condition of the road marking itself, the condition of the vehicle's headlights and the effect of approaching vehicles, to name but a few.

1.2 The Road Collision Picture

During 1998 a total of 511605 collisions had been reported and included in the official South African statistics.[1] This included 4270 fatal collisions in cities and towns and 2990 fatal collisions in other areas (say rural). Casualties during this period numbered 129672 of which 4888 fatalities occurred in cities and towns and 4180 fatalities in other areas. The number of casualties on South African roads and streets during 1998 nevertheless, was markedly lower than previous years and was of a similar magnitude as the number recorded in 1993.

The typical pattern of road accidents was retained from that of the previous years. 53% (3840) of all fatal collisions occurred at night. 363 rural fatal collisions were the result of lane changing, overtaking or swerving. 238 fatal head on collisions occurred outside cities and towns killing 626 people. A very disturbing statistic is the fact that some 92% (2761) of all fatal collisions in rural areas occurred on general road sections other than at intersections or at points of control.[2] In these collisions a total of 3852 people had been killed.[3] All in all the total cost of collisions were estimated to amount to R13 446million during the year[4], or an incredible amount of R 36,8million per day!

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1 Statistics South Africa, Road traffic collisions, 1998, Pretoria, (Statistics SA Report; No.71-61-01(1998))
2 *op.cit*….Table 31.
3 *op. cit.* Table 66.
4 AA Road Traffic Safety Foundation, Annual Traffic Safety Audit, 1998

This paper does not intend to show any specific relationship between these collision statistics and the quality (or lack of quality) of road markings. It merely suggests that improved road markings potentially have a meaningful influence on the behaviour of the driver and that they might influence the extent and degree of the type of collisions for which the statistics have been quoted above.

1.3 Objective

The objectives of this paper are to give an overview of road marking practice in South Africa and to indicate why a fundamental change in attitude towards road markings should take place. The paper also serves to introduce the changes that had already been initiated by two road authorities and the implications that this revised approach to road markings will have on the road marking industry.

2 ROAD MARKINGS IN PRACTICE

2.1 Extent of Road Markings

A review of the maintenance management systems for certain of the provincial road authorities in South Africa confirmed that the length of road markings to be maintained is not kept up to date. It is therefore not that simple to estimate the length of road markings in South Africa with any real confidence. One way is to extrapolate from the total length of roadway in the country. Edge lines on single carriageway roads means that a minimum of 2,3 km of road markings is applied per kilometre of roadway. On dual carriageway roads this ratio increases to 4,3 km of road markings per kilometre of road.

Another way to estimate the extent of road markings is to assess the market for the application of road markings. A conservative estimate would indicate that some R40million is spent annually on the painting and re-painting of roads and streets. If the re-painting cycle and the state of the maintenance of road markings were taken into account, an order of magnitude guesstimate for the replacement value of all road markings in the country would amount to at least R100million.

Irrespective of the way that one looks at road markings, the investment amounts to a significant value. The loss to the economy as a direct result of inferior materials and workmanship is similarly significant.

Based on before and after studies over a period of more than twenty years in the USA, it has been estimated that improved road markings and delineation can account for a reduction of some 13% in fatalities[5]. In other studies the potential benefit/cost ratio for improving road markings had been estimated at 16:1. If one, therefore, assesses the effect of inferior road markings on the safety of the road user and considers the potential consequential losses as a result of the failure of road markings, the implications become huge and the potential benefits of improved road markings highly attractive.

2.2 Function of Road Markings

The handling of a vehicle is often called a control task. One therefore refers to the control of the lengthwise and the crosswise position of the vehicle. To follow the geometry of the road and to avoid collisions with other vehicles drivers must see and understand their future paths and the surroundings. The driver must therefore clearly recognise the following:

- The position of his vehicle in relation to roadway features along the road,
- The position of his vehicle relative to cross sectional features,

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[5] FHWA, Office of Highway Safety, The 1994 Annual Report on Highway Safety Improvement Programs, May 1994, Washington D.C. Table IV-5

- The position of his vehicle relative to other roadway users.

