

SIGNFACE MATERIALS

SECTIONS

- 17.0 Contents
- 17.1 Introduction
- 17.2 Principles of Retrorefection
- 17.3 Factor Affecting Visual Effectiveness of Road Signs
- 17.4 Specification SANS 1519: Road Signs
- 17.5 Replacement Criteria for Signface Materials
- 17.6 Durability and Economics
- 17.7 Practical Considerations
- 17.8 Sign Fabrication
- 17.9 Handling, Stockpiling and Installation
- 17.10 References
- 17.11 Retroreflectivity – Literature Review
- 17.12 Literature Study

MAY 2012



SARTSM – VOL 2

CHAPTER

17

TITLE SOUTH AFRICAN ROAD TRAFFIC SIGNS MANUAL Volume 2 Chapter 17			
ISBN	STATUS Digitised Version	DOT FILE 000/0/0/0	DATE Digitised May 2012
DIGITISING CARRIED OUT BY Transport and Traffic Technology Africa (Pty) Ltd P O Box 1109 SUNNINGHILL 2157			
COMMISSIONED BY Department of Transport Private Bag X193 PRETORIA 0001			
ORIGINAL AUTHOR J J Prinsloo		PUBLISHER ENQUIRIES Director-General: Transport Private Bag X193 PRETORIA 0001	
It is impossible for a publication of this nature to free of errors. It would be appreciated if errors be brought to the notice of - Director-General: Transport Department of Transport Infrastructure Network Management Private Bag X193 PRETORIA 0001			
COPYRIGHT This publication is protected by copyright under the Bern Convention. In terms of the Copyright Act No. 98 of 1978, no part of this publication may be produced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording or by any information storage or retrieval system, without permission in writing from the publisher. © National Department of Transport 1999, 2012			
KEYWORDS ROAD SIGN, ROAD MARKING, REGULATORY, WARNING			
COST: VOLUME 2			
VOLUME SET		R	
Chapter 1	R	Chapter 11	R
Chapter 2	R	Chapter 12	R
Chapter 3	R	Chapter 13	R
Chapter 4	R	Chapter 14	R
Chapter 5	R	Chapter 15	R
Chapter 6	R	Chapter 16	R
Chapter 7	R	Chapter 17	R
Chapter 8	R	Chapter 18	R
Chapter 9	R	Chapter 19	R
Chapter 10	R		

CHAPTER 17: SIGNFACE MATERIALS

CONTENTS

17.0.1 Sections and Subsections

Number	Title	Page No.
17.0	CONTENTS	17.0.1
17.0.1	Sections and Subsections	17.0.1
17.0.2	Figures	17.0.2
17.0.3	Tables	17.0.2
17.1	INTRODUCTION	17.1.1
17.1.1	General	17.1.1
17.2	PRINCIPLES OF RETROREFLECTION	17.2.1
17.2.1	General	17.2.1
17.3	FACTORS THAT AFFECT VISUAL EFFECTIVENESS OF ROAD SIGNS	17.3.1
17.3.1	General	17.3.1
17.3.2	Driver Factors	17.3.1
17.3.3	Sign Factors	17.3.1
17.3.4	Vehicle Factors	17.3.1
17.3.5	Roadway Factors	17.3.1
17.3.6	Environmental Factors	17.3.1
17.3.7	Principle Factors	17.3.1
17.3.8	Driver Visibility Needs	17.3.2
17.3.9	Brightness	17.3.2
17.3.10	Contrast	17.3.2
17.3.11	Conspicuity	17.3.3
17.3.12	Legibility	17.3.3
17.4	SPECIFICATION SANS 1519 – ROAD SIGNS	17.4.1
17.4.1	General	17.4.1
17.5	REPLACEMENT CRITERIA FOR SIGNFACE MATERIALS	17.5.1
17.5.1	General	17.5.1
17.5.2	Retroreflective Sheeting	17.5.1
17.5.3	Recommended Criteria	17.5.1
17.6	DURABILITY AND ECONOMICS	17.6.1
17.6.1	General	17.6.1
17.7	PRACTICAL CONSIDERATIONS	17.7.1
17.7.1	General	17.7.1
17.8	SIGN FABRICATION	17.8.1
17.8.1	Application of Sheeting for Substrates	17.8.1
17.8.2	Application of Legend	17.8.1
17.9	HANDLING, STOCKPILING AND INSTALLATION	17.9.1
17.9.1	Handling and Stockpiling	17.9.1
17.9.2	Sign Installation	17.9.1

Number	Title	Page No
17.10	REFERENCES	17.10.1
17.10.1	General	17.10.1
17.11	RETROREFLECTION – LITERATURE REVIEW	17.11.1
17.11.1	General	17.11.1
17.11.2	Principles of Retroreflection	17.11.1
17.11.3	Types of Retroreflective Sheeting	17.11.1
17.11.4	Properties of retroreflective Sheeting	17.11.1
17.12	LITERATURE REVIEW	17.12.1
17.12.1	General	17.12.1
17.12.2	Night-time Visibility of Retroreflective Road Signs	17.12.1
17.12.3	Durability of Road Signs with Regard to Retroreflectivity	17.12.3

17.0.2 Figures

Figure No.	Title	Page No.
Fig 17.1	Principles of Retroreflection	17.2.4
Fig 17.2	Chromaticity Chart: Boundaries for daylight Surface Colours	17.4.5
Fig 17.3	Proposed Boundaries for Red, Yellow, Green and Blue	17.4.6
Fig 17.4	Sections Through Types of Retroreflective Sheeting	17.11.7
Fig 17.5	Entrance and Observation Angles	17.11.8
Fig 17.6	Luminance of Road Signs as a Function of the Distance from the Sign	17.12.2

17.0.3 Tables

Table 17.1	Comparison of the Visual Acuities of UK, US and SA Drivers	17.3.3
Table 17.2	Minimum Coefficients of retroreflection for New Signface Materials of Different Colours (Specifications SANS 1519-1:2006 and SANS 1519-2:2004)	17.4.1
Table 17.3	Chromaticity Coordinates for Daylight Colours of New Signs	17.4.2
Table 17.4	Chromaticity Coordinates for Daylight Colours of Weathered Signs	17.4.5
Table 17.5	Luminance Factor	17.4.5
Table 17.6	Guidance on Selection of Retroreflective Sheeting	17.5.2
Table 17.7	Guidelines on Minimum Acceptable Coefficients of Retroreflection and Colour Limits for the Replacement of Sign on Urban Roads	17.5.3
Table 17.8	Guidelines on Minimum Acceptable Coefficients of Retroreflection and Colour Limits for the Replacement of Sign on Rural Roads	17.5.4

CHAPTER 17: SIGNFACE MATERIALS

17.1 INTRODUCTION

17.1.1 General

- 1 Traffic signs are an essential component of streets and roads. They help motorists find their way in a safe manner by providing for the orderly and predictable movement of traffic. For signs to accomplish their needed purpose, they must be visible to the motorists. Although sign visibility is generally not a problem during daylight, signs with inadequate retroreflectivity may not be sufficiently visible at night and can contribute to accidents.
- 2 Road signs also have to be conspicuous and legible from a reasonable distance. To ensure good conspicuity and legibility there has to be a high colour and luminance contrast between, firstly, the sign and the background that it is viewed against (external contrast) and secondly, the sign legend or symbol and the background of the signface (internal contrast). To maintain a high colour and luminance contrast at night, signs have to be partly or fully reflective. New signs normally comply to these requirements but as time passes, colours and retroreflectivity deteriorate. This deterioration is not constant but is influenced by factors such as ultra-violet radiation, temperature, humidity and material characteristics.
- 3 While visibility can be accomplished through external illumination of the signs, retroreflection is the most commonly used means of making signs visible to the driver at night. Retroreflection is where light is reflected back towards its source. In the case of retroreflection from road signs, the source of light is commonly the headlights of vehicles during night-time.
- 4 Those responsible for designing, constructing and maintaining roads need to be familiar with the many aspects of sign retroreflection, of which some are:
 - (a) the types, specifications and properties of retroreflective materials for signs;
 - (b) retroreflective sheeting application guidelines;
 - (c) sign fabrication;
 - (d) handling, stockpiling and installation of retroreflective signs.
- 5 Better understanding of these aspects can ensure that motorists will be provided with adequate visibility of roadway signs for safe navigation. The purpose of this chapter is to explain relevant principles of sign retroreflection and to:
 - (a) give guidance on the selection of retroreflective sheeting for new signs;
 - (b) discuss the minimum retroreflective values and colour limits for replacement purposes;
 - (c) recommend retroreflective values for different road signs used in different circumstances.

It is intended to aid those who apply the specifications found in SANS 1519-1 and SANS 159-2.

- 6 Certain of the good practices and detailed information related to signing are not discussed in this chapter. Therefore, readers should be familiar with the key publications listed in Section 17.10.
- 7 This chapter concentrates on **materials for vertical road signs** whilst Volume 2, Chapter 18 deals with materials for horizontal road sign material

17.2 PRINCIPLES OF RETROREFLECTION

17.2.1 General

- 1 Retroreflection occurs when light rays strike a surface and are reflected back towards the source of light. Two principles followed to achieve retroreflectivity for road signs are prismatic and spherical lens retroreflection. Prismatic, also known as cube-corner retroreflection, is achieved through total internal reflection.
- 2 Incoming light hits the first surface and reflects to the rear surface, which reflects it to the last surface which then reflects the light rays back towards the light source. In the second type, spherical lens retroreflection is achieved through a combination of a glass sphere (bead) and a reflecting (mirror type) surface placed at the focal point. The incoming ray is refracted and directed inwards towards the back of the sphere, reflecting off the reflective surface, and after being refracted at the exterior of the sphere, redirected towards the light source. These two principles for achieving retroreflection are illustrated in Figure 17.1 and further described in Section 17.11. Three references (3, 8, 9) are suggested for thorough discussion of the principles of sign retroreflectivity (see Section 17.10).

- 3 Retroreflective sheeting consists of micro cube-corners or spheres enclosed in weather resistant, transparent plastic film. To reflect a colour, a pigment or dye is inserted into the film, or onto the reflecting surface.

There are three types of spherical lens (bead) retroreflective sheeting:

- (a) exposed glass bead;
 - (b) enclosed glass bead; and
 - (c) encapsulated glass bead (see Section 17.11 for more detail).
- 4 In the exposed lens sheeting the front half of the glass beads are exposed to the outside air. Because of the small size of the beads, a film of water can cover the beads when it rains and can greatly reduce the retroreflectivity of the beads. Hence, this type of sheeting is not recommended for traffic signs and is not included in specifications.
 - 5 Enclosed lens sheeting material consists of a layer of transparent plastic of appropriate colour in which glass beads are embedded. A metallic reflection shield is provided behind the plastic together with a layer of adhesive, and with a protective liner that is removed during sign fabrication. The plastic covering enables the sheeting to be equally bright under dry and wet weather conditions.
 - 6 With encapsulated lens sheeting the glass beads are protected by a transparent material that is supported slightly above the beads by a wall creating an air-filled compartment. The back of the beads are covered with a reflective surface. The resulting airspace in front of the beads enhances the quality of the retroreflection and this type of sheeting is therefore known as **high intensity** sheeting.
 - 7 One of the most important properties of retroreflective sheeting is the ability to return light that is commonly described by a variety of terms including brightness, retroreflectivity, luminance

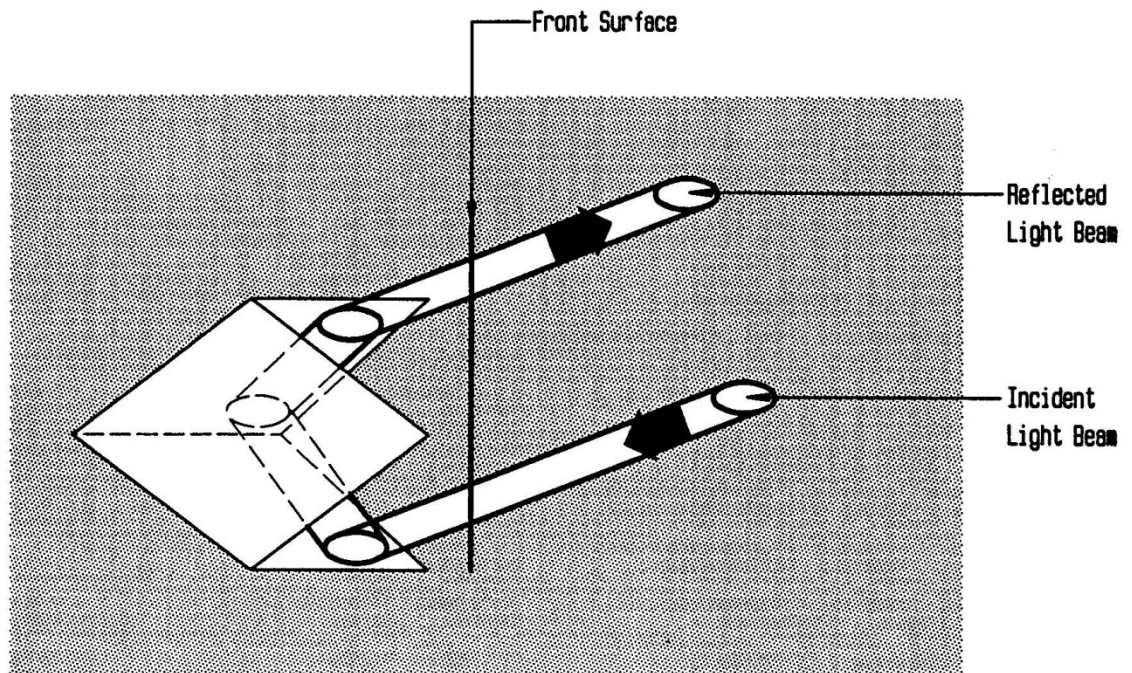
and candlepower. The International Commission of Illumination (CIE) uses the term **co-efficient of luminous intensity** which is defined as:

$$\text{ratio} = \frac{\text{Luminous intensity of reflector in the direction of observation}}{\text{Illumination at the retroreflector on a plane perpendicular to the light}}$$

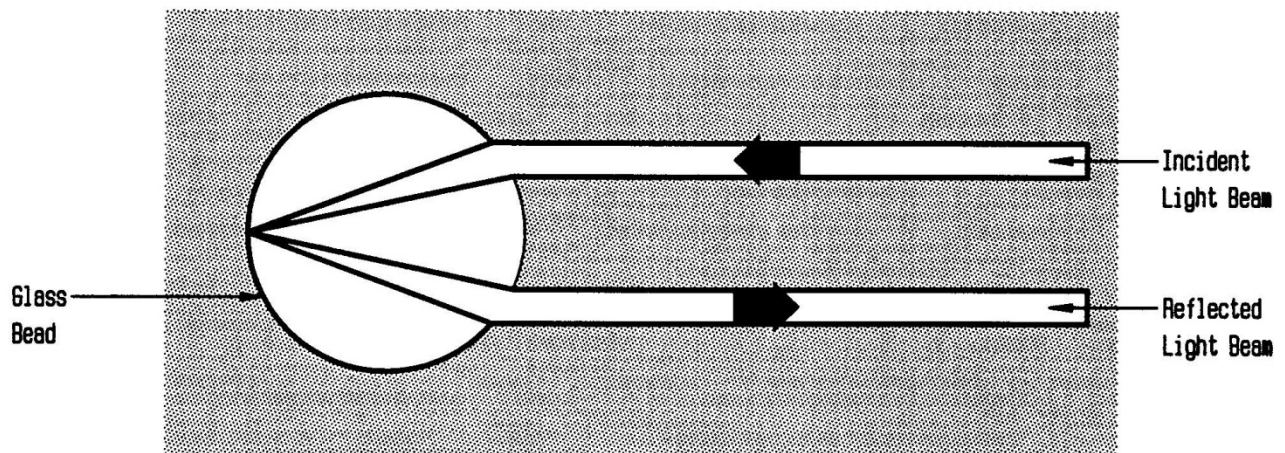
In the metric system, designated as the International System of Units (SI), the co-efficient of luminous intensity is expressed as candelas (cd) per lux (lx). **The co-efficient of luminous intensity is a measure of efficiency of the retroreflector because it describes the amount of luminance (candelas) that emerges from the retroreflector per amount of light (lux) entering from the light source, i.e.. the vehicle headlights.** This definition treats the retroreflector as a point source. Because signs have a relatively large area, they are treated as an extended light source which may be thought to consist of many point sources, each with a luminance intensity of one candela. The co-efficient of luminous intensity divided by the area is expressed in SI units as candelas per lux per square metre and identified as the **co-efficient of retroreflection, R**. This can also be described as specific intensity per unit area (SIA). The SIA designation will be used throughout this chapter.

- 8 The retroreflectivity of sheeting material is described in the context of another important property, namely its **angularity**, which is defined by the entrance (of the light) and the observation (of the motorist) angles (see Section 17.11). The entrance angle is the angle formed between a light beam striking the surface of a sign and a line emerging perpendicular to the surface. The observation angle is the angle between the incoming light beam and the reflected light beam, and is a function of the height of the driver's eye with respect to the vehicle headlamps. In SANS 1519 and other specifications, minimum specific intensity per unit area (SIA) are prescribed for each different type of sheeting for two observation angles, two entrance angles, and for different colours.
- 9 Retroreflective materials are supplied according to the CSRA Standard Specifications, in the following classes and should comply with the requirements of SANS 1519:
 - (a) Class I - Engineering grade retroreflective material (medium intensity sheeting); generally an enclosed lens glass bead material;
 - (b) Class II - Super-engineering grade retroreflective material; generally an enclosed glass bead or prismatic material;
 - (c) Class III - High intensity grade retroreflective material; generally an enclosed glass bead or prismatic material.

The durability of these materials is normally guaranteed for 7 years or 10 years.



Detail 17.1.1 Corner Cube Retroreflection



Detail 17.1.2 Spherical Lens Retroreflection

Fig 17.1

Principles of Retroreflection

17.3 FACTORS THAT AFFECT THE VISUAL EFFECTIVENESS OF ROAD SIGNS

17.3.1 General

1 There are a number of inter-related factors that affect the visual effectiveness of road signs. The relationship between these factors is complex since each factor, listed below, is in itself multi-faceted:

- (a) the driver;
- (b) the sign;
- (c) the vehicle;
- (d) the roadway; and
- (e) the environment.

17.3.2 Driver Factors

- 1 Visual acuity - is the ability of a driver to resolve small detail and primarily affects the legibility of a sign. Visual acuity is reduced by old age of the driver and at low luminance values.
- 2 Colour vision - is the driver's ability to discriminate between colours. Approximately 8% of men and 0,6% of women have a visual colour deficiency.
- 3 Glare sensitivity - this is the reduction in a driver's visual ability due to glare (mostly from oncoming vehicle headlights at night). Old age increases this problem.
- 4 Reaction time - this is the ability of a driver to react quickly to a sensory input. The reaction time varies from person to person and is increased by alcohol and drugs. Further deteriorating factors are fatigue and old age.
- 5 Expectation - depends on the alertness of the driver and attention given to the driving task. The driver's experience and education in relation to traffic matters are also important by a driver.
- 6 Reading ability - the speed at which words can be read on signs by a driver is important.

17.3.3 Sign Factors

- 1 Luminance - the luminance and luminance contrast between the sign and the background that it is viewed against, **and** the sign legend or symbol and the background of the signface, have a major effect on the visual effectiveness of a sign.
- 2 Colour - the colour coding and therefore the colour contrast of the sign affect the visibility.
- 3 Age of the sign - exposure to the weather reduces the retroreflectivity and colours fade towards white. Different signface materials have different deterioration rates.
- 4 Sign and shape - larger sizes of sign are more effective. Certain shapes are easily recognised and increase effectiveness.
- 5 Class of retroreflective sheeting - the retroreflectivity of the various classes of sheeting differs. This has an effect on the night-time visibility.

17.3.4 Vehicle Factors

- 1 Headlight beam - the beam shape and light intensity in the direction of a road sign have an effect on the night-time.

visibility Most headlights comply with the United Nations Economic Commission for Europe (ECE) regulation while some older vehicles and replacement lights are of the Society of Automotive Engineers of the USA (SAE) type.

- 2 Headlight beam aim - for headlights to be effective they have to be correctly adjusted according to the Road Traffic Act.
- 3 Type of Vehicle - a car and a large commercial vehicle have different stopping abilities and also distances between the lights and driver's eyes are different which affect the observation angle to the sign.
- 4 Speed of vehicle - this affects the amount of attention given to signs and affects the stopping distance.
- 5 Transmission of windscreen - this affects the luminance of the sign as seen by the driver. A transmission factor for the windscreen is stipulated in the Road Traffic Act. Dirt will decrease the transmission factor of a windscreen.

17.3.5 Roadway Factors

- 1 Horizontal and vertical curvature - these curvatures affect the amount of light which falls on the signs from the vehicle headlights. The headlight beam is optimum when the road is straight and level.
- 2 Roadway width - this also affects the amount of light which falls on the sign from the vehicle's headlights. On multi-lane roads large vehicles can block the view of the sign.
- 3 Sign position - signs are normally placed on the left hand side of the road. On freeways some signs are applied overhead and on curves some signs are placed on the right hand side of the road. The headlight beam produces different illumination values in these positions.

17.3.6 Environmental Factors

- 1 Background - seen against uncluttered backgrounds (i.e. on a dark road) the conspicuity of signs is increased, while complex backgrounds with relatively high ambient light levels, which are found in the CBDs at night, can reduce the conspicuity.
- 2 Fog and rain - reduce the transmission of light in the atmosphere so that less light is received by the sign and the driver. The light is also scattered by the water droplets which reduces the visibility.
- 3 Dew - in certain atmospheric conditions dew droplets are formed on retroreflective signs which reduces their visibility at night.

17.3.7 Principle Factors

- 1 As has been noted, there are many factors which affect the visibility of a sign. The above-mentioned factors can have an accumulative effect on the effectiveness of a sign. An older driver with poor visual acuity, in an old un-roadworthy vehicle on a rainy night, will require signs of high quality to enable him to perform his driving task safely. It would be difficult to determine an exact minimum standard, taking all the above factors into consideration, but an attempt must be made to

accommodate most circumstances encountered on the road.

- 2 It is therefore difficult to provide prescriptive recommendations on the selection of different types of retroreflective sheeting for different applications. The above-mentioned factors affect the decisions to be taken by road authorities who may give different priorities to these factors depending upon their policy, location and method of operation.
- 3 It is, however, important to focus on the principle factors when considering the selection of retroreflective sheeting, namely:
 - (a) driver visibility needs;
 - (b) durability and the economics of signface material;
 - (c) practical considerations.

17.3.8 Driver Visibility Needs

- 1 Certainly an important criterion for selecting the type of sheeting is the driver's visibility requirements. The ability of a driver to see and read a sign is dependent upon many factors including those that relate directly to the sign, namely:
 - (a) brightness;
 - (b) contrast;
 - (c) conspicuity; and
 - (d) legibility.

17.3.9 Brightness

- 1 Brightness refers to the amount of light reflected from the sign that reaches the driver's eye. Brightness varies for each colour and type of retroreflective material. In general, the brighter the sign, the more conspicuous it will be. However, high brightness letters or symbols mounted on a low brightness background may reduce legibility because of a halo effect of the brighter characters, commonly known as overglow.
- 2 In addition to the type of material, colour, and specific intensity per unit area, sign brightness will be determined by the following factors:
 - (a) headlamp type, aiming, high or low beam;
 - (b) driver's eye height;
 - (c) windshield filtering;
 - (d) weather (frost, dew, rain);
 - (e) surrounding ambient light;
 - (f) road curvature;
 - (g) mounting height and orientation angle;
 - (h) placement of sign: left shoulder, overhead, median, right mounted, etc.;
 - (i) viewing distance from sign.
- 3 Of these factors affecting sign brightness, the first five are beyond the control of the traffic engineer. Road curvature, mounting height and orientation angle of the road sign are discussed in Volume 1, Chapter 1, Section 1.6. Placement and viewing distance and how they influence sign brightness are discussed below.
- 4 **Placement** - Sign placement is an important factor in the consideration of sheeting selection. In general, signs mounted overhead or on the right shoulder of undivided roads require

higher degrees of retroreflectivity to appear equally as bright as signs on the left shoulder. Therefore, generally speaking, overhead signs and right shoulder signs should have significantly higher levels of retroreflectivity than signs placed on the left shoulder.

- 5 **Distance** - A major consideration in the choice of retroreflective material is the distance at which motorists must be able to detect a device so that, if necessary, they will be able to take any action required, in a safe and timely manner. The distance from the sign where this must occur is the distance which provides adequate time at the operating speed to allow for the following to occur:
 - (a) detection of a traffic control device (TCD) critical to the driving task;
 - (b) recognition of the message contained on the TCD;
 - (c) decision making regarding the alternative actions to be taken;
 - (d) initiation of the appropriate response;
 - (e) implementation and completion of the vehicle manoeuvre in a safe manner.
- 6 Not all signs require all of these actions to occur and therefore not all signs must be visible at equal distances. Many signs do not require a vehicle manoeuvre, and of those that do, many do not require the movement to be completed prior to the sign. Signs which require lane changes with merging activity and those which require a complete stop, must be detected and read at considerable distances from the sign. At 120 km/h, for example, the required distances are of the order of 250 m to 330 m. At a speed of 60 km/h, or when the sign does not require a driver decision or vehicle manoeuvre, the distance may be as little as 60 m to 70 m.
- 7 The visibility distance of signs at night cannot be increased indefinitely simply by increasing the level of retroreflectivity. There is an optimum level above which signs become more difficult to read. To accommodate long detection and legibility distances, larger signs with larger letters may be needed.
- 8 Volume 1, Chapter 4, Section 4.2 gives details on the determination of adequate height of letters on signs.

17.3.10 Contrast

- 1 When specifying the manufacture of a road sign which requires the superimposition of one colour of retroreflective material on another, contrast ratios are achieved from the sign for the message to be legible. The minimum co-efficient of retroreflection for the three standard classes of material for each colour is given in SANS 1519. The actual co-efficient of retroreflection for a given sample and colour may vary widely from the minimum, and for new materials, these values are commonly higher than the value given in SANS 1519. Colour contrast and therefore legibility, is normally sought by placing a dark letter on a light background, or vice versa. The contrast between the luminance of the sign legend and the luminance of the sign background is a key measure that has been related to sign brightness. For signs with a black legend on colour background the legibility is determined by the luminance of the colour portion of the sign. As a general rule a contrast ratio of the

coefficients of retroreflection of colours placed on each other is recommended as follows:

- (a) for small finely detailed areas (letters and symbols) - a minimum ratio for light-to-dark of 7 to 1, with a preference for 10 to 1 or more;
- (b) for large areas (arrow or blocks) - a minimum ratio of 3,5 to 1, with a preference for 5 to 1.

17.3.11 Conspicuity

- 1 Conspicuity refers to the probability that a sign located in the visual periphery will be seen at a given distance. The level of conspicuity for any sign depends upon the following factors:

- (a) peripheral to line of sight;
- (b) degree to which sign is expected and/or being looked for;
- (c) visual complexity of the surrounding area;
- (d) external contrast;
- (e) size of sign.

- 2 "**Peripheral to line of sight**" refers to the fact that the further the sign is located from the driver's line of sight, the less likely it is that it will be seen. Signs mounted on the right of a multi-lane road or on the left side of roads with unusually wide shoulders or parking/turning lanes may be less conspicuous. Eccentricity is generally not a problem for conspicuity at the long distances where detection generally occurs. However, eccentricity may be a problem when a sign is used with an unusually short sight distance (e.g. after a turn or a merge area). Hence, for these situations it is advisable to use sheeting that maintains its retroreflectivity thorough wide angles.
- 3 Signs are more conspicuous to drivers who are **looking for them**. On this basis alone guidance signs are more likely to be seen than regulatory or warning signs. Also any sign following another sign that alerted the driver to its presence (e.g. STOP AHEAD), will be more conspicuous because of the advance warning.
- 4 **Visual complexity** refers to the presence of both reflected and direct light sources in the driver's field of view. Signs located in areas of low visual complexity are more likely to be seen than signs in high complexity areas. Rural roads with just a few point sources of light are definitely not complex. However not all roads with many light sources are visually complex. In general, lights or reflective sources in the area where signs are located add to complexity, while such distractions away from the sign (i.e. right side of road) do not. Roads with activity which complicates the driving task (e.g. traffic signals and intersections) are visually more complex.

- 5 Conspicuity is most easily improved by increasing size and/or **external contrast**. Larger signs provide greater conspicuity than small signs. Brighter signs are generally more conspicuous than dimmer signs. For practical reasons, **sign size** may not be increased beyond certain limits. Likewise, brightness is limited both by the availability of materials and by the fact that excessive luminance may degrade legibility and/or produce overglow discomfort. Since sign brightness improves conspicuity by increasing its external contrast, it may be possible to increase conspicuity by placement of the sign so that it is seen against a darker background.

17.3.12 Legibility

- 1 Volume 1, Chapter 4, Section 4.2 describes the design factors for legibility in detail. One of these factors is the luminance of the signface. For any given driver, the letter size, contrast and surrounding luminance interact to determine dual legibility distance. With letter size and stroke width remaining constant, the legibility index of partially retroreflective signs is primarily determined by the luminance of the retroreflective material, and the surrounding luminance. The legibility index of fully retroreflectorised signs is determined by the internal contrast of the brighter reflective components to the other portions of the sign.
- 2 The luminance of the reflective component of partially retroreflectorised signs should be at least 2 cd/m², but 10 cd/m² is a far safer specification. In general the contrast ratio of fully retroreflectorised signs should be 5 to 1 as described in Subsection 17.3.10.
- 3 Different letter stroke widths and symbols have different legibility indices. Symbols vary in legibility in ways that cannot be formally specified; however, symbols are typically larger than letters for the same size of sign, which generally gives them a greater legibility distance.
- 4 A major factor concerning the legibility of a sign is the visual acuity of the road user population. The visual acuity is the ability to resolve small detail. The Human Science Research Council conducted a study to determine the visual acuity of South African motorists. Table 17.1 gives the results. In the same table results of studies conducted in the USA and UK are given as well. The Snellen notation 6/6 indicates the ability to resolve an angle of one minute of arc. South African law requires that applicants for drivers' licences have a visual acuity of 6/12 (two minutes of arc).

TABLE 17.1	COMPARISON OF THE VISUAL ACUITIES OF UK, US AND SA DRIVERS		TABLE 17.1
Criterion	UK (Davison & Irving) N = 1368	US (Burg) N = 3848	SA (Present Study) N = 2045
6/6 or better	90.7	85.8	75.2
6/9 or better	97.0	86.1	95.3
6/12 or better	99.0	99.0	98.8
6/18 or better	99.6	99.8	99.5
Worse than 6/18	0.4	0.2	0.5

17.4 SPECIFICATION SANS 1519: ROAD SIGNS

17.4.1 General

- 1 Specification SANS 1519 on road signs was re-published during 2004 (Part 2) and 2006 (Part 1). The purpose of this specification is to ensure that road signs are effective over a relatively long time span (+/- seven years in the field). The co-efficient of retroreflection is given for the three classes of sheeting. The minimum coefficients of retroreflection for these three classes when the samples are new, are given in Table 17.2. After a weathering test the minimum values should be 80% of the values given in the table. The values given in Table 17.2 are based on international practice. The coefficient of retroreflection of Class 1, Class 2 and Class 3 has a ratio of magnitude of 1:2:3 (Red is 10 for Class 1, 20 for Class 2 and 30 for Class 3).
- 2 The observation angle of 0,33° and an entrance angle of 5° are relevant for motor cars at approximately 200 m while the observation angle of 2° and an entrance angle of 30° are relevant at approximately 30 m. These distances are somewhat short for heavy vehicles where the distances between the lights and drivers' eyes are larger.
- 3 Table 17.3 gives the chromaticity coordinates for daylight colours of new sign materials and Table 17.4 gives the required values of the co-ordinates after samples have been subjected to a weathering test. Figure 17.2 gives the chromaticity diagram for daylight surface colours and Figure 17.3 gives the proposed colour boundaries for red, yellow, green and blue. Table 17.5 gives the luminance factor for the different ordinary colours (paints, plastic film or opaque inks) and for the three classes of retroreflective sheeting after weathering. These values are based on international practices.
- 4 The colour specifications are only for daylight. During the hours of darkness, ordinary colours will appear black, while retroreflective sheeting will show similar colours to those shown in daylight. At present there is no specification for retroreflective colours, but a CIE committee is looking at this problem. A number of materials are imported from the USA which comply to their specification, but fail the SANS specification regarding the Red colour.

TABLE 17.2 **MINIMUM COEFFICIENTS OF RETROREFLECTION FOR NEW SIGNFACE MATERIALS OF DIFFERENT COLOURS** **TABLE 17.2**
SPECIFICATIONS SANS 1519-1:2006 and 1519-2:2004




Class	Observation Angle (Degrees)	Entrance Angle (Degrees)	Coefficient of Retroreflection for Different Colours of Material When Measured With Standard Illuminant A* cd/lx/m ² , Minimum							
			Red	Orange	Yellow	Green	Blue	Purple	White	Brown
1	0.33	5	10	20	35	7	3	2	50	3
	2	30	0.4	0.8	1.5	0.3	0.1	0.1	2.5	0.1
2	0.33	5	20	40	70	14	6	4	100	6
	2	30	0.4	0.8	1.5	0.3	0.1	0.1	2.5	0.1
3	0.33	5	30	60	105	21	9	6	150	9
	2	30	0.4	0.8	1.5	0.3	0.1	0.1	2.5	0.1
	0.22	40	13	22	64	11	7.0	3.2	95	0.5

TABLE 17.3

**CHROMATICITY CO-ORDINATES FOR
DAYLIGHT COLOURS OF NEW SIGNS**

TABLE 17.3

Colour	Type*	Chromaticity Co-ordinates of the Corners of the Region on the Chromaticity Diagram (Illuminant D65, 45/0 Geometry)				
		Co-ordinates	1	2	3	4
Yellow	O + R	x	0.690	0.640	0.606	0.655
		y	0.310	0.312	0.342	0.345
Orange	O + R	x	0.610	0.570	0.536	0.570
		y	0.390	0.381	0.416	0.429
Yellow	O	x	0.529	0.500	0.470	0.494
		y	0.467	0.450	0.480	0.505
Yellow	R	x	0.545	0.513	0.470	0.494
		y	0.454	0.437	0.480	0.505
Green	R	x	0.170	0.110	0.110	0.170
		y	0.415	0.415	0.500	0.500
Green	O	x	0.270	0.230	0.230	0.270
		y	0.480	0.480	0.520	0.520
Blue	O	x	0.190	0.150	0.150	0.190
		y	0.120	0.120	0.160	0.160
Blue	R	x	0.160	0.130	0.130	0.160
		y	0.086	0.086	0.140	0.140
Purple	O + R	x	0.302	0.307	0.374	0.457
		y	0.064	0.203	0.247	0.136
White	O + R	x	0.335	0.305	0.295	0.325
		y	0.345	0.315	0.325	0.355
Grey	O	x	0.335	0.305	0.295	0.325
		y	0.345	0.315	0.325	0.355
Black	O	x	0.385	0.300	0.260	0.345
		y	0.355	0.270	0.310	0.395
Brown	O	x	0.470	0.445	0.445	0.470
		y	0.350	0.350	0.390	0.390
Brown	R	x	0.550	0.500	0.460	0.505
		y	0.380	0.368	0.406	0.425

-  Ordinary colours of new specimen
 Retro-reflective colours of new specimen
 After weathering