The visual requirements of these seemingly simple tasks are rather simple as well. The clarity of important geometric features greatly influences the perception time of the driver and assists in the sorting out of information. In critical situations the roadway might, unfortunately, not provide sufficiently strong stimuli and might even provide confusing stimuli. Consequently, the driver could benefit significantly if his task of "reading" the information given to him, could be assisted in a standardised format. Road markings provide a consistent way of supporting the driver in his information interpretation task.

The functions thus performed by road markings include assisting the driver with:

- Selection of a route (e.g. route numbers painted on the road)
- Selection of specific manoeuvres (e.g. directional arrows)
- Control of specific manoeuvres like overtaking (e.g. no-overtaking lines)
- Selection and control of elementary manoeuvres like the lateral positioning within a lane (e.g. edge and lane lines)

All of these functions can easily be performed by road markings provided the driver can see them. The visibility of road markings depends primarily on the contrast between the markings and the adjacent portions of the road surface. Because markings are applied directly on the road surface, one can accept that the illumination of the marking and the surface is identical. Visual contrast is therefore determined by the difference in the optical properties of the marking and the surface. These properties are characteristic of the road marking materials used and the condition of the road markings themselves.

2.3 Road Marking Materials

An extensive overview of road marking materials has been included in the latest edition of the South African Road Traffic Signs Manual[6].

A number of different road marking products are available in South Africa. Most of the road markings used in the South African road marking industry in the past had been solvent based paint which were applied using high pressure spray paint systems. These markings are particularly thin (averaging ± 300µm dry thickness). Combined with the brittleness of the paint they are particularly susceptible to chipping off from a coarse road surface, thus exposing the road surface itself. Hot spray-on thermoplastic material had sometimes been used on high traffic volume roads where the more traditionally road markings were considered to be unable to show the required resilience. Due to the ever-increasing traffic volumes a marked move towards the increased utilisation of thermoplastic has been identified. Thermoplastic material can be sprayed to a thickness of some 1,4mm providing a significantly more durable marking.

Road marking paint *per se* is not very visible under nighttime conditions. Small glass beads are added to the paint to provide improved nighttime visibility; generally by means of a sprayed-on application. The formulation of the thermoplastic materials provides for some 20% by mass glass beads to be mixed into the rest of the components. The quality and size of glass beads play an important role in providing nighttime visibility.

A major problem in marking roads is to ensure adequate visibility of road markings when the road is wet. With a layer of water covering road markings, light is mainly reflected at the outer surface of the water. The retroreflection characteristics of the glass beads are impaired with the result that markings are practically invisible. This may be improved by using thermoplastic (thicker lines) or larger beads.

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6 South African Road Traffic Signs Manual. 1999, Department of Transport, Volume 2, Chapter 18)

3 LEGAL BASIS

3.1 National Road Traffic Act, 1996

The National Road Traffic Act, 1996, and the National Road Traffic Regulations, 2000, prescribe the display of road traffic signs (including road markings). Both these pieces of legislation stop short from prescribing what will be constituted as *acceptable* road markings. The fact that the Regulations require road traffic signs to be manufactured in reasonable compliance with the SA Road Traffic Signs Manual (SARTSM) provide the SARTSM with a degree of legal standing.

3.2 South African Road Traffic Signs Manual

Discussion of the different road traffic signs and markings in the SARTSM is structured to firstly give the legal significance of each particular sign or marking. It then proceeds to describe typical applications and guidelines for the use of that particular sign. The SARTSM also stops short of establishing what *acceptable* road markings would be. Under a general discussion of road markings and under explicit proviso that it does not have legal standing, guidelines are given on possible levels of retroreflection for new road markings and for possible minimum levels prior to repainting. As far as the author could ascertain, these threshold levels had never been incorporated in any specifications for the application of road markings under any contract in South Africa prior to the initiatives that are being reported in this paper.

4 CURRENT SOUTH AFRICAN ROAD MARKING PRACTICE

4.1 SABS Standard

Road marking paint used to be specified based on SABS Standard 731. This standard was, however, completely revised and a *new* standard published in 1995. The latter standard, SABS 731 Part 1[7]:, no longer is a road marking paint standard, but is a road marking standard. Although this seems to be a small difference, in practice this means a major deviation from the previous standard.