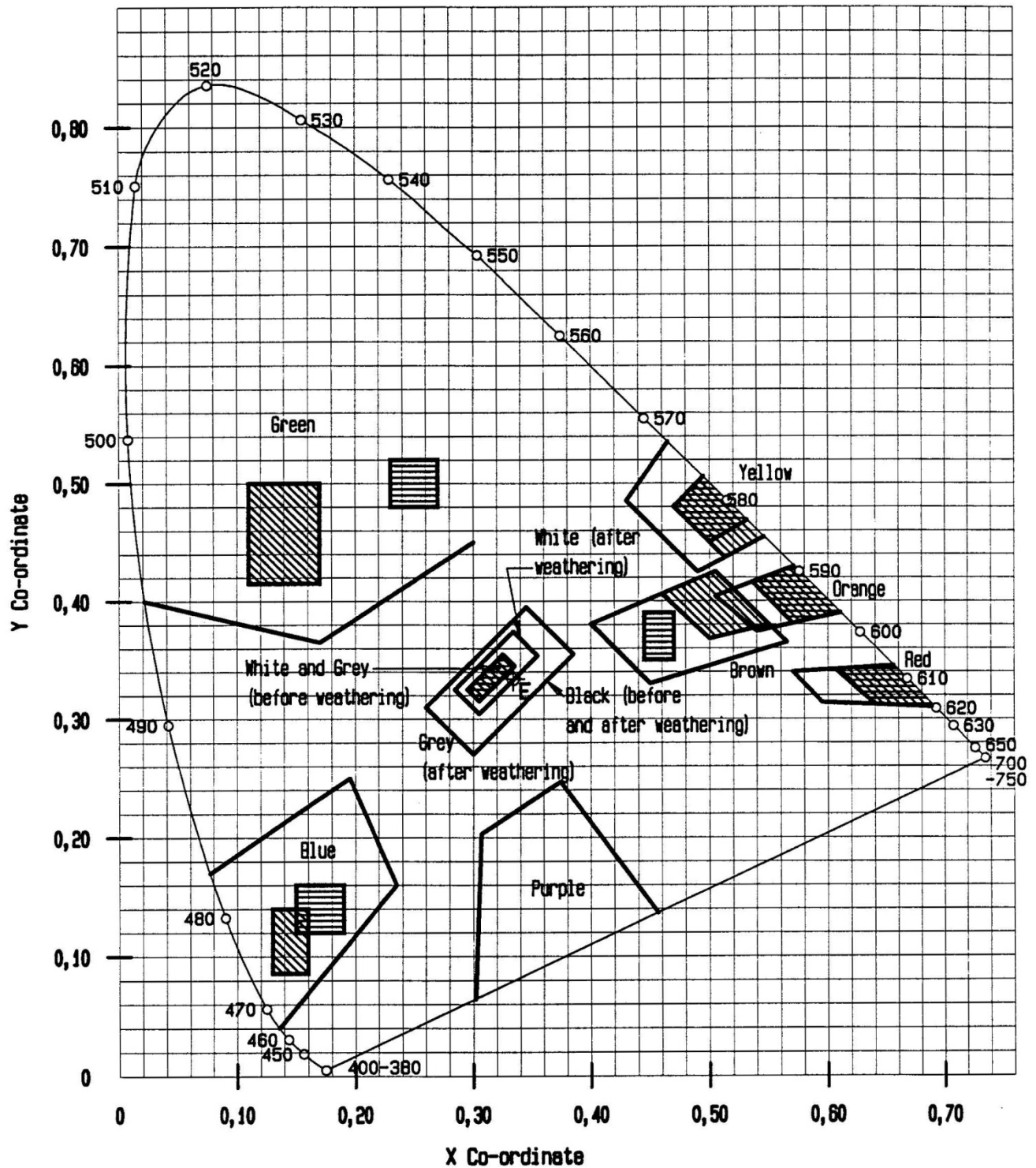


Fig 17.2 Chromaticity Chart: Boundaries for Daylight Surface Colours

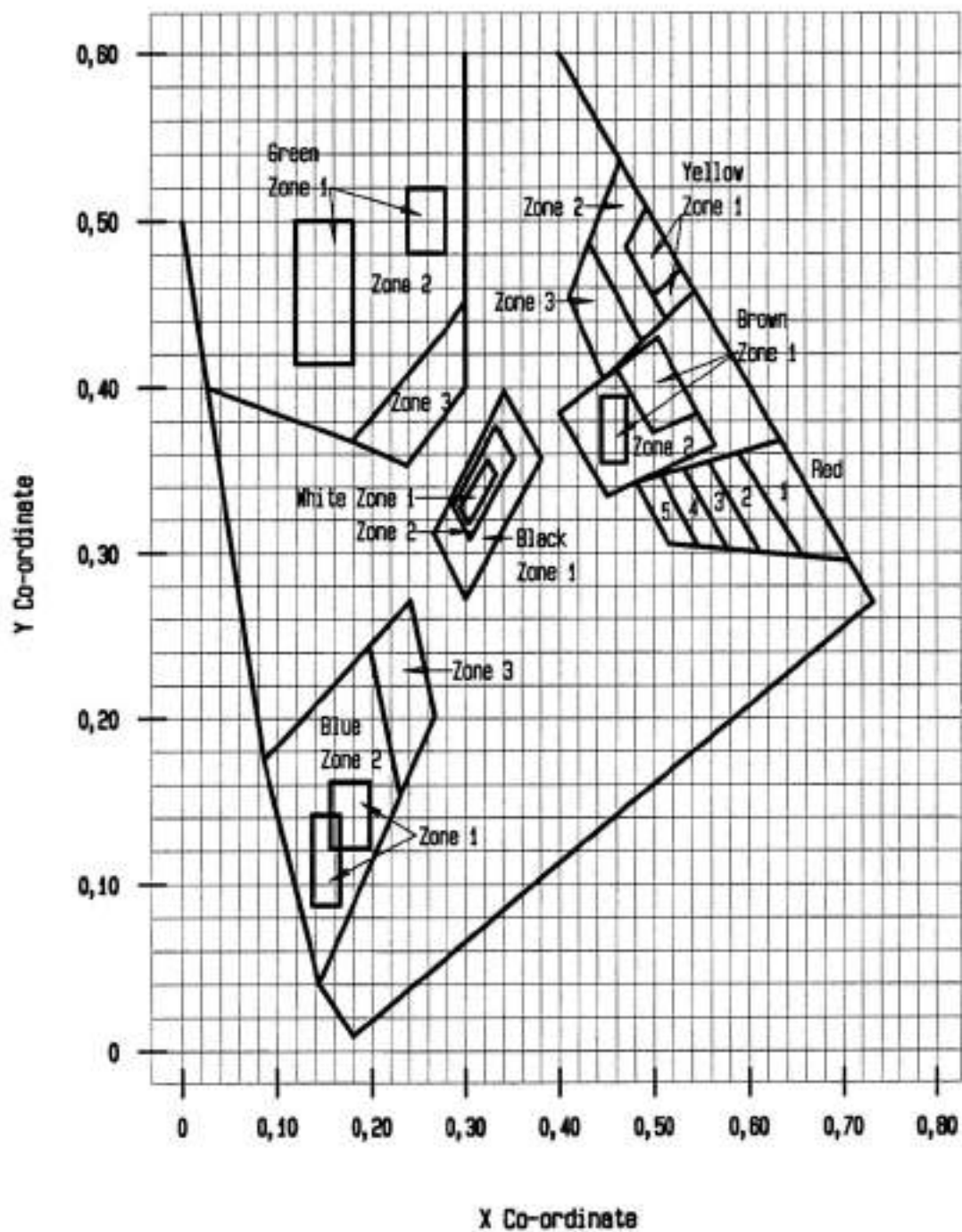


Fig 17.3

Proposed Boundaries for Red, Yellow, Green and Blue

TABLE 17.4 CHROMATICITY CO-ORDINATES FOR DAYLIGHT COLOURS OF WEATHERED SIGNS TABLE 17.4

Colour	Type*	Chromaticity Co-ordinates of the Corners of the Region on the Chromaticity Diagram (Illuminant D65, 45/0 Geometry)				
		Co-ordinates	1	2	3	4
Red	O + R	x	0.690	0.595	0.569	0.655
		y	0.310	0.315	0.341	0.345
Orange	O + R	x	0.610	0.535	0.506	0.570
		y	0.390	0.375	0.404	0.429
Yellow	O + R	x	0.545	0.487	0.427	0.465
		y	0.454	0.423	0.483	0.534
Green	O + R	x	0.300	0.300	0.170	0.026
		y	0.690	0.450	0.364	0.399
Blue	O + R	x	0.078	0.196	0.023	0.137
		y	0.171	0.250	0.160	0.038
Purple	O + R	x	0.302	0.307	0.374	0.457
		y	0.064	0.203	0.247	0.136
White	O + R	x	0.355	0.305	0.285	0.335
		y	0.355	0.305	0.325	0.375
Grey	O	x	0.385	0.300	0.260	0.345
		y	0.355	0.270	0.310	0.395
Black	O	x	0.385	0.300	0.260	0.345
		y	0.355	0.270	0.310	0.395
Brown	O + R	x	0.565	0.450	0.400	0.505
		y	0.360	0.330	0.380	0.425

* O = Ordinary colours, R = retroreflective colours

TABLE 17.5 LUMINANCE FACTOR TABLE 17.5

Colour	Luminance Factor, Min			
	Ordinary	Retroreflective Class		
		I	II	III
Red	0.07	0.05	0.04	0.03
Orange	0.20	0.17	0.15	0.14
Yellow	0.45	0.27	0.21	0.16
Green	0.10	0.04	0.03	0.03
Blue	0.05	0.01	0.01	0.01
Purple	0.05	0.03	0.02	0.02
White	0.75	0.35	0.31	0.27
Grey*	0.10	—	—	—
Black +	—	—	—	—
Brown #	0.03	0.03	0.03	0.03

* Max. = 0.24

+ Max. = 0.03

Max. = 0.09

17.5 REPLACEMENT CRITERIA FOR SIGNFACE MATERIALS

17.5.1 General

- 1 It is clear from the previous sections that most of the visual problems concerning signs are related to the hours of darkness. For this reason many studies have concentrated on the retroreflectivity of signs. A literature survey review is set out in Section 17.12 which highlights the "Night Time Visibility of Retroreflective Road Signs." Relatively few studies have been conducted on the daylight visibility of signs.
- 2 Based on the research done overseas and by the National Department of Transport locally, guidelines for the replacement of road sign materials in this chapter deal with minimum requirements for retroreflective sheeting for night-time visibility, and minimum requirements for retroreflective sheeting for night-time visibility and minimum requirements for sign colours for daylight visibility.

17.5.2 Retroreflective Sheeting

- 1 The CIE has produced international recommendations for the minimum retroreflective values for various signs at which the sign should be placed (see Section 17.11). It has been recommended that these minimum retroreflective values be adopted as a basis for developing a system for South Africa.
- 2 A model has been developed to calculate the terminal retroreflective value for road sign based on three components:
(a) the minimum luminance required from the sign;
(b) the distance from which the sign needs to be seen;
(c) the geometry of the situation.
- 3 The following factors are taken into consideration when the minimum distance the sign needed to be seen, is determined:
(a) the legibility distance should be about 1,5 times the "minimum required distance";
(b) the time to correctly read a sign having N words is taken as $t = 0.32 N - 0.2$;
(c) symbolic signs (including STOP signs) are taken as equivalent to two words to read;
(d) the distance to read signs is $= V \times t$ where V is speed of vehicle;
(e) drivers will not read signs at lateral angles of 10° or higher (for overhead signs a limiting vertical angle is taken as 5°);
(f) for lane changes the lateral speed of 1m/sec is used;
(g) for stopping distance a mean deceleration rate of 0.45 m/s² is used;
(h) the deceleration rate for slowing down is 0.259 m/s².
- 4 Once the minimum distance has been determined, the level of illumination on the sign may be found. The geometry of the site is required. For this model the ECE low beam headlight intensity distribution is used. From the illumination values and the minimum luminance (determined by laboratory experiment) the retroreflective values can be calculated.
- 5 Road signs are located in different road environments on different classes of roads. These environments are critical to the ambient luminance and the visual complexity around the sign location.

- 6 It should be recognised that the development of minimum retroreflectivity values is not an exact process. This complex problem involves many driver, vehicle, roadway and sign factors. The values given in Tables 17.2 and 17.5 should provide road authorities with objective values that can be used in deciding what type of new sign sheeting should be applied. Subsequent to these tables, Table 17.6 gives further guidance on the selection of retroreflective sheeting for different road signs in different environments.
- 7 It is believed that the luminance values balance the desire to satisfy all drivers in all situations and the need to provide practical, implementable values. Based on current knowledge the recommended replacement values provide an acceptable level of driver accommodation, while not putting an undue burden on road authorities in terms of percentage of signs to be replaced at any point in time.

17.5.3 Recommended Criteria

- 1 The night-time visibility and the colour limits of signs have been researched by a number of organisations and the CIE has published an international recommendation. It is proposed that the CIE recommendation should form the basis for the criteria to replace road signs in South Africa.
- 2 Tables 17.7 gives the colour limits for urban streets. The four different types of street, as well as the different types of signs, are classified according to Volume 1. The retroreflective value is cd/lx/m² measured at an observation angle of 0.333° and an entrance angle of 5° is given for the symbol, background and border for each sign group. The colour limits are given in zones as indicated by Figure 17.2 for the symbol, background and border. Table 17.8 gives the same information for rural roads. The minimum contrast for night-time conditions is 5:1. For daytime conditions a minimum contrast of 5:1 should also be maintained, but this is not always possible with certain colour and material combinations.
- 3 These recommendations should be incorporated into a signs management system, as explained in Chapter 16, which will ensure a cost effective sign replacement policy.

TABLE 17.6

GUIDANCE ON SELECTION OF RETROREFLECTIVE SHEETING

TABLE 17.6

Sign Type		Road Environment Category	* Road Class	Signface Background	Text (including arrows, borders and symbols)
GUIDANCE SIGNS	Location Signs (GL Series)	Rural Urban	All Classes	White: Class I	Black: Semi-matt (coloured symbols in Class I material)
	Route Marker Signs (including trailblazer signs) (GE Series)	Rural Urban	A1	Blue, Green or Brown : Class I	Route Number: Yellow: Class III (including brackets and cardinal directions) All others: White: Class I
	Direction Signs (see below for Class A1 freeway) (GD Series)	Rural Urban	B & C1 B & C	Ground-mounted: Green: semi-matt or Class I Ground-mounted and Overhead signs: Green: Class I	Route Number: Yellow: Class III (including brackets and cardinal directions) All others: Ground-mounted White: Class I All others: Overhead White: Class III
	Freeway Direction Signs (GA and Toll Series) Cross Road approach signs	Rural Urban Rural Rural and Urban	A1 A1 A2 B	Blue: Class I Blue: Class III Green : Class I Blue and Green: Class I	Route Number Yellow: Class III (including brackets and cardinal directions) Interchange Number / Local Authority Name Black: semi-matt All others: ground-mounted White: Class I All other: Overhead White: Class III
	Tourist Direction Signs (GF series) Local Directions Signs (GDL Series)	Rural and Urban	A1 + A2 (NO GDL signs on freeways) B, C1 + C2	Tourist Direction : Brown: Class I Tourist Direction : Brown: semi-matt or Class I Local Direction : White: Class I	Tourist Direction : All legend (except route numbers which shall be Yellow : Class III) White: Class I Local Direction : All legend Black : Semi-matt (coloured symbols in Class I material) Local Direction: Border: Blue: Class I
	Diagrammatic Signs (GS Series)	Rural and Urban	All Classes	White: Class I (including IN11 signs)	Border and Blocks Red: Class I All other (including IN11 signs) Black: Semi-matt
WARNING SIGNS	All permanent and temporary warning signs shall have a fully retroreflective background and border and shall be manufactured using at least Class I retroreflective materials. The symbol on permanent and temporary warning signs shall be provided in a durable semi-matt material or finish.				
REGULATORY SIGNS	All permanent and temporary signs shall have a fully retroreflective background. Control signs shall be fully retroreflective, with the exception of those areas which are black, which shall be provided in a durable semi-matt material or finish. In addition, the symbol and border on permanent command, reservation and comprehensive signs, and the border on all permanent and temporary prohibition signs shall be fully retroreflective. The symbol on permanent and temporary prohibition signs and the symbol and border on temporary command, reservation and comprehensive signs shall be provided in a durable semi-matt material or finish. Regulatory signs manufactured using any form of silkscreening process shall only be used after strict manufacturing control and with a guarantee from the manufacturer. Any retroreflective materials used to manufacture signs shall be of at least Class I quality.				

* See Volume 2, Chapter 9, Subsection 9.2.2 for classification of urban roads and Volume 1, Chapter 1, Subsection 1.2.2 for other roads.

TABLE 17.7 GUIDELINES ON MINIMUM ACCEPTABLE CO-EFFICIENTS OF RETROREFLECTION AND COLOUR LIMITS FOR THE REPLACEMENT OF SIGNS ON URBAN ROADS

Type of Sign	Colour ⁽¹⁾⁽²⁾	Type of Street																										
		Freeway Class A							Arterials Class B							Collector-distributor Class C							Residential Class D					
		CIL/m ² cd/lx/m ²			Colour limits ⁽³⁾			CIL/m ² cd/lx/m ²			Colour limits (3)			CIL/m ² cd/lx/m ²			Colour limits (3)			CIL/m ² cd/lx/m ²			Colour limits (3)					
		Symbol/ Legend	Back- ground	Border	Symbol/ Legend	Back- ground	Border	Symbol/ Legend	Back- ground	Border	Symbol/ Legend	Back- ground	Border	Symbol/ Legend	Back- ground	Border	Symbol/ Legend	Back- ground	Border	Symbol/ Legend	Back- ground	Border	Symbol/ Legend	Back- ground	Border			
Regulatory Control	R1	W R W BA W R	40 0	8 40	40 8	WZ2 BAZ1	RZ2 WZ2	WZ2 RZ2	35 0	6 35	35 6	WZ2 BAZ1	RZ3 WZ2	WZ2 RZ3	35 0	6 35	35 6	WZ2 BAZ1	RZ4 WZ2	WZ2 RZ4	30 0	4 30	30 4	WZ2 BAZ1	RZ5 WZ2	WZ2 RZ5		
Command	R101 TR101	W BU W BA Y BA	40 0	2 30	40 0	WZ2 BAZ1	BUZ2 YZ2	WZ2 BAZ1	35 0	2 30	35 0	WZ2 BAZ1	BUZ2 YZ2	WZ2 BAZ2	30 0	2 30	30 0	WZ2 BAZ1	BUZ3 YZ2	WZ2 BAZ1	30 0	2 30	30 0	WZ2 BAZ1	BUZ3 YZ3	WZ2 BAZ1		
Prohibition	R201 TR201	BA W R BA Y R	0 0	40 5	8 8	BAZ1 BAZ1	WZ2 YZ2	RZ2 RZ2	0 0	35 30	6 6	BAZ1 BAZ1	WZ3 YZ2	RZ3 RZ3	0 0	30 30	4 4	BAZ1 BAZ1	WZ2 YZ2	RZ4 RZ4	0 0	30 30	4 4	BAZ1 BAZ1	WZ2 YZ3	RZ5 RZ5		
Reservation	R301 TR301	W BU W BA Y BA	40 0	2 30	40 0	WZ2 BAZ1	BUZ2 YZ2	WZ2 BAZ1	30 0	2 25	30 0	WZ2 BAZ1	BUZ3 YZ3	WZ2 BAZ1	30 0	2 20	30 0	WZ2 BAZ1	BUZ3 YZ3	WZ2 BAZ1	30 0	2 20	30 0	WZ2 BAZ1	BZ3 YZ3	WZ2 BAZ1		
Other ⁽⁴⁾	R401-(R)501-R601 TR401-(TR)501-TR601	W BU R BA Y R	40 0	2 35	8 8	WZ2 BAZ1	BUZ2 YZ2	RZ2 RZ2	35 0	2 25	6 6	WZ2 BAZ1	BUZ3 YZ3	RZ3 RZ3	30 0	2 20	4 4	WZ2 BAZ1	BUZ3 YZ3	RZ4 RZ4	30 0	2 20	4 4	WZ2 BAZ1	BUZ3 YZ3	RZ4 RZ4		
Warning Road Layout	W101 TW101	BA W R BA Y R	0 0	40 35	8 8	BAZ1 BAZ1	WZ2 YZ2	RZ2 RZ2	0 0	40 35	8 8	BAZ1 BAZ1	WZ2 YZ3	RZ3 RZ3	0 0	35 30	6 6	BAZ1 BAZ1	WZ2 YZ3	RZ4 RZ4	0 0	30 30	4 4	BAZ1 BAZ1	WZ2 YZ3	RZ5 RZ5		
Movement	W201 TW201	BA W R BA Y R	0 0	40 35	8 8	BAZ1 BAZ1	WZ2 YZ2	RZ2 RZ2	0 0	40 35	8 8	BAZ1 BAZ1	WZ2 YZ3	RZ3 RZ3	0 0	30 35	6 6	BAZ1 BAZ1	WZ2 YZ3	RZ4 RZ4	0 0	30 30	4 4	BAZ1 BAZ1	WZ2 YZ3	RZ5 RZ5		
Symbolic	W301 TW301	BA W R BA Y R	0 0	40 35	8 8	BAZ1 BAZ1	WZ2 YZ2	RZ2 RZ2	0 0	40 35	8 8	BAZ1 BAZ1	WZ2 YZ3	RZ3 RZ3	0 0	35 30	6 6	BAZ1 BAZ1	WZ2 YZ3	RZ4 RZ4	0 0	30 30	4 4	BAZ1 BAZ1	WZ2 YZ3	RZ5 RZ5		
Hazard Marker	W401 TW401	R W — BA Y Y	8 0	40 30	— 30	RZ2 BAZ1	WZ2 YZ2	— YZ2	8 0	40 30	— 30	RZ2 BAZ1	WZ2 YZ3	— YZ3	8 0	40 30	— 30	RZ3 BAZ1	WZ3 YZ3	— YZ3	8 0	40 30	— 30	RZ4 BAZ1	WZ2 YZ3	— BAZ1		
Guidance Location	GL1	BA W BA	0	40	0	BAZ1	WZ2	BAZ1	0	40	0	BAZ1	WZ2	BAZ1	0	30	0	BAZ1	WZ2	BAZ1	0	30	0	BAZ1	WZ2	BAZ1		
Route Marker ⁽⁵⁾⁽⁶⁾	GE1 TGE1	Y/W G W BA Y BA	30/40 0	6 30	40 0	YZ2/WZ2 BAZ1	GZ2 YZ2	WZ2 BAZ1	30/40 0	4 30	40 0	YZ2/WZ2 BAZ1	GZ2 YZ2	WZ2 BAZ1	30/35 0	4 30	35 0	YZ3/WZ2 BAZ1	GZ3 YZ2	WZ2 BAZ1	30/30 0	2 30	30 0	YZ3/WZ2 BAZ1	GZ3 YZ2	WZ2 BAZ1		
Direction ⁽⁵⁾	GD1 TGD1	Y/W G W BA Y BA	30/40 0	6 30	40 0	YZ2/WZ2 BAZ1	GZ2 YZ2	WZ2 BAZ1	30/40 0	6 30	40 0	YZ2/WZ2 BAZ1	GZ2 YZ2	WZ2 BAZ1	30/35 0	4 30	35 0	YZ3/WZ2 BAZ1	GZ3 YZ2	WZ2 BAZ1	30/30 0	2 30	30 0	YZ3/WZ2 BAZ1	GZ3 YZ3	WZ2 BAZ1		
Freeway ⁽⁵⁾	GA1 TGA1	Y/W BU W BA Y BA	30/40 0	2 30	40 0	YZ2/WZ2 BAZ1	BUZ2 YZ2	WZ2 BAZ1	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —		
Freeway Overheads		Y/W BU W	80/120	2	120	YZ2/WZ2	BUZ2	WZ2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
Tourist Direction	GF1	W B W	40	2	40	WZ2	BZ2	WZ2	40	2	40	WZ2	BZ2	WZ2	35	2	35	WZ2	BZ2	WZ2	30	2	30	WZ2	BZ2	WZ2		
Local Direction	GDL1	BA W BU	—	—	—	—	—	—	0	40	2	BAZ1	WZ2*	BUZ2	0	35	2	BAZ1	WZ2	BUZ2	0	30	2	BAZ1	WZ2	BUZ2		
Diagrammatic	GS1 TGS1	BA W R BA Y R	0 0	40 35	8 8	BAZ1 BAZ1	WZ2 YZ2	RZ2 RZ2	0 0	40 35	8 8	BAZ1 BAZ1	WZ2 YZ2	RZ2 RZ2	0 0	35 30	6 6	BAZ1 BAZ1	WZ2 YZ2	RZ3 RZ3	0 0	30 25	4 4	BAZ1 BAZ1	WZ2 YZ2	RZ4 RZ4		

NOTE:

- (1) COLOURS: W=White; BA=Black; R=Red; BU=Blue; Y=Yellow; B=Brown.
- (2) Colour coding is shown thus - BA Y BA - Symbol/Background/Border.
- (3) COLOUR LIMITS: WZ2=White Zone 2; RZ3= Red Zone 3; YZ2 = Yellow Zone 2; BAZ1 = Black Zone 1; BUZ2= Blue Zone 2; GZ2=Green Zone 2.
- (4) R401 series shown - (R)501 and R601 should comply with the requirements for the sign series with which they are used.
- (5) Y/W corresponds to yellow route marker legend with all other legend in white.
- (6) Route Marker (incl. Trailblazer) sign background can also be blue or brown. Use values for Freeway and Tourist Direction signs respectively.
- (7) For temporary signs used at roadworks the contrast between yellow and red surfaces should be more than 4:1. For signs using semi-matt backgrounds the value of "retroreflectivity" should be taken to be 0.

TABLE 17.8 GUIDELINES ON MINIMUM ACCEPTABLE CO-EFFICIENTS OF RETROREFLECTION AND COLOUR LIMITS FOR THE REPLACEMENT OF SIGNS ON RURAL ROADS

TABLE 17.8

Type of Sign		Colour ⁽¹⁾⁽²⁾	Type of Street																							
			Freeway Class A						Arterials Class B						Collector-distributor Class C						Residential Class D					
			CIL/m ² cd/lx/m ²			Colour limits ⁽³⁾			CIL/m ² cd/lx/m ²			Colour limits (3)			CIL/m2 cd/lx/m ²			Colour limits (3)			CIL/m2 cd/lx/m ²			Colour limits (3)		
			Symbol/ Legend	Back- ground	Border	Symbol	Back- ground	Border	Symbol	Back- ground	Border	Symbol	Back- ground	Border	Symbol	Back- ground	Border	Symbol	Back- ground	Border	Symbol	Back- ground	Border	Symbol	Back- ground	Border
Regulatory Control	R1	W R W BA W R	40 0	8 40	40 8	WZ2 BAZ1	RZ2 WZ2	WZ2 RZ2	35 0	6 35	35 6	WZ2 BAZ1	RZ3 WZ2	WZ2 RZ3	35 0	6 35	35 6	WZ2 BAZ1	RZ4 WZ2	WZ2 RZ4	30 0	4 4	30 —	WZ2 BAZ1	RZ5 WZ2	WZ2 RZ5
Command	R101 TR101	W BU W BA Y BA	40 0	2 30	40 0	WZ2 BAZ1	BUZ2 YZ2	WZ2 BAZ1	35 0	2 30	35 0	WZ2 BAZ1	BUZ2 YZ2	WZ2 BAZ2	30 0	2 30	30 0	WZ2 BAZ1	BUZ3 YZ2	WZ2 BAZ1	30 0	2 30	30 0	WZ2 BAZ1	BUZ3 YZ2	WZ2 BAZ1
Prohibition	R201 TR201	BA W R BA Y R	0 0	50 35	10 8	BAZ1 BAZ1	WZ2 YZ2	RZ2 RZ2	0 0	40 35	8 8	BAZ1 BAZ1	WZ3 YZ2	RZ3 RZ3	0 0	35 30	6 6	BAZ1 BAZ1	WZ2 YZ2	RZ4 RZ4	0 0	30 30	4 4	BAZ1 BAZ1	WZ2 YZ3	RZ5 RZ5
Reservation	R301 TR301	W BU W BA Y BA	40 0	2 30	40 0	WZ2 BAZ1	BUZ2 YZ2	WZ2 BAZ1	35 0	2 30	35 0	WZ2 BAZ1	BUZ3 YZ3	WZ2 BAZ1	30 0	2 25	30 0	WZ2 BAZ1	BUZ3 YZ3	WZ2 BAZ1	30 0	2 25	30 0	WZ2 BAZ1	BZ3 YZ3	WZ2 BAZ1
Other ⁽⁴⁾	R401-(R)501-R601 TR401-(TR)501-TR601	W BU R BA Y R	40 0	2 35	8 8	WZ2 BAZ1	BUZ2 YZ2	RZ2 RZ2	35 0	2 25	6 6	WZ2 BAZ1	BUZ3 YZ3	RZ3 RZ3	30 0	2 20	4 4	WZ2 BAZ1	BUZ3 YZ3	RZ4 RZ4	30 0	2 20	4 4	WZ2 BAZ1	BUZ3 YZ3	RZ4 RZ4
Warning Road Layout	W101 TW101	BA W R BA Y R	0 0	50 35	10 8	BAZ1 BAZ1	WZ2 YZ2	RZ2 RZ2	0 0	50 35	10 8	BAZ1 BAZ1	WZ2 YZ3	RZ3 RZ3	0 0	40 30	8 6	BAZ1 BAZ1	WZ2 YZ3	RZ4 RZ4	0 0	35 30	6 6	BAZ1 BAZ1	WZ2 YZ3	RZ5 RZ5
Movement	W201 TW201	BA W R BA Y R	0 0	50 35	10 8	BAZ1 BAZ1	WZ2 YZ2	RZ2 RZ2	0 0	50 35	10 8	BAZ1 BAZ1	WZ2 YZ3	RZ3 RZ3	0 0	40 30	8 6	BAZ1 BAZ1	WZ2 YZ3	RZ4 RZ4	0 0	35 30	6 6	BAZ1 BAZ1	WZ2 YZ3	RZ5 RZ5
Symbolic	W301 TW301	BA W R BA Y R	0 0	50 35	10 8	BAZ1 BAZ1	WZ2 YZ2	RZ2 RZ2	0 0	50 35	10 8	BAZ1 BAZ1	WZ2 YZ3	RZ3 RZ3	0 0	40 30	8 6	BAZ1 BAZ1	WZ2 YZ3	RZ4 RZ4	0 0	35 30	0 6	BAZ1 BAZ1	WZ2 YZ3	RZ5 RZ5
Hazard Marker	W401 TW401	R W — BA Y Y	10 0	50 35	— 35	RZ2 BAZ1	WZ2 YZ2	— YZ2	10 0	50 35	— 35	RZ2 BAZ1	WZ2 YZ3	— YZ3	10 0	50 35	— 35	RZ3 BAZ1	WZ3 YZ3	— YZ3	10 0	50 35	— 35	RZ4 BAZ1	WZ2 YZ3	— YZ3
Guidance Location	GL1	BA W BA	0	50	0	BAZ1	WZ2	BAZ1	0	40	0	BAZ1	WZ2	BAZ1	0	30	0	BAZ1	WZ2	BAZ1	0	30	0	BAZ1	WZ2	BAZ1
Route Marker ⁽⁵⁾⁽⁶⁾	GE1 TGE1	Y/W G W BA Y BA	35/50 0	7 35	50 0	YZ2/WZ2 BAZ1	GZ2 YZ2	WZ2 BAZ1	30/40 0	6 35	40 0	YZ2/WZ2 BAZ1	GZ2 YZ2	WZ2 BAZ1	30/40 0	6 30	40 0	YZ3/WZ2 BAZ1	GZ3 YZ2	WZ2 BAZ1	30/30 0	4 30	30 0	YZ3/WZ2 BAZ1	GZ3 YZ2	WZ2 BAZ1
Direction ⁽⁵⁾	GD1 TGD1	Y/W G W BA Y BA	35/50 0	7 35	50 0	YZ2/WZ2 BAZ1	GZ2 YZ2	WZ2 BAZ1	30/40 0	6 30	40 0	YZ2/WZ2 BAZ1	GZ2 YZ2	WZ2 BAZ1	30/40 0	6 30	40 0	YZ3/WZ2 BAZ1	GZ3 YZ2	WZ2 BAZ1	30/30 0	2 30	30 0	YZ3WZ2 BAZ1	GZ3 YZ3	WZ2 BAZ1
Freeway ⁽⁵⁾	GA1 TGA1	Y/W BU W BA Y BA	35/50 0	2 35	50 0	YZ2/WZ2 BAZ1	BUZ2 YZ2	WZ2 BAZ1	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	
Freeway Overheads		Y/W BU W	80/120	2	120	YZ2/WZ2	BUZ2	WZ2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Tourist Direction	GF1	W B W	40	2	40	WZ2	BZ2	WZ2	40	2	40	WZ2	BZ2	WZ2	35	2	35	WZ2	BZ2	WZ2	30	2	30	WZ2	BZ2	WZ2
Diagrammatic	GS1 TGS1	BA W R BA Y R	0 0	50 35	10 8	BAZ1 BAZ1	WZ2 YZ2	RZ2 RZ3	0 0	50 35	10 8	BAZ1 BAZ1	WZ2 YZ2	RZ2 RZ3	0 0	40 35	8 8	BAZ1 BAZ1	WZ2 YZ2	RZ3 RZ3	0 0	30 25	4 4	BAZ1 BAZ1	WZ2 YZ2	RZ4 RZ4

NOTE:

- (1) COLOURS: W=White; BA=Black; R=Red; BU=Blue; Y=Yellow; B=Brown.
- (2) Colour coding is shown thus - BA Y BA - Symbol/Background/Border.
- (3) COLOUR LIMITS: WZ2=White Zone 2; RZ3= Red Zone 3; YZ2 = Yellow Zone 2; BAZ1 = Black Zone 1; BUZ2= Blue Zone 2; GZ2=Green Zone 2.
- (4) R401 series shown - (R)501 and R601 should comply with the requirements for the sign series with which they are used.
- (5) Y/W corresponds to yellow route marker legend with all other legend in white.
- (6) Route Marker (incl. Trailblazer) sign background can also be blue or brown. Use values for Freeway and Tourist Direction signs respectively.
- (7) For temporary signs used at roadworks the contrast between yellow and red surfaces should be more than 4:1. For signs using semi-matt backgrounds the value of "retroreflectivity" should be taken to be 0.

17.6 DURABILITY AND ECONOMICS

17.6.1 General

- 1 Another consideration in the selection of the type of retroreflective sheeting is the relative durability and service life of the different types of sheeting and any economic implications. If a more expensive sheeting has a longer life, it may prove to be economically advantageous to use that sheeting especially if it provides a higher level of reflectivity over the life of the sign. A life-cycle cost analysis using the road authority's experience, will identify any cost benefits.
- 2 In preparing a life-cycle cost analysis several factors should be taken into consideration:
 - (a) cost of the sheeting and exchange rates;
 - (b) cost of the sign in-place, including the substrate material, posts and installation;
 - (c) cost of signs against total cost of road project;
 - (d) service life;
 - (e) benefits.
- 3 A simple procedure for making the comparative cost analysis is to divide the total cost by the performance life. This can be expressed as:

$$C = \frac{TC}{PL}$$

Where:

- C = Cost per year of useful life
 TC = Total cost of material and the sign during the life of the sign
 PL = Performance life, which can be the service life of the sheeting or the sign or the manufacturer's guarantee

- 4 Some road authorities believe that cost of the sign in-place should be used rather than just the sheeting cost. These cost elements include the substrate, manufacture, posts and installation expenses.