SABS 731-1 now also contains traffic wear requirements. The traffic wear index is a requirement that estimates the extent to which the road marking has been worn away. It gives an indication of the daytime visibility of the road marking and is based on an assessment of the remaining paint cover on a specific surface area. After the application of a rating and weighting procedure, the tester is left with an aggregate value called the Traffic Wear Index. The larger the index, the greater the degree of wear.
This test method is based on a procedure in use in the United Kingdom and is more fully described in SABS Method 1248.

The nighttime visibility is measured directly by means of a portable field retro-reflectometer. The test is fully described in SABS Method 1261: 1999 and measures the Co-efficient of Retro-reflectance (R_{L30m}) (as the ratio of the retro-reflected light (that which reaches the driver's eye) to the light falling on to unit area of road marking using a standard illuminant. The measurement is made in millicandelas per lux per square metre (*mcd/lx/m*^{2}). The values so measured are particularly sensitive for different angles of incident and reflected light. Worldwide standardisation has been achieved to measure in accordance with the so-called 30m-geometry.

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[7] SA Bureau of Standards, SABS 731-1, *Road and Runway markings* Part 1: *Single-pack solvent borne and waterborne paints,* 1995

The 30m geometry means that the angles for the test set-up have been calculated based on a system where the road marking will be illuminated at a spot 30m in advance of vehicle headlights set at 0,65m above the road. The position of the eyes is 1,2m above the roadway. Retroreflectometers measuring at a different set of angles may be used to estimate the Co-efficient of Retroreflectance (30m) through the application of a conversion formula. The spread around the actual R_{L30m} is dependent upon the retroreflectometer used and may be significant.

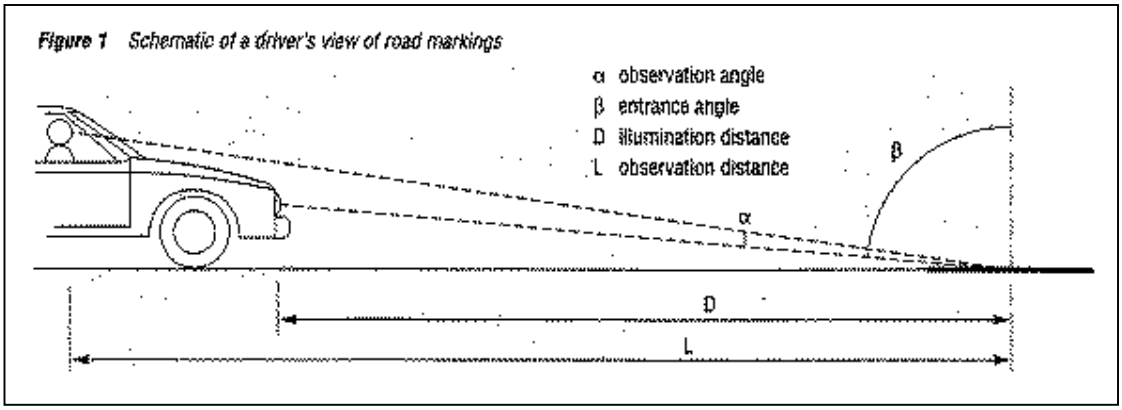

Figure 1 Schematic of a driver's view of road markings

4.2 Project Specifications for Road Markings

The standard specifications in use for road markings on rural roads in South Africa are contained in the COLTO Standard Specifications[8]. The application of road markings on a particular contract is determined by the project specifications which are prepared to allow for specific conditions encountered on that particular project.

The COLTO specifications are basically all written in a recipe-type style and call for paint to comply with SABS 731-1. The application rate is specified at a nominal rate of 0,42l/m^2 which provides for a dry thickness of some 300µm. Glass beads have to be added to the lines at a rate of 0,8kg/l paint (or some 0,34kg/ m^2 road marking).