- 5 A critical determinant in the economic analysis is the selected performance life. Service lives of the various types of retroreflective sheeting are highly variable and dependent upon environmental conditions. Enclosed material sheeting has a reported maximum service life of 7 - 10 years and encapsulated sheeting is reported to have a 10 - 15 year service life. Instead of using an estimated service life, the manufacturer's performance life guarantee could be used.
- 6 However, the service life of the sign is as important as the service life of the sheeting itself. In areas of frequent vandalism, signs may have a short life span. Also, a sign may become obsolete because it was installed for a temporary situation or a new standard sign may necessitate its removal.
- 7 In selecting the appropriate performance life the road authorities should draw on their own experience where possible.
- 8 Although the economic analysis could be carried out on life-cycle costs alone, benefits derived by using a sheeting that maintains a higher level of reflectivity over its useful life could be included. One way to do this is to include a factor for the average luminance provided over the service life. This could be done by using the following equation:

$$C = \frac{TC}{\frac{L_n \times L_o}{2} \times PL}$$

Where:

C , TC and PL are as defined above

L_n = Luminance (SIA of new material), and

L_o = Luminance (SIA of worn material) at end of useful life.

However, this requires amassing data on the sign reflectivity at the end of the service life or guarantee or warranty period.

17.7 PRACTICAL CONSIDERATIONS**17.7.1 General**

- 1 Some practical considerations may influence the decision concerning which type sheeting to use. These are:
 - (a) if the signs are frequently vandalised (i.e. gun shots), which may be the case for a very low volume (i.e. rural locations), the apparent economic benefit of high performance sheeting would not be realised and the decision concerning which type sheeting to use would be based solely on driver requirements without regard to durability;
 - (b) having to stockpile and possibly manufacture signs using different sheeting may not be efficient.

17.8 SIGN FABRICATION

17.8.1 Application of Sheeting for Substrates

1 The sign manufacturing process typically starts with applying the blank or background retroreflective sheeting onto a rigid backing, known as the substrate, in one of two ways:

- (a) pressure sensitive adhesive; or
- (b) heat-activated adhesive.

For many small signs, pre-screened signfaces can be purchased and applied to the substrate.

2 If the pressure-sensitive adhesive is used, the sheeting is applied using either a manually driven squeeze roller or a larger power driven squeeze roller. If heat-activated adhesive is used, the sheeting shall be applied by heat lamp vacuum application method. The material manufacturer's specifications shall be adhered to.

3 One advantage of the pressure-sensitive adhesive method is that it can be applied much faster than the heat activated method. This is of particular concern for manufacturers producing a large volume of signs. However, many small volume sign manufacturers purchase pre-screened sign faces for their smaller signs such as STOP, YIELD and warning signs. These are more easily applied using the heat activated vacuum applicator method because the dry adhesive allows for proper positioning of the sign face on the pre-cut substrate. This is particularly advantageous for small guidance signs where individual letters are placed on the sheeting backing.

17.8.2 Application of Legend

1 The sign message or legend, which can consist of letters, numbers or symbols with borders, is applied by one of four methods:

- (a) screen process;
- (b) direct applied legend;
- (c) demountable legend.

2 During the screening method the message and borders are printed on the retroreflective sheeting using either a direct or reverse screen process. In both cases the message and border is photo-stencilled onto a screen film. This screen is set into a frame which is placed over the sheeting. The process colour is then poured over the screen and squeezed over the entire screen.

3 In the direct screen process, the process colour is printed through the message and border portions of the screen onto the sheeting. A typical example of this process is the application of black opaque ink to yellow sheeting for some construction signs. In the reverse screen process the process colour is printed through the background allowing the base sheeting to provide the message. A STOP or YIELD sign is made by the reverse screen process, with red transparent ink applied to white sheeting.

4 With the screening process, the quality of the colour dye or ink is crucial as early failure of the sign can occur when using the wrong ink. Sign manufacturers should follow the sheeting manufacturer's recommendations concerning inks or use a suitable substitute. Purchasers of pre-screened signfaces should obtain certification that the appropriate ink has been used.

5 In the direct application process, the message and borders are cut out of sheeting and this sheeting is placed directly on the background sheeting in the appropriate locations. This legend sheeting is attached by adhesive using either the pressure or vacuum application method. This method could be employed for guidance signs that are mounted at the side of the roadway, and for STREET NAME signs.

6 For alterations to larger side-mounted and overhead guidance signs, the legend is prepared as individual cut-outs of retroreflective sheeting applied to a thin metal substrate and attached to the background sign panel with screws, bolts or rivets.

17.9 HANDLING, STOCKPILING AND INSTALLATION

17.9.1 Handling and Stockpiling

- 1 The proper handling and stockpiling of retroreflective sheeting and fabricated signs are important to avoid premature failure. In all cases, follow the instructions and cautions of the manufacturer or suppliers. In general, good practices consist of the following;
 - (a) rolls of unapplied sheeting should be stored horizontally in the shipping carton or from a rod or pipe in a cool, dry area; unprocessed sheets should be stored flat;
 - (b) keep all finished signs dry; should signs become wet, dry off immediately;
 - (c) stack finished signs in racks with separations between faces.
 - (d) excessive pressure on signfaces can affect the sign's brightness;
 - (e) outdoor storage is not recommended but if necessary:
 - (i) place signs upright on edge on blocks to keep them off the ground;
 - (ii) provide space between signs to allow air circulation and moisture evaporation;
 - (iii) avoid signface contact with treated wood posts.
 - (f) when signs are transported for field installation they should be secured vertically in racks to prevent signs from rubbing against one another;
 - (g) packaging tape on the front of the sign should be avoided.

17.9.2 Sign Installation

- 1 The effectiveness of a new reflectorised sign can be comprised if not installed correctly. Several aspects of sign installation influence the sign's visibility and effectiveness. These include:
 - (a) location and position;
 - (b) longitudinal location along the highway;
 - (c) lateral clearance;
 - (d) height above ground;
 - (e) orientation angle.

Standards and guidelines on these aspects are provided in Volume 1, Chapter 1, Section 6.

17.10 REFERENCES

17.10.1 General

- 1 The following documents represent a useful reference base for those wishing to read further on the subject of signface materials, either generally or on specific points of detail.
 1. Federal Highway Administration, Manual on Uniform Traffic Control Devices for Streets and Highways. US Department of Transportation, Washington D.C., 1988.
 2. LUMIA, J.J., A Mobile System for Measuring Retroreflectance of Traffic Signs, NCHRP Project 5-10, February 1989.
 3. CUNARD, R.A., Maintenance Management of Street and Highway Signs, NCHRP Synthesis of Highway Practice 157. Transportation Research Board, National Research Council, Washington D.C., September 1990.
 4. Instrumental Photometric Measurement of Retroreflective Material and Retroreflective Devices, Federal Test Method Standard, March 1977.
 5. MACE, D.J., Sign Legibility And Conspicuity. Transportation Research Board, Special Report 218, Volume 2, pp. 270-293, 1988.
 6. Institute of Transportation Engineers, Traffic Sign Illumination with External Fluorescent Pictures, Technical Committee 7-C, Traffic Engineering 30, No. 6, March 1960.
 7. ALLEN, T.M., ET AL., Luminance Requirements for Illuminated Signs, Highway Research Record 179, 1967.
 8. MCGEE, H.W. and MACE, D.L., Retroreflectivity of Roadway Signs for Adequate Visibility: A Guide, Report No. FHWA/DF-88/001, Federal Highway Administration, Office of Direct Federal Programs, November 1987.
 9. International Commission on Illumination, Guide to the Properties and Uses of Retroreflectors at Night, Publication CIE No. 72, Vienna, Austria 1987.
 10. International Commission of Illumination. Road Signs. Publication CIE No. 74, Vienna, 1988.
 11. GOLDING, A.P., Eyesight on the Roads: A Demographic Investigation of the Relationship Between Visual Acuity and Accident Risk in Drivers. NIPN, Contract Report PERS 355, Pretoria, Human Sciences Research Council, 1984.
 12. PERCHONOK, K., and POLLACK, L., Luminous Requirements for Traffic Signs, Interim Report, Institute for Research, State College, Pennsylvania, December 1981.
 13. MACE, D.J. ET AL., Traffic Signs in Complex Visual Environments, Report No. FHWA/RD/82/102 November 1982.
 14. BHISE, V.D. ET AL., Modelling Vision with Headlights in a System Context, Society of Automobile Engineers, No. 770238, March 1977.
 15. DAHLSEDT, S.M., Luminance Uniformity and Legibility of Traffic Signs, Lighting Research and Technology 6, No. 4, 1974.
 16. OLSON, P.L., Minimum Requirements for Adequate Nighttime Conspicuity of Highway Signs, The University of Michigan Transportation Research Institute, Ann Arbor, Michigan. UNTRI-88-8, 1988.
 17. MORALES, J.M., Retroreflective Requirements for Traffic Signs - A Stop Sign Case Study, Report No. FHWA/RD-87-017, January 1987.
 18. WAGNER, J.A., Investigation of the Legibility of Sign Letter and Background Type Combination Under Various Conditions of Weather and Viewing and Durability of Reflective Sheeting, Florida Department of Transportation, FL/DOT/SMO/357-89, 1989.
 19. LAGERGREN, E., Traffic Sign Retroreflectivity Measurements Using Human Observers, Washington State Department of Transportation, WA-RD 140.1, 1987.
 20. MACE, D.J., ET AL., Signs Luminance Requirements for Various Background Complexities, Institute for Research, State College, Pennsylvania, Report FHWA/RD-85/056, September 1985.
 21. SATOR, W., Road Signs Replacement, Division of Roads and Transport Technology, CSIR, Pretoria for the Department of Transport (South Africa). Draft Research Report.
 22. International Commission of Illumination, Maintained Night-time Visibility of Retroreflective Road Signs, Publication CIE No. 113, 1995.
 23. MORALES, J.M., Reflective Requirements for Traffic Signs - A Stop Sign Case Study, Federal Highway Administration, FHWA/RD-87-017, January 1987.
 24. OLSON, P.L., Minimum Requirements for Adequate Night-time Conspicuity of Highway Signs, The University of Michigan, Report No UMTRI-88-8, February 1988.
 25. JENKINS, S.E., GENNAUI, F.R. Terminal Values of Road Traffic Signs, Australian Road Research Board Ltd. Special Report No, 49, Vermont South, ARRB, March 1992.

17.11 RETROREFLECTION - LITERATURE REVIEW

17.11.1 General

1 The following three topics are focused on in this review of literature:

- (a) principles of retroreflection and retroreflective sheeting materials;
- (b) specifications for retroreflective sheeting materials;
- (c) sign luminance requirements, feasibility of performance standards and sign maintenance practices.

17.11.2 Principles of Retroreflection

- 1 Nearly all road signs have to be legible and colour distinguishable at night as well as during the day. While this can be accomplished through external illumination of the signs, retroreflection is the most commonly used means of making signs visible to the driver at night. Three reports, "Retroreflectivity of Roadway Signs for Adequate Visibility: A Guide" (8), "Maintenance Management of Street and Highway Signs" (3) and "Guide to the Properties and Users of Retroreflectors at Night" (9) are the primary sources of the background information (see Section 17.10).
- 2 Retroreflection occurs when light rays strike a surface and are reflected back to the sources of light. Two principles followed to achieve retroreflectivity for road signs are prismatic and spherical lens retroreflection. Prismatic, also known as cube-corner, retroreflection is achieved through total internal reflection. As shown in Detail 17.1.1, incoming light hits the first surface and reflects to the rear surface, which reflects it to the last surface, which then reflects the light rays back to the source. Typically, the prismatic device reflects light off these surfaces at 90 degrees to each other, i.e. the corner of the cube. In the second type, spherical lens retroreflection is achieved through a combination of a glass sphere (bead) and a reflecting (mirror type) surface placed at the focal point. As shown in Detail 17.1.2 an incoming ray is bent and directed inside towards the back of the sphere, reflecting off the reflective surface, and after being bent at the exterior of the sphere.

17.11.3 Types of Retroreflective Sheeting

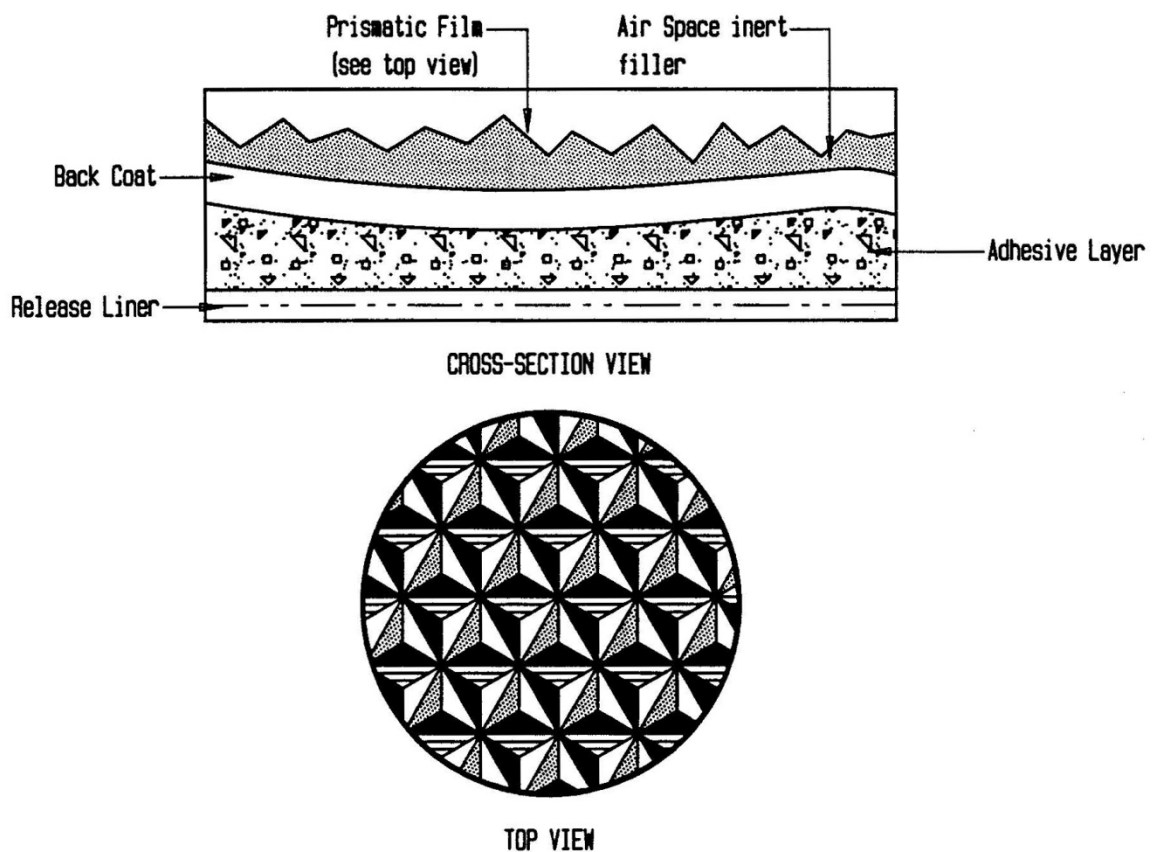
- 1 Retroreflective sheeting consists of micro cube-corners or spheres enclosed in a weather resistant transparent plastic film. To reflect colour, pigment or dye is inserted into the film or onto the reflecting surface. Figure 17.4 shows a typical construction of cube-corner retroreflective sheeting. This type of sheeting is typically manufactured with an air cushion behind the cubes. A unique property of this sheeting is its high co-efficient or retroreflection at low entrance angles, which means it appears bright at long distance if the device is not too far laterally removed from the light source.
- 2 There are three types of spherical lens (bead) retroreflective sheeting:
 - (a) exposed glass bead;
 - (b) enclosed glass bead;
 - (c) encapsulated glass bead.

These are shown in Detail 17.4.2.

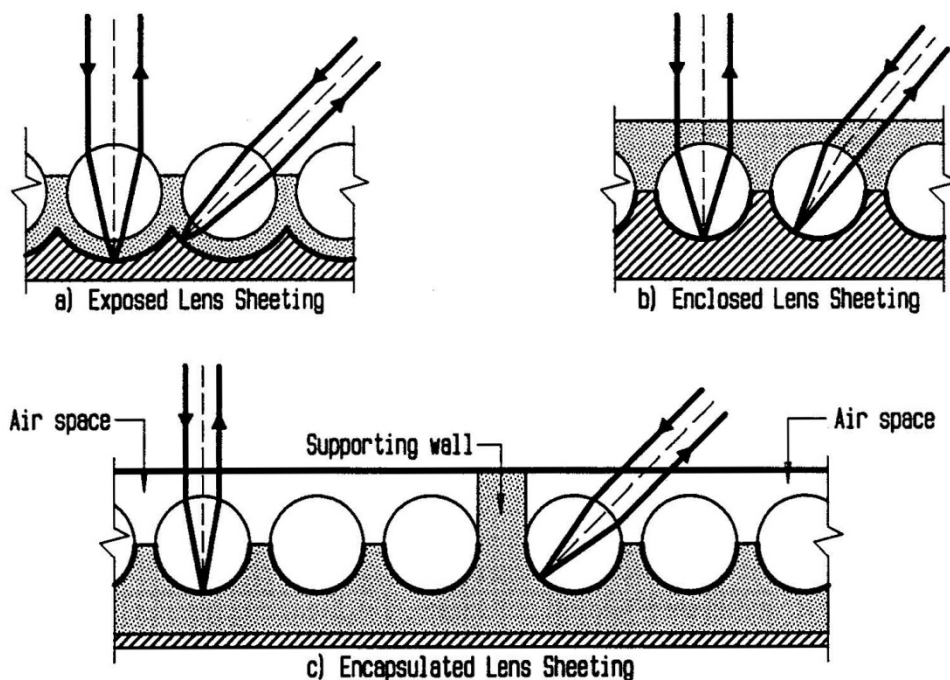
- 3 In the exposed lens sheeting the front half of the glass beads are exposed to the outside air. Glass beads work best when exposed to the air. However, because of the small size of the beads, a film of water can cover the beads when it rains and can greatly reduce the retroreflectivity of the beads. Hence, this type of sheeting is not recommended for road signs, and generally is not included in specifications. Nonetheless, exposed lens sheeting is still found on road signs on some low-volume rural roads controlled by local jurisdictions.
- 4 Enclosed lens sheeting material consists of a layer of transparent plastic of appropriate colour in which glass beads are imbedded. A metallic reflection shield is provided behind the plastic, with a layer of adhesive at the rear, which is covered by a protective liner that is removed during sign manufacture. The plastic covering enables the sheeting to be equally bright under dry and wet weather conditions.
- 5 With encapsulated lens sheeting the glass beads are also protected by a transparent material that is supported slightly above the beads by walls creating an air filled compartment. The back of the beads are covered with a reflective surface. The resulting airspace in front of the beads makes this type of sheeting more highly retroreflective, and is hence known as high performance sheeting.