Numerous requirements pertaining to the application of the markings are set to ensure the acceptability of the road markings. These include requirements on the equipment used for the application process as well as dimensional tolerances on the road markings themselves.

The COLTO specifications refer to the possible use of hot melt thermoplastic as a possible road marking material, subject to its specification in the project specifications. No further guidance or specifications for this material is given.

The section on quality control in the COLTO specifications includes several quality control methodologies for use in the road and bridge construction process, including quite extensive description on the tests to be performed on geotextiles. **No reference whatsoever is given to the control of road markings.** This may be one of the reasons why the current level of road marking quality control in South Africa leaves much to be desired.

4.3 Quality Control

The aspects that, in theory, can be readily monitored are the application rates of paint and glass beads as well as the conformance of the markings with the dimensional tolerances – virtually all part of the existing recipe-type specification. The unfortunate aspect of this system is the fact that it requires the road-marking inspector to be on-site whenever new road markings are being applied. Should he not be there the only aspect that can be readily confirmed afterwards is the compliance

[8] COLTO, Standard specifications for road and bridge works for state road authorities, 1998.

with the dimensional tolerances. This problem is compounded by the fact that the larger part of road markings being applied on our roads is being done as a routine road maintenance action. Very often the quality control is left to fairly junior or inexperienced personnel or is restricted only on the correctness of invoices submitted for payment!

Experience has shown that it is very easy for the road painter to deviate from the prescribed road marking procedures. Typical malpractices that might occur include the under-application of paint and glass beads, the non-uniform application of the beads, the thinning of paint prior to application, non-compliance with the width and length requirements of the markings and even the use of sub-standard paints and beads.

All of these aspects have an influence on the durability and the visibility of the markings. These in turn have a direct effect on the proper information transfer to the motorist. If this information transfer process fails, the exposure of the motorist to increased risk also increases significantly.

To do proper quality control of road markings on-site, it is essential that the organisation letting a contract do quality control on what is included in the project specifications. This in turn requires that the specifying organisation stays abreast of developments and acquires the necessary knowledge to properly specify road markings and relevant quality control processes.

5 SHORTCOMINGS

5.1 Specifications

The COLTO specifications were written in a recipe type format. If one considers the needs and requirements of the driver and compares this to the specifications, it is clear that the specifications do not address the problems directly. They approach the actual problem very much in an indirect way; we expect durability — and therefore the quantity of paint to be applied is specified; we want good night-time visibility — and therefore the application rate of the glass beads is specified.

Because we do not know what the effect of varying surface textures are on the durability of road markings this aspect is ignored and only a *nominal* paint application rate specified. The same occurs for the application rate for glass beads. Furthermore, because everybody is concerned about the cost of road markings, the contractor is not told what the life expectancy of the road marking ought to be. In reality we seldomly, if ever, really tell the contractor what we objectively expect of the road markings!

The COLTO specifications also do not take into account the most significant changes that had been introduced in the revised SABS 731 standard. In particular no performance requirements are set for the initial retroreflection of the markings, nor for the terminal values of retroreflection and the traffic wear index, nor for the skid resistance of the markings.

These aspects are also very seldomly included in the project specifications.

5.2 Quality Control

If the specifications for road markings are found to be lacking, so too, are the requirements for the quality control of these markings. It is left to the resident engineer to determine the application rate for the road marking paint. This is sometimes done through checking that 4762 meters of 100mm wide line are painted with a full drum of paint. The effect of paint build-up in the tank is not taken into account. In a similar way it can be checked that during the same period 160kg of beads have been used. It is only possible to assess the variation in the application of the paint and the beads over the entire section. The variability in the application cannot be established at any specific point. It is also extremely difficult to inspect a line and estimate the bead content or the paint application

rate based on the visual appearance thereof. This means that if the quality controller had not been present at the actual time of application, there is very little chance of establishing the quality of newly applied road markings. It is even more difficult (read *downright impossible*) to establish the acceptability of that same marking three or six or twelve months later because on the one hand, *nothing had been specified* and on the other, *no methodology had been set to determine the acceptability*. This regularly leads to confrontation because the contractor was left to guess what the intention of the specification writer had been.