17.11.4 Properties of Retroreflective Sheeting

- 1 One of the most important properties of retroreflective sheeting is the ability to return light which is commonly described by a variety of terms including brightness, retroreflectivity, luminance or candlepower. The International Commission of Illumination (SIE) (6) uses the term co-efficient of luminous intensity, which is defined as the ratio of luminous intensity of reflector in the direction of the observation to the illumination at the retroreflector on a plane perpendicular to the light. In the International System of Units (SI), i.e. the metric system, it is expressed as candelas (cd) per lux (lx). It is a measure of efficiency of the retroreflector, because it describes the amount of luminance (candelas) that emerge from the retroreflector per amount of light (lux) entering from the light source, i.e. the vehicle headlights. This definition treats the retroreflector as a point source. But because signs have a relatively large area they are treated as an extended light source which may be thought of as consisting of many point sources each with a luminance intensity of one candela. To account for this term, co-efficient (R) of retroreflection has been adopted by the CIE. It is merely the co-efficient of luminous intensity divided by the area and expressed in SI units as candelas per lux per square metre. (The English equivalency is candelas per foot-candle per square foot and is described as specific intensity per nit are (SIA). The conversion from English to metric (SI) is unity; hence, a value expressed in SIA terms is the same value in R terms).
- 2 The retroreflectivity of sheeting material is described in the context of another important property, namely angularity. Angularity is defined by the entrance (of the light) and the observation (of the motorist) angles. The entrance angle is the angle formed between a light beam striking the surface of a



Detail 17.4.1 Cross-Section and Top View of Cube-Corner Retroreflective Sheeting



Detail 17.4.2 Cross-Section View of Three Types of Spherical Lens Retroreflective Sheeting

Fig 17.4

Sections Through Types of Retroreflective Sheeting

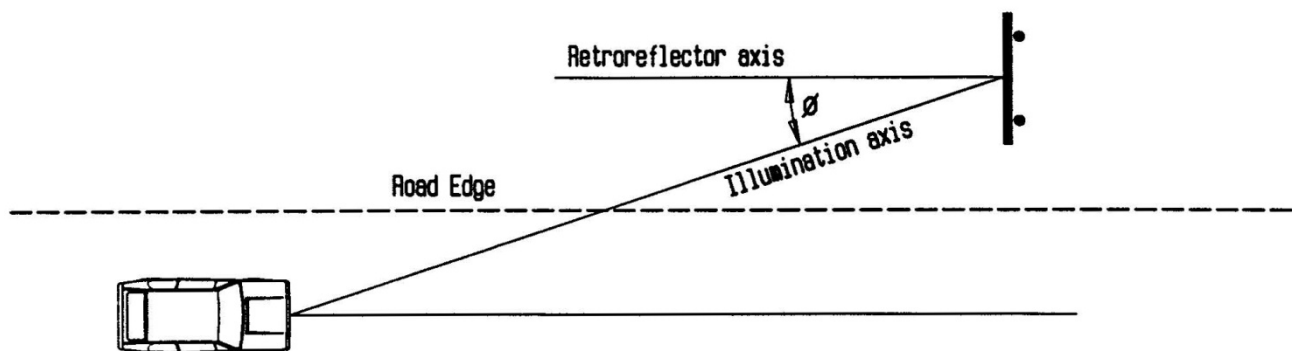
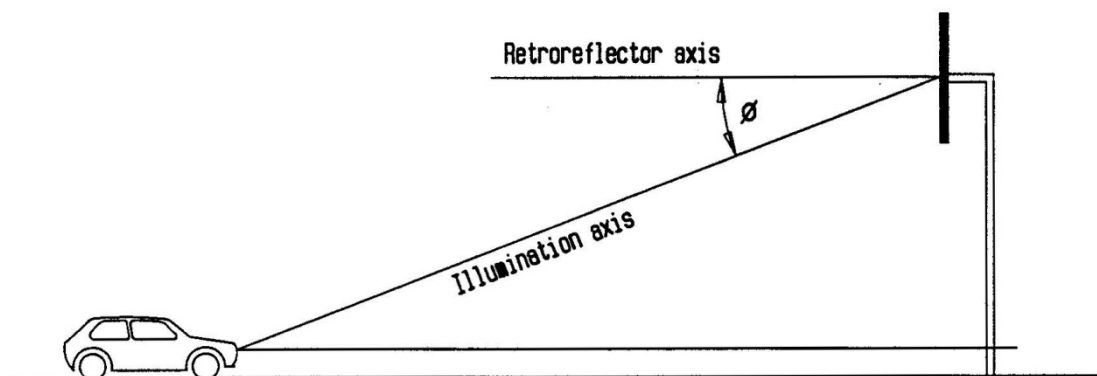
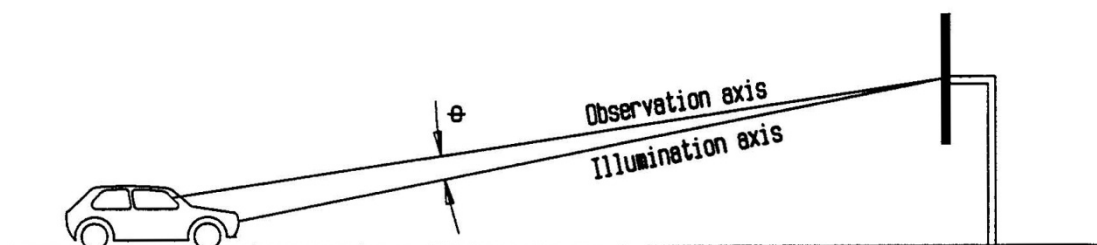
Detail 17.5.1 Entrance Angle (\emptyset) For Roadside SignDetail 17.5.2 Entrance Angle (\emptyset) For Overhead SignDetail 17.5.3 Observation Angle (Θ), Either Type Sign

Fig 17.5

Entrance and Observation Angles

sign and a line emerging perpendicular to the surface. The entrance angle changes with distance between the vehicle and is a function of the location of the sign and the vehicle. An entrance angle of 30 degrees is considered wide for highway signing. The observation angle is the angle between the incoming light beam, and the reflected light beam, and is a function of the height of the driver's eye with respect to the vehicle headlamps. Figure 17.5 illustrates the entrance and observation angles.

- 3 Since a retroreflective material is supposed to reflect most of the light directly back to the source, the optimum observation angle should be zero. However, in reality this is not the case since the driver's eye is higher than the vehicle headlight and can range from 530 mm for small cars to as much as 1625 mm for large trucks. A wide observation angle is anything over 2 degrees. For purchase specifications, minimum SIA is prescribed for each type of sheeting for two observations angles, two entrance angles, and the different colours.

17.12 LITERATURE SURVEY

17.12.1 General

- 1 It is clear from Section 17.3 that most of the visual problems concerning signs are related to the hours of darkness. For this reason many studies have concentrated on the retroreflectivity of signs. Relatively few studies have been conducted on the daylight visibility of signs (see Section 17.10 for relevant authors and studies).

17.12.2 Night-time Visibility of Retroreflective Road Signs

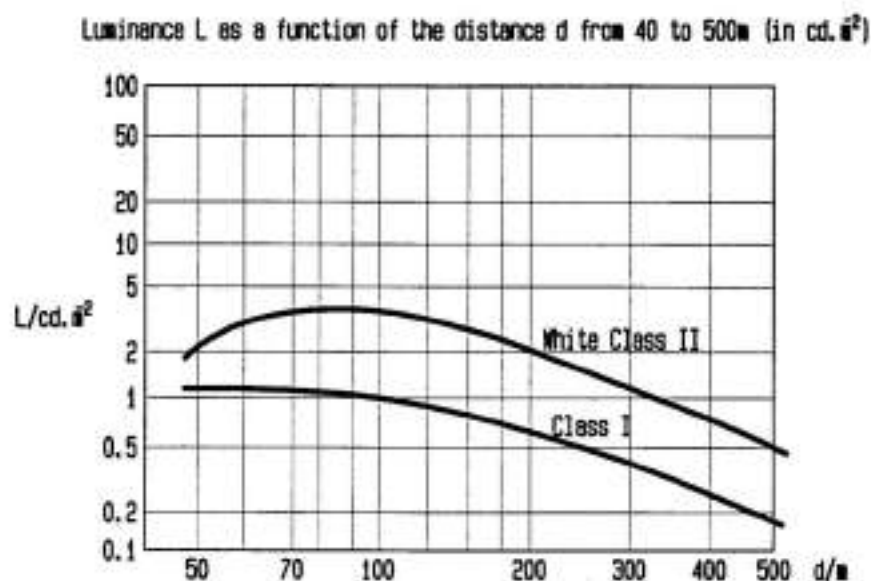
- 1 The CIE has produced a technical report on the night-time visibility of road signs. All the major research studies carried out internationally have been incorporated into this report. Two major reports on the minimum retroreflectivity requirements for traffic signs have also been produced, one in the USA and the other in Australia. Also of interest are two reports prepared in the USA on the minimum retroreflective requirements for STOP, warning and direction signs by Morales.
- 2 Morales conducted research into the minimum retroreflective values for STOP signs. A field test is used to obtain a relationship between the retroreflectivity and the recognition distance. He concludes that retroreflectivity is important but that the contrast ratio between the red and white for stop signs is not that important, because the stop sign is recognised by its unique shape, and does not necessarily have to be read to be understood.
- 3 Table 17.9 gives the minimum overall co-efficient of retroreflection for various approach speeds under ideal conditions as shown by Morales. He assumes a deceleration of $2,44 \text{ m/sec}^2$ and a perception-reaction time of 1,5 sec, with the overall co-efficient of retroreflection (cd/lx/m^2) = $0,76 \times \text{Red co-efficient of retroreflection} + 0,24 \text{ white co-efficient of retroreflection}$.
- 4 Olson investigated the conspicuity of signs at night. He found that background complexity, age of driver and colour of sign had a significant effect on the conspicuity of signs.

- 5 Table 17.10 gives the minimum values for red retroreflective values for STOP signs for the area complexity as found by Olson. These values apply to a 750 mm (USA 30 inch) STOP sign and are corrected for driver expectancy.
- 6 A major study on the terminal values of road signs has been conducted in Australia. The study carried out by Jenkins *et al*, was divided into five parts, namely literature review, daytime survey, night-time survey, laboratory experiment, to determine the terminal value of signs, and model for the determination of the terminal value of signs. The findings of this study are given below.
- 7 Literature review - Different studies determined the luminance of signs at different distances using two types of headlight beams (SAE and ECE). Figure 17.6 shows the luminance of overhead and shoulder mounted signs from 40 m to 500 m using ECE low beam headlights (Schmidt - Clausen 1983).
- 8 The night-time legibility of a sign as a function of its luminance has been studied over many years. Sivch and Olson reviewed 18 experiments and found that the geometric mean of these studies was $2,4 \text{ cd/m}^2$.
- 9 Furthermore, a number of studies into the night-time legibility of a sign as a function of its retroreflectivity have been conducted. It has been found that differences between the studies are significant. This is partly due to high legibility distances which had been chosen. Several studies have been conducted to determine the range of distances at which signs are used. A range of 50 m - 120 m was proposed.
- 10 The degradation of white Class I retroreflective sheeting has been studied in a number of countries. The regression lines found in Germany, Australia and South Africa are as follows:
 - (a) $\text{CIL/m}^2 = 83 - (3,30) (\text{Age})$;
 - (b) $\text{CIL/m}^2 = 106 - (3,30) (\text{Age})$;
 - (c) $\text{CIL/m}^2 = 82 - (3,30) (\text{Age})$.

TABLE 17.9 MINIMUM OVERALL RETROREFLECTIVE VALUES FOR SIGNS (SAE TYPE HEADLIGHTS) OF TWO SIZES (760 mm AND 610 mm) TABLE 17.9

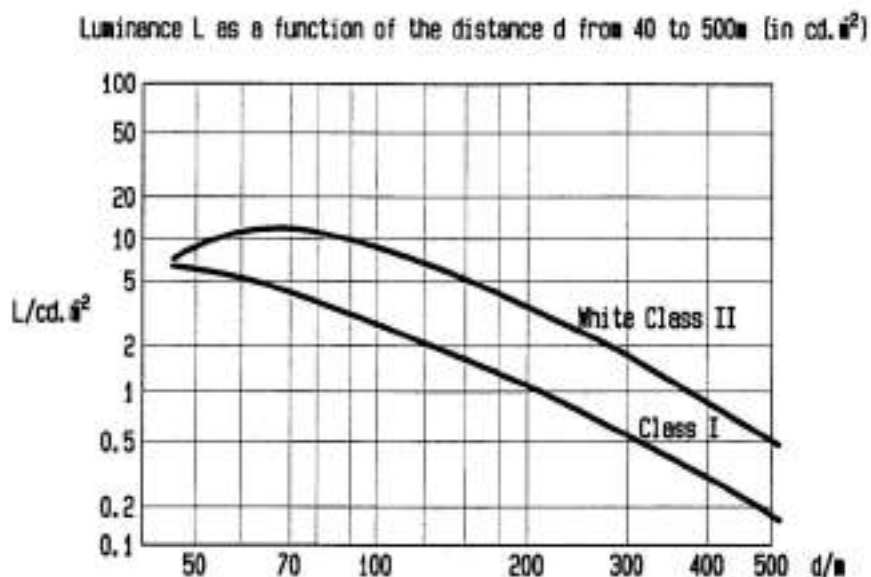
Speed	Stopping Distances	Overall Coefficient of Retroreflection	
		760 mm in 30 m	610 mm in 24 m
40 km/h	42 m	3	4
48 km/h	57 m	4	7
56 km/h	74 m	5	11
64 km/h	92 m	7	35
72 km/h	113 m	10	40
80 km/h	135 m	18	40
89 km/h	161 m	40	40
97 km/h	188 m	40	40

Luminance of white retroreflective material of Class I and II on an overhead sign illuminated by European asymmetrical H4 passing headlights (low beam)



Detail 17.6.1 Luminance of an Overhead Sign by Direct Illumination

Luminance of white retroreflective material of Class I and II on a shoulder mounted sign illuminated by European asymmetrical H4 passing headlights (low beam)



Detail 17.6.2 Luminance of a Shoulder Mounted Sign by Direct Illumination

Fig 17.6 Luminance of Road Signs as a Function of the Distance from the Sign

TABLE 17.10 **MINIMUM RED RETROREFLECTIVE VALUES** **TABLE 17.10**
FOR STOP SIGNS (cd/lx/m²)

Speed	Area Complexity		
	High	Medium	Low
48 km/h	8	3	2
56 km/h	26	5	3
64 km/h	30	11	4
72 km/h	70	25	8
80 km/h	170	63	14
89 km/h	*	155	30
97 km/h	*	*	70
105 km/h	*	*	150

* The use of supplementary warning signs is recommended

11 Daytime survey - 2 661 signs were measured in the field. The retroreflectivity of the symbol and background was measured with a field retroreflectometer (the entrance angle was -4° and the observation angle was $0,2^\circ$). The ages of 2 441 signs were recorded, these varied from 1 to 18 years. The deterioration of the retroreflectivity (CIL/m²) can be presented by the following linear regression for the different classes and colours:

- (a) White Class III CIL/m² = 294 - (4,05) (Age);
- (b) White Class I CIL/m² = 116 - (5,62) (Age);
- (c) Yellow Class I CIL/m² = 96 - (5,07) (Age);
- (d) Red Screened Class III CIL/m² = 16 + (3,1) (Age);
- (e) Green Class I CIL/m² = 22 - (1,02) (Age).

12 From data in North Queensland it was found that degradation was higher than average due to the higher UV. The regression equations were:

- (a) White Class I CIL/m² = 111 - (8,6) (Age);
- (b) Yellow Class I CIL/m² = 96 - (7,1) (Age).

13 The above results showed that white Class III material fell to 80% of its CIL/m² after about 14 years, and for Class I material the CL/m² fell to 50% after 10 years for white, yellow and green. The red screened signs showed that the colour faded to white and the CIL/m² increased with time.

14 The study also looked at the internal contrast between the sign legend and the sign background (recommended to be 7:1). For most signs (except STOP signs) the internal contrast could be considered to remain over the life of the sign. Due to the colour fading of the red on STOP signs the contrast is reduced with age. Class III STOP signs degraded below this value (7:1) after 8 years and class I after 4 years.

15 Night-time survey - the purpose of the night-time survey was to obtain photometric values of signs that were subject rated as being close to their effective life. Two hundred and ten retroreflective signs were judged. The results showed the following mean values:

- (a) 11 cd/lx/m² for White;
- (b) 4 cd/lx/m² for Red (screened);
- (c) 6 cd/lx/m² for Yellow;
- (d) 2 cd/lx/m² for Green.

There was a wide spread of results due to the difficulty of the subjective rating.

16 Laboratory experiment - the purpose of this experiment was to determine the minimum luminance and internal contrast of signs to ensure that they are conspicuous and legible.