As indicated above these problems are compounded even more when one considers the maintenance characteristics of road marking. Under these conditions the quality of the road markings provided to a road authority depends largely upon the honesty of the operator of the road marking machine and that of his superiors.

The unfortunate truth is that none of the reasons why road markings are applied to the road is assessed directly for compliance.

6 INTERNATIONAL ROAD MARKING PRACTICE

6.1 Road Marking Materials

In first world countries extensive use is made of durable road marking materials. Such markings not only means hot spray thermoplastic as used in South Africa, but also include two component cold plastic or epoxy material, pre-formed road marking tape and more durable water-based paints. Due to the influence of the Environmental Protection Agency in the United States the use of solvent based road marking paints have been virtually stopped and replaced by more environmentally friendly materials.

Technology to spray thermoplastic at very low application rates (0,4 – 0,6mm) has been developed and is being used to mark roads with lower traffic volumes. The durability of this material coupled with the low traffic volumes provides markings that last maintenance-free for a long time. Various developments with ordinary spray application thermoplastics have also been developed. These include the application of thermoplastic in a slight depression formed in asphalt to ensure that the road marking does not stand proud of the surface. In this way the markings are not damaged when snow ploughing is done. Specially ribbed thermoplastic markings are being used increasingly for edge lines. These markings have a rumble effect when driven over and also stand proud of a sheet of water, thus providing improved wet line visibility. None of these developments have been implemented in South Africa yet.

Normally two component epoxy materials are very costly. They are therefore only suitable for high traffic volume roads. For this reason such road marking material found particular application on some European major roadways. Attempts had been made to introduce it in South Africa. Although short test sections had been laid, the introduction to date had not been successful.

Pre-formed tape is widely used in the United States, especially in an urban environment. The cost thereof in the South African context proved to be extremely high. Various grades of tape are available. These range from a temporary application to be used at construction sites, to a product available for transverse applications like Stop lines, to a high performance marking with guaranteed retention of retroreflective properties. The latter product contains highly reflective ceramic beads allowing longer warranty periods.

This had been used for pre-cut symbols on the Pretoria Eastern Bypass where a fast lane lane-drop required extraordinary measures to improve the long-term safety of road users. Because of the particular raised pattern of the material it stands slightly proud of the water surface under wet conditions. The same product was also used at the V&A Waterfront in Cape Town at pedestrian crossings.

One product that might find its way into South Africa in the near future, is the use of water-based paint. The technology had been developed to such a level that the paint now seriously competes with solvent-based paints. Paint drying-time as well as the glass bead retention over time have been addressed and proved to be highly competitive.

6.2 Quality Control Principles

A number of different quality control principles are in use in different parts of the world. These are either based on the input side or on the output side of the road marking process.

Input side quality control refers to procedures directed towards the components of the markings and the control of the application process. These processes encompass the methodologies that had been available in South Africa for a long time. They also include certain aspects that have not been regularly used in the past.

Road marking machines can be rigged with an additional wheel running on the road surface. This wheel co-ordinates the quantity of paint pumped with the road speed of the machine. One application of this technology required separate wheels controlling the individual spray nozzles with supplying pumps per nozzle. This proved to be particularly expensive and prone to repeated breakdown. The system was proposed in South Africa a long time ago but were met with rejection because of the cost thereof and the fact that it does not suit all spraying systems.

A second method to improve control of the application rate is the use of an electronic flow meter reading the flow of the paint through the delivery hoses. This is co-ordinated with sensors picking up the road speed. The application rate is displayed on a display unit on the machine. As soon as the application rate deviates from the pre-set rate by a particular margin a buzzer sounds to caution the operator of the situation developing. For unknown reasons this system has not been introduced in South Africa.

Output side control refers to procedures directed towards the assessment of the quality of the road marking as applied to the road surface. A deliberate and extensive move is underway in various countries to determine functional criteria to which road markings have to comply. The extent and the methodology differ from country to country. The basic principles are the same, however. The road authority determines and prescribes a minimum functional performance with which the markings have to comply. The contractor either paints to such a new specification and allows the markings to deteriorate to a pre-set minimum threshold level after a period of time, or the contractor brings the markings to a prescribed functional level and retain it at that level for the period of the contract. The quality control process is determined by the functional requirements to which the markings have to comply.