17 Slides were used of traffic scenes which fell into three (low, medium and high) visual complexity categories. On the slides, warning and guidance signs were superimposed. For the conspicuity experiment the test person had to detect the sign in the traffic scene in a short time. For the legibility experiment the test person had to determine in which direction the gap in a Landolt C, which was marked on the signs, was pointing.

18 It was found that the average luminance for guidance signs should be 3,2cd/m² with the legend luminance of 16,2 cd/m² and a background luminance of 2,3 cd/m². For warning signs luminance should be 9,7 cd/m². It was also found that the contrast should be greater than 3.

17.12.3 Durability of Road Signs with Regard to Retroreflectivity

1 Transportek has been investigating the durability of road signs in South Africa since 1981. These investigations concentrated on the changes of retroreflective value and colour over time. A number of surveys have been carried out on public roads, mostly in the then Transvaal because the date of manufacture of signs was recorded on the back. From this the age of the sign could be determined, which made it possible to determine a relationship between the change in retroreflectivity and the sign's age.

2 It was found that the regression lines were as follows:

(a) White Class I retroreflection = $82 - (3,06) (\text{Age})$;

(b) Red Class I (pigmented) retroreflection = $21 - 0,97 (\text{Age})$.

For the other coloured sheeting an adequate relationship could not be found.

3 These regression lines show that the durability with regard to retroreflectivity for white and red sheeting is very good. For the white sheeting to deteriorate to the SANS value specified for weathered samples (40 cd/lx/m^2) would take 13,7 years while red (8 cd/lx/m^2) would take 13,2 years.

4 The main problems found with the durability was the fading of the red colour, especially if the colour was screened. When SANS colour boundaries were used, approximately 59% of the pigmented and 96% of the screened signs failed.

5 Transportek has also conducted accelerated natural weathering tests on sign materials since 1987. Similar results were obtained as in the field surveys. The regression equation for white Class I was found to be retroreflection = $73 - (3,38) (\text{Age})$.

6 The literature study shows that these equations are similar to relationships found in Australia and Germany. The accelerated natural weathering test also showed that the fading of the red screen colour is the main problem. Recently, new red screened samples have been tested and are showing an improved result.

7 Green, blue and yellow road sign materials did not prove to be a problem with regard to durability.

ROAD MARKING MATERIALS

SECTIONS

- 18.0** Contents
- 18.1** Introduction
- 18.2** Driver's Needs and Road Marking Characteristics
- 18.3** Retroreflectivity for Night Visibility
- 18.4** Painted Markings
- 18.5** Thermoplastics and Other Durable markings
- 18.6** Roadstuds (raised Pavement Markers)

MAY 2012



TITLE SOUTH AFRICAN ROAD TRAFFIC SIGNS MANUAL Volume 2 Chapter 18			
ISBN	STATUS Digitised Version	DOT FILE 000/0/0/0	DATE Digitised May 2012
DIGITISING CARRIED OUT BY Transport and Traffic Technology Africa (Pty) Ltd P O Box 1109 SUNNINGHILL 2157			
COMMISSIONED BY Department of Transport Private Bag X193 PRETORIA 0001			
ORIGINAL AUTHORS J J Prinsloo S E Grosskopf F J J Labuschagne D Bain		PUBLISHER ENQUIRIES Director-General: Transport Private Bag X193 PRETORIA 0001	
It is impossible for a publication of this nature to free of errors. It would be appreciated if errors be brought to the notice of - Director-General: Transport Department of Transport Infrastructure Network Management Private Bag X193 PRETORIA 0001			
COPYRIGHT This publication is protected by copyright under the Bern Convention. In terms of the Copyright Act No. 98 of 1978, no part of this publication may be produced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording or by any information storage or retrieval system, without permission in writing from the publisher. © National Department of Transport 1999, 2012			
KEYWORDS ROAD SIGN, ROAD MARKING, REGULATORY, WARNING			
COST: VOLUME 2			
VOLUME SET		R	
Chapter 1	R	Chapter 11	R
Chapter 2	R	Chapter 12	R
Chapter 3	R	Chapter 13	R
Chapter 4	R	Chapter 14	R
Chapter 5	R	Chapter 15	R
Chapter 6	R	Chapter 16	R
Chapter 7	R	Chapter 17	R
Chapter 8	R	Chapter 18	R
Chapter 9	R	Chapter 19	R
Chapter 10	R		

CHAPTER 18: ROAD MARKING MATERIALS

CONTENTS

18.0.1 Sections and Subsections

Number	Title	Page No.
18.0	CONTENTS	18.0.1
18.0.1	Sections and Subsections	18.0.1
18.0.2	Figures	18.0.2
18.1	INTRODUCTION	18.1.1
18.1.1	General	18.1.1
18.1.2	Objectives	18.1.1
18.1.3	Coverage of this Chapter	18.1.1
18.1.4	SABS Standards	18.1.1
18.1.5	Road Marking Classification	18.1.2
18.2	DRIVER'S NEEDS AND ROAD MARKING CHARACTERISTICS	18.2.1
18.2.1	General	18.2.1
18.2.2	Roadway Geometry	18.2.1
18.2.3	Climatic Characteristics	18.2.1
18.2.4	Traffic Characteristics	18.2.1
18.2.5	Effect of Road Surfaces	18.2.2
18.2.6	Implication of Variables	18.2.4
18.3	RETROREFLECTIVITY FOR NIGHT VISIBILITY	18.3.1
18.3.1	General	18.3.1
18.3.2	Reflective Properties of Glass Beads	18.3.1
18.3.3	Refractive Index	18.3.1
18.3.4	Bead Size or Gradation	18.3.4
18.3.5	Flotation Beads	18.3.4
18.3.6	Application Techniques	18.3.4
18.3.7	Pre-mixed Marking Materials	18.3.4
18.3.8	Volume of Beads Applied	18.3.4
18.3.9	Summary of Glass Bead Usage	18.3.4
18.4	PAINTED MARKINGS	18.4.1
18.4.1	General	18.4.1
18.4.2	Uses	18.4.1
18.4.3	Materials	18.4.1
18.4.4	Classification of Paint	18.4.1
18.4.5	Essential Properties of Paint	18.4.1
18.4.6	Paint Formulation	18.4.2
18.4.7	Performance	18.4.2
18.4.8	Causes of failure	18.4.3
18.4.9	Range of Service Life	18.4.3
18.4.10	Application	18.4.3
18.4.11	Equipment	18.4.3
18.4.12	Line Protection and Safety	18.4.4
18.4.13	Crew Size	18.4.5
18.4.14	Maintenance	18.4.5
18.4.15	Scheduling of Re-marking Activities	18.4.5
18.4.16	Spotting	18.4.5
18.4.17	Pre-treatment of the Surface	18.4.5
18.4.18	Removal of Paint Markings	18.4.6

18.5	THERMOPLASTICS AND OTHER DURABLE MARKINGS	18.5.1
18.5.1	General	18.5.1
18.5.2	Uses	18.5.1
18.5.3	Materials	18.5.1
18.5.4	Properties of Thermoplastic	18.5.1
18.5.5	Use and Properties of Cold Applied Thermoplastic	18.5.1
18.5.6	Application	18.5.2
18.5.7	Application Thickness	18.5.2
18.5.8	Installation of Hot Applied Thermoplastics	18.5.2
18.5.9	Application Equipment	18.5.2
18.5.10	Storing and Field Handling of Materials	18.5.2
18.5.11	Conditioning the Road Surface	18.5.2
18.5.12	Installation of Cold Laid Plastics	18.5.3
18.5.13	Service Life	18.5.4
18.5.14	Maintenance	18.5.4
18.5.15	Staining	18.5.4
18.5.16	Patching	18.5.4
18.5.17	Replacement	18.5.4
18.5.18	Removal	18.5.4
18.6	ROADSTUDS (RAISED PAVEMENT MARKERS)	18.6.1
18.6.1	General	18.6.1
18.6.2	Uses	18.6.1
18.6.3	Functional Applications	18.6.1
18.6.4	Considerations for Applications	18.6.1
18.6.5	Materials	18.6.1
18.6.6	Physical Characteristics of RPM's	18.6.1
18.6.7	Adhesion Characteristics	18.6.2
18.6.8	Temporary Delineation Using RPM's	18.6.4
18.6.9	Application of Self Adhesive Markers	18.6.4
18.6.10	Performance	18.6.4
18.6.11	Conventional Markers	18.6.4
18.6.12	Installation Procedures	18.6.5
18.6.13	General Practice	18.6.5
18.6.14	Using Epoxy Adhesives	18.6.5
18.6.15	Maintenance	18.6.5
18.6.16	Routine Maintenance Levels	18.6.6
18.6.17	"As Needed" Maintenance	18.6.6
18.6.18	Cleaning RPM's	18.6.6

18.0.2 Figures

Figure No.	Title	Page No.
Fig 18.1	Representative Plots of Service Life v AADT	18.2.3
Fig 18.2	Retroreflection and Reflection	18.3.2
Fig 18.3	Focal Point for Commonly Used Glass Beads	18.3.3
Fig 18.4	Retroreflecting Brads for Road Markings	18.3.5
Fig 18.5	Principle and Structure of Corner-Cube Retroreflector	18.6.3

CHAPTER 18: ROAD MARKING MATERIALS

18.1 INTRODUCTION

18.1.1 General

- 1 Road markings, as we know them, first appeared at the beginning of this century as painted, unbroken, white centre lines to denote dangerous bends and the brows of hills. Today they are used extensively and universally, and come in a variety of configurations and materials. The two major materials are paint and thermoplastic.
- 2 Road markings, particularly longitudinal markings, play a valuable role in maintaining the continuity of visual information to drivers. The provision of continuous road markings along a road is practical, whereas the provision of continuous visual information by means of road signs is not. Such road markings are thus important to the driving task and in particular the task of vehicle control in terms of the disciplined use of road space (see Volume 1, Chapter 1, Sections 1.7 and 1.8).
- 3 As with most technologies, the development of road marking materials went through several stages in an endeavour to find the road marking material with the lowest cost which also provides the safest operating environment. In this context, it is necessary to consider road marking materials with:
 - (a) low initial cost;
 - (b) good day-time and night-time visibility in dry and wet conditions;
 - (c) adequate skid resistance;
 - (d) application methods with minimum traffic interference.
- 4 The application of road markings is more than a matter of painting lines. It is, in effect, the installation of a traffic regulating system on a highway. As with all other traffic control devices, road markings must be readily recognised and understood, and this goal can only be achieved by using a uniform system of road markings, and only when they are desired and warranted. Motorists should be confronted with the same type and quality of road markings whenever they travel by road, and these road markings should convey exactly the same meaning wherever they are encountered.

18.1.2 Objectives

- 1 The objectives to be aimed for in providing road markings are:
 - (a) road safety;
 - (b) conformity of practice;
 - (c) good traffic management leading to optimum road capacity;
 - (d) provision of the correct marking first time.
- 2 The application of road markings to the road surface, and the subsequent maintenance of them represents an on-going budgetary problem for all road authorities. It is therefore the objective of this chapter (together with Chapter 2: *Road Marking Applications*) to provide sufficient information and guidance to those involved with road markings to create an awareness of the need to ensure the effectiveness of the markings they provide as well as good quality road marking materials.

18.1.3 Coverage of this Chapter

- 1 Individual road markings and their functions and basic dimensions are detailed in Volume 1, Chapter 7. Detailed dimensions of individual road markings, such as arrows and symbols, previously included in Volume 4, Chapter 12, have been incorporated into Chapter 2 of this volume of the manual to enhance the completeness of that chapter. The specification of road markings and the materials from which they are created is limited. Details of the specifications are given in Chapters 1 and 7 of Volume 1.
- 2 Typical examples of road marking applications are given in Chapter 2, and concentrate on combinations of road markings, and where appropriate, their dimensional relationship.
- 3 The major part of this chapter is based on the "Roadway Delineation Practices Handbook" of the USA Federal Highway Administration. There is little published specific to South African road marking practices and materials, and it remains necessary that on-going attention be given to the development of the local road marking materials and their application.
- 4 The coverage of this chapter focuses on the following aspects:
 - (a) drivers needs and delineation characteristics (Section 18.2 and 18.3);
 - (b) painted markings (Section 18.4);
 - (c) thermoplastics and other durable markings (Section 18.5);
 - (d) raised pavement markings (Section 18.6).

18.1.4 SABS Standards

- 1 A few SABS Standards are applicable to road markings specifically. These standards are listed below for reference purposes and although very important in terms of the application of road marking materials, this chapter does not cover their technicalities:
 - (a) SANS 731 - 1: 2006 - *Road Marking Paints*:
 - (i) Types:
 - solvent-borne paints;
 - water-borne paints;
 - skid-resistant paints;
 - obliterating paints;
 - (ii) Retroreflectivity:
 - (iii) Practical aspects:
 - conditions in container;
 - storage stability;
 - application properties;
 - colour and luminance factors;
 - drying time;
 - skid resistance;

(iv) Laboratory Aspects

- sagging;
- hiding powers;
- loss;
- resistance to bleeding;
- resistance to artificial weathering;
- resistance to abrasion;
- alkali resistance;

(v) Maintenance Aspects:

- resistance to traffic wear:
 - ~ Wear Index;
 - ~ retroreflectivity;
 - ~ skid resistance;

(vi) Packaging and Working Requirement:

- brand name;
- type of paint (typical application and number);
- colour;
- suitability for drop-on beads;
- drying time classification;
- batch identification;
- directions for use;

(vii) Tender Specifications:

- paint type;
- site description;
- road surface type;
- retroreflectivity requirements;
- drying time classification;
- colour;
- resistance to traffic wear;

(b) SANS 731 - 2: 2006 *Hot-melt Thermoplastics*:

based on BS3262, namely:

(i) Part 1: Materials and Mixtures;

(ii) Part 2: Road Performance;

(iii) Part 3: Application;

- application types:
 - ~ screeded lines (2 mm to 5 mm);
 - ~ sprayed lines (0.8 mm to 1,5 mm);
 - ~ extruded lines (2,5 mm to 3,5 mm);

(c) SANS 1442: 2008 - *Roadstuds*:

(i) Classification:

- A: corner cube reflectors;
- B: biconvex reflectors;
- C: omnidirectional reflectors;

(ii) Physical Attributes:

- construction;

- height;
- colour;
- retroreflectivity;
- resistance requirements to penetration by water, heat fuel, lubricating oil, corrosion.

18.1.5 Road Marking Classification

1 Road markings are made up of the following types:

- (a) transverse markings (approximately at right angles to the roadway centre line);
- (b) longitudinal markings;
- (c) arrows;
- (d) painted islands;
- (e) symbols;
- (f) words, letters and/or numerals;
- (g) parking markings;
- (h) roadstuds;
- (i) other delineation devices.

2 Road markings are classified by their functional purpose. In this way a particular type of marking such as an arrow, which is identical in shape to another arrow, may take on a different function according to the manner in which it is used or according to its colour. It should be noted that whilst different markings are applied in different colours, specific colours are not linked to specific functions i.e. **Whilst (with one minor exception) yellow is only used for regulatory markings, all regulatory markings are not yellow in colour.** The exception to the use of yellow occurs when SYMBOL MARKINGS GM6 and/or WORD MARKINGS GM7 are used with a regulatory marking, under which circumstances it is recommended that the GM6 and/or the GM7 markings also be applied in yellow. Approved legal road marking styles, patterns, and symbols are illustrated in Chapter 2, Section 2.0.

3 The functional classification of road markings is as follows:

- (a) regulatory markings;
- (b) warning markings;
- (c) guidance markings;
- (d) roadstuds;
- (e) other delineation devices.

4 The following rules apply in general to the wide range of road markings:

- (a) broken longitudinal lines are permissive;
- (b) continuous longitudinal lines are restrictive;
- (c) double continuous solid longitudinal lines indicate maximum levels of restriction;
- (d) an increase in the width of a line and/or in the "density" of a broken line, is an indication of increased emphasis in the message given by the marking;
- (e) no road marking shall be less than 100 mm in width.

5 **Broken line markings are not random patterns of lines and gaps.** Each such marking type has specific dimensions and the patterns are repeated at regular intervals as MODULES (see Chapter 2).

18.2 DRIVER'S NEEDS AND ROAD MARKING CHARACTERISTICS

18.2.1 General

- 1 The primary purpose of a roadway delineation system is to provide the visual information needed by the driver to steer a vehicle safely in a variety of situations. The delineation technique used must define the field of safe travel, must be visible in daylight and darkness, and in periods of adverse weather such as rain and fog.
- 2 There are several key variables that should be considered in determining the most appropriate delineation treatment and technique. These include the geometry of the roadway, the climatic characteristics, traffic volumes and composition, and the type of pavement surface. A brief review of the significant effects of these variables is given in subsequent subsections.

18.2.2 Roadway Geometry

- 1 Roadway geometry has more effect on the delineation "treatment" than on the various delineation techniques. In this context, "treatment" refers to such issues as the installation of dividing lines, edge lines, etc., as well as width, spacing, colours etc. "Techniques" involve the various delineation devices, materials and application procedures.
- 2 The following geometric situations are the most important:
 - (a) tangent sections;
 - (b) horizontal curves;
 - (c) no overtaking zones;
 - (d) pavement width transitions;
 - (e) merging/diverging areas;
 - (f) turns;
 - (g) turns with deceleration and/or storage lanes;
 - (h) STOP approaches;
 - (i) railway crossings, pedestrian crossings etc.

Each of these situations has a unique set of driver information needs and associated delineation requirements.

18.2.3 Climatic Characteristics

- 1 The prevailing climate and weather conditions greatly influence the effectiveness of delineation techniques from the standpoint of a driver's visual ability. Durability of materials and installation activities are also influenced by weather.
- 2 Rain, at any time, reduces the ability of the drivers to visualise their surroundings. At night, glare from the headlights of on-coming vehicles, windscreen wiper action, and the slippery pavement surface coupled with degraded reflectivity of painted markings make the driving task on rainy nights particularly hazardous and difficult. Retroreflective raised pavement roadstuds and post delineators are much more effective than painted markings which lose their reflectivity due to the film of surface water. During daytime rainy periods, the roadstuds do little to improve visibility, but the audible effect of passing over the roadstuds serves to alert the driver to a potential inadvertent encroachment into an adjacent lane.
- 3 Fog creates an extremely hazardous situation by seriously reducing driver's visual ability. There are no really cost-effective

delineation techniques that will provide adequate roadway delineation although experiments overseas with various types of surface highway lighting have been undertaken.