These normally include the nighttime visibility, daytime visibility and/or contrast with the immediately surrounding surface and the durability of the markings. In urban areas with extensive pedestrian movement, the need to control the skid resistance of the markings is also emphasised.

7 PROPOSED FUNCTIONAL PERFORMANCE SPECIFICATIONS

7.1 Proposed Basis for Specification

The Provincial road authorities in South Africa maintain the road markings on roads under their jurisdiction by means of general period contracts whereby private contractors paint the roads when directed so by the authority. As indicated above the quality of these road markings are often the subject of lengthy arguments. The Mpumalanga Chief Directorate: Roads and AFRICON over a lengthy period discussed the problems experienced and ways and means to improve the quality and durability of road markings.

A Functional Performance Specification was developed to transfer the nighttime visibility and durability requirements from SABS 731-1 to a project specification for use in the Mpumalanga period contract for road markings. The specification adopted the *new* and *one year* requirements and introduced an *18-month* requirement for all road markings to be applied during remarking on Mpumalanga roads. Because new bituminous surfaces are particularly aggressive to solvent based road-marking materials the same durability requirements could not be introduced for road markings on newly laid surfaces. Certain amendments were therefore made to accommodate these problems. A methodology to provide for differences in road surface texture and traffic conditions on the road was also developed.

The SA National Roads Agency was experiencing similar problems. After discussions the Northern Region adopted the same principles for application on national roads under their jurisdiction. The first contracts based on this Functional Performance Specification for road markings were let during the first quarter of 2001.

7.2 Implications for Road Marking Applications

The revised project specifications have significant implications for the road marking industry as a whole. Under this specification the road authority no longer prescribes to the contractor which marking material has to be used, nor the application rate. In this specification the threshold values for the functional performance of the road marking are specified for the *new*, *9-month* and *18-month* conditions. The payment structure provides for payment to be done in instalments subject to the compliance by the markings with the set thresholds and for penalties, should the markings not comply.

The onus is now on the contractor, who is considered to be an expert in his field, to use appropriate materials and at appropriate application rates to be able to guarantee the successful performance of the markings for a period of at least 18 months. Where paint manufacturers had been pressured in the past to develop least cost products, the pressure is now on to develop materials which will last a longer period. The opportunity now exists for the contractor to scan international developments and to introduce leading edge materials into this country when it might prove economical.

In short, a significant part of the risk that the road authority had to carry as a result of potentially sub-standard or marginal work, has now been transferred to the only party that can ensure that consistently good standards are achieved — the contractor. This increase in risk acceptance also means that the road-marking contractor would require remuneration commensurate with the risks taken. From a road authority viewpoint this should be offset against the reduced risk of sub-standard workmanship, which road authorities had to accept for a long time.

7.3 Implications for Quality Control

As part of the development of SABS 731: 1995 standard methods for the measurement of the retro-reflective properties of road markings and of the determination of the deterioration of road markings were developed.

Both these test methods have now been incorporated as quality control measures into the Functional Performance Specification. Both methods provide for the objective determination of road marking properties. They therefore offer a prime opportunity for the collection of data from various sources to improve our understanding of the deterioration characteristics of different road marking materials under different usage scenarios.

A better understanding of the product that we are working with will lead to a better understanding of the shortcomings of that product under particular conditions. This in turn could spark a clear brief for the development or introduction of specific products that would improve the performance under particular conditions, which, in turn, will lead to the improved meeting of road user needs!

8 THE WAY FORWARD

Two road authorities realised that the ever-increasing spiral of providing road markings at lower prices under increased price competition does not lead to better road markings. These road authorities realised that the current approach towards the specification and quality control of road markings were not conducive to any improvement of the service being rendered to the road user and that something deliberately different needed to be done.

These two road authorities made a paradigm shift. It is high time that others follow suit — for safety's sake.