- 4 Blowing sand, like fog, can seriously reduce driver's visual ability. It can also collect on the roadway and obscure pavement markings. It may damage paint and thermoplastic by the abrasive and sandpaper effect of tyre action on the sand over the marking. Because of the hazards inherent in blind driving through fog or blowing sands, some road authorities close the highway or provide escorts for platoons of vehicles through the affected areas.
- 5 In addition to the physical presence of rain, snow, fog or blowing sands, weather in terms of extremely hot or cold climates can influence delineation. For example, some materials such as thermoplastics or paint are specially formulated to withstand extreme temperatures. The effects of a freeze-thaw cycle on the pavement surface as well as the delineation materials can induce early failure by weakening the bond with the pavement surface.
- 6 In summary, the climatic and weather conditions must be considered to determine not only the most appropriate delineation treatment (spacing etc.), but to assure that the delineation techniques and materials are compatible with the site specific conditions. The reduced visibility associated with the effects of weather such as rain, snow, fog, etc., make driving extremely hazardous. Consequently, the safety aspects of providing the best possible guidance to the driver in such situations, transcends the traditional cost effectiveness concerns.

18.2.4 Traffic Characteristics

- 1 Traffic conditions can effect the choice of delineation treatments and techniques from two stand-points:
 - (a) traffic volumes;
 - (b) traffic composition.
- 2 Traffic volumes are important in that the average annual daily traffic (AADT) is often the major criterion used to select specific types of delineation techniques. For example, high density roadways may be better served by the installation of high durability devices such as roadstuds, hot laid thermoplastic, or epoxy. These will not only provide long-term delineation, but will avoid the necessity of frequent re-marking. Hence the exposure of maintenance crews and traffic disruption can be significantly reduced. Higher initial cost can be balanced against the safety and long-term economic benefits of the more durable materials.
- 3 Low AADT may indicate that painted markings alone, or in combination with roadstuds or post delineators are adequate and may last one or more years without re-marking. It may be found that markings for very low density roadways can be served by reduced thickness or line width depending on the site characteristics.

- 4 Traffic composition can affect the effective life of various delineation materials. Trucks, buses and other heavy equipment constituting the majority of traffic can damage or wear out roadway markings much faster than traffic composed of passenger vehicles. Rural farm-to-market low traffic density roads or industrial access roads, for example, may therefore require heavier or more durable applications than would be indicated strictly on the basis of the AADT.
- 5 As a general rule, however, AADT is most often correlated with service life as shown in the example in Figure 18.1. Some agencies have developed more complex correlations. For example, the District of Columbia, in USA, uses the number of wheels crossing as an indicator rather than the simple AADT. The reasoning being that traffic abrasion occurs only when the wheels of a vehicle pass over a marking. Edge lines or heavily travelled freeway lane lines may not experience the same wear as lower AADT areas in which crisscrossing or encroachment is more pronounced.
- 6 A technique used for calculating the life expectancy as a function of traffic flow is based on the following functions and definitions:
 - (a) wear of road marking materials is a function of the second power of the number of vehicles per lane passing over the materials laid normal to the direction of traffic flow;
 - (b) **Life Expectancy** is defined as measured by the total number of vehicles per lane that have passed over the marking when it is worn completely from the wheel paths;
 - (c) **Service Life** is a measure of the number of vehicles per lane that have passed over the material when the marking is no longer serviceable on account of having lost its lustre or its retroreflectivity (night visibility) of having been worn completely from the surface in the wheel paths;
 - (d) road markings on conventional traffic paint and instant setting materials lost their lustre and beads lose their retroreflectivity to the extent to which they should be renewed when material in the wheel paths has been worn away to half its original area;
 - (e) thermoplastic markings retain brightness and beads are retroreflective until all of the material in the wheel paths has been worn away from the road surface;
 - (f) **Cost Effectiveness** is the ratio of the cost per linear metre of marking to the service life expressed in millions of vehicles per lane of traffic.

This technique appears to work well for high density facilities. Whether general or sophisticated correlations are developed depends on the types and functions of the specific site. **The point of emphasis is that the traffic characteristics of a given site can become an important consideration especially in evaluating cost effectiveness of the more durable delineation techniques.**

18.2.5 Effect of Road Surface

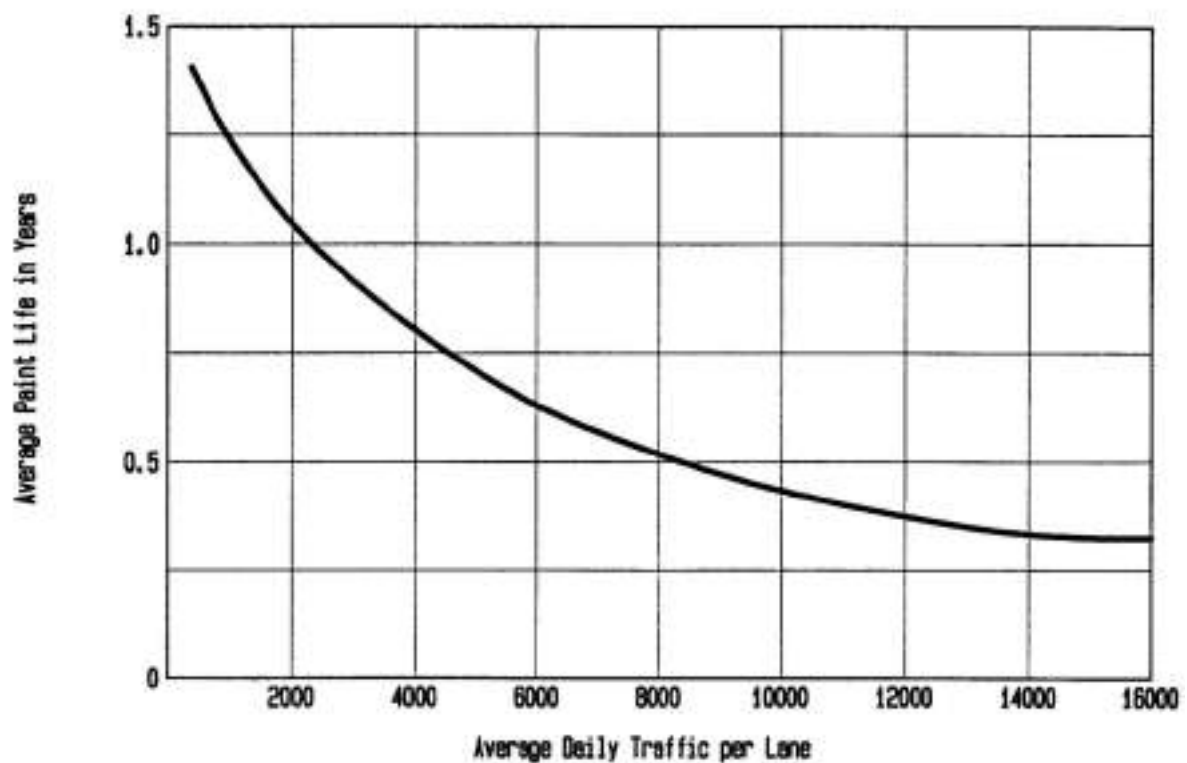
- 1 Variations in type and condition of the pavement determines to a large extent, the durability and visibility of the materials used in road markings. It is therefore appropriate to review the basic characteristics of the two most widely used pavement surfaces. Basically, the road surfaces upon which road markings are applied fall into two general categories:
 - (a) asphalt; and

(b) concrete.

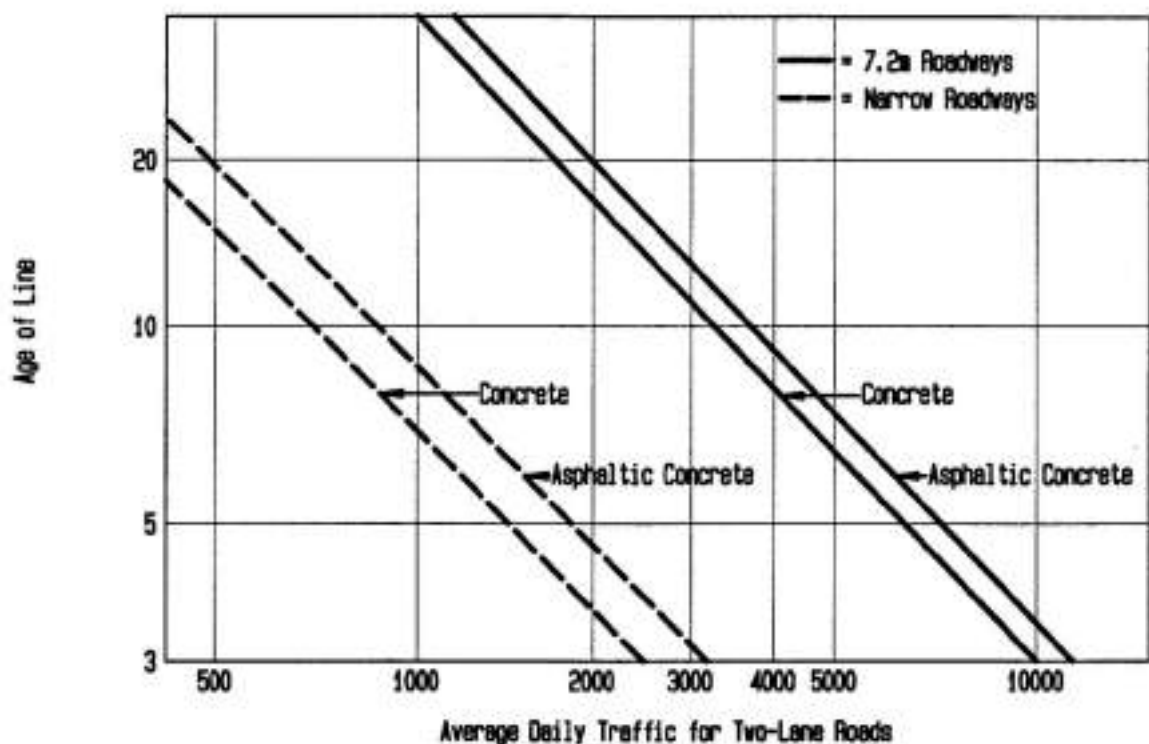
- 2 Asphalt denotes a dense graded road surface made of hot mineral aggregates plant-mixed with hot asphalt. The coarse aggregate is generally crushed stone, crushed slag, or crushed gravel to which is added sand, or sand and filler.
- 3 Another form of asphalt concrete is referred to as "open-graded". In this form, only coarse aggregate is used. When applied as a surface course, it has a high porosity and permeability as well as a rough surface texture. The porous characteristics minimise the potential for hydroplaning by allowing numerous escape channels for water beneath a moving tyre. Of importance to delineation, water ponding on the pavement surface is reduced, thereby minimising the time in which pavement markings are made ineffective as reflective devices.
- 4 Concrete road surfacing consists of a relatively rich mixture of cement, sand, coarse aggregate and water laid as a single course. When properly designed and constructed, it has a long life and relatively low maintenance requirements. A minimum of five to seven days curing time is required before the pavement is ready for use.
- 5 As the service life of asphalt pavements is dependent on so many variables (type of aggregate, type of base, traffic density, climate conditions etc) and "average" life expectancy is of little value. It is, however, a general "rule of thumb" that concrete pavements outlast asphalt ones by about 2:1. Another major difference is that concrete pavements are much smoother than asphalt pavements and are often "scored" or treated to increase skid resistance.
- 6 The life of the pavement is particularly significant when considering the application of highly desirable delineation treatments. For example, roadstuds or thermoplastic markings, under certain circumstances could out last an aging asphalt surface. The relatively high initial cost of these treatments is justifiable on the basis of durability and longevity. Since imminent resurfacing or reconditioning of asphalt pavements would cancel out one of the major advantages of such long term application techniques, alternate methods should be considered for the interim period.
- 7 Greater quantities of paint or hot-applied thermoplastic materials are required for the open-graded pavement surface because of its porous nature. It does, however, provide better wet-night visibility. With raised markers, the problem in obtaining a secure bond with the rough surface results in a high percentage of dislodged markers.
- 8 These properties and characteristics have a profound effect on the performance of various delineation materials and devices. Accordingly, the type and condition of the pavement surface should be carefully considered in the selection of the most appropriate delineation system.

18.2.6 Implications of Variables

- 1 The ideal form of delineation is that which provides the best overall return as measured by informed driver behaviour, safety, free movement of traffic, and cost. There are various marking and delineation techniques which may be used individually or collectively, as appropriate.



Detail 18.1.1 Paint Marking as Affected by Traffic Density for Both Bituminous and Concrete Pavement



Detail 18.1.2 Conditions for Noticeable Traffic Line Wear (White Traffic Paint Placed at 0.38mm Wet with 0.61kg of Beads per litre)

Fig 18.1

Representative Plots of Service Life v AADT

- 2 The particular advantages or drawbacks of each of these techniques and their general characteristics are described in the following sections. In order that best use be made of the funds available for marking devices, it is necessary to choose delineation techniques that meet the requirements of a specific site economically and adequately.
- 3 The selection of delineation techniques and materials purchase is a recurring activity for road authorities. There is no universal configuration that serves all needs equally well. To achieve the best balance among driver requirements, safety aspects, and economic considerations, each of the variables discussed above must be assessed to determine their impact on effectiveness. The following sections seek to place in perspective current practices and rationale used in the decision process.

18.3 RETROREFLECTIVITY FOR NIGHT VISIBILITY

18.3.1 General

- 1 According to Volume 1, Chapter 7, "...markings which must be visible at night shall be reflectorised unless ambient illumination assures adequate visibility". There are so few roads within a road authority's jurisdiction that are typically well illuminated that the trend amongst road authorities is to reflectorise all road markings, with the possible exception of painted kerbs and parking bays.
- 2 Glass beads are mixed with, or dropped on, the paint, thermoplastic, polyester, and epoxy road markings to provide the necessary reflectivity. The characteristics, typical usage, and the major factors influencing the application of glass beads are discussed in the following subsections. The corner cube reflectivity technique used in raised roadstuds is discussed in Section 18.6.

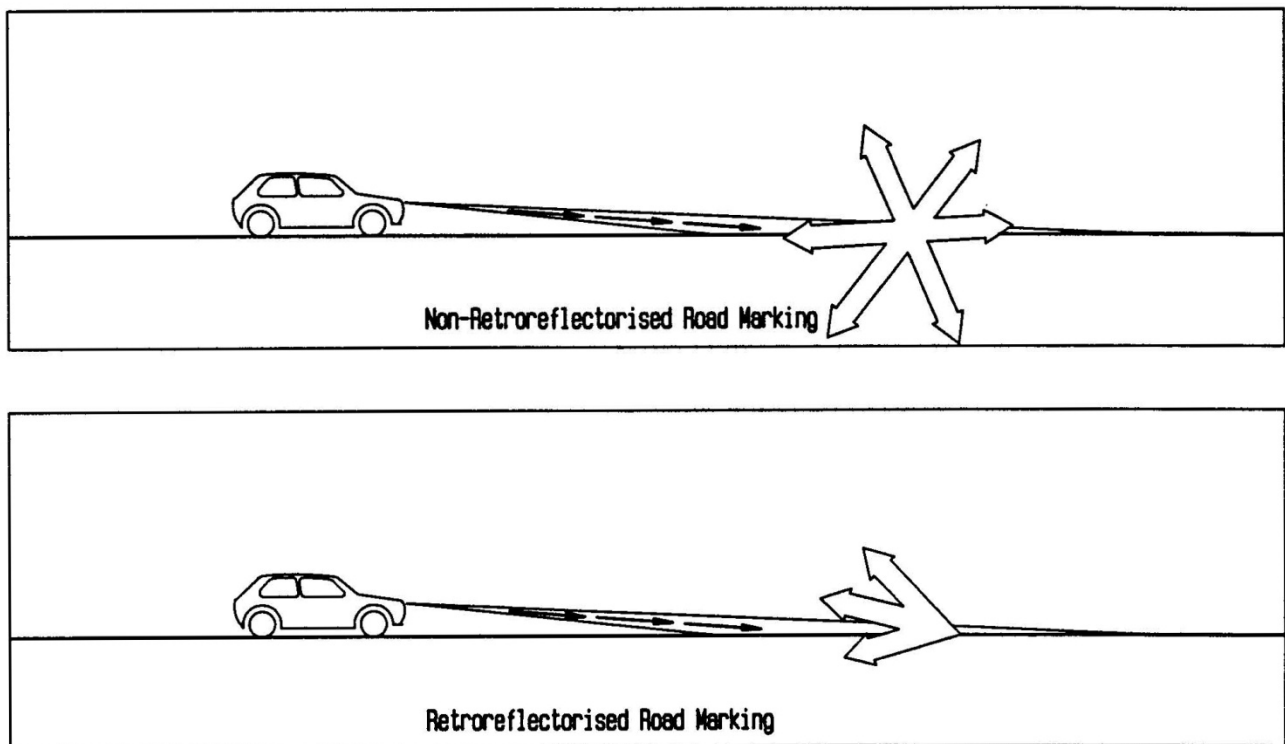
18.3.2 Reflective Properties of Glass Beads

- 1 The amount of light reflected by glass beads is a function of three factors, namely:
 - (a) index of refraction;
 - (b) bead shape, size and surface characteristics; and
 - (c) the number of beads present and exposed to light rays.
- 2 The scientific principle involved in the use of glass beads to reflectorise road markings is based on retroreflection. That is, the light is reflected back to the light source. Typically, the major source of light available during night driving is provided by vehicle headlights. As shown in Figure 18.2, Detail 18.2.1 the light rays from headlight beams shining on an unbeaded (non-retroreflective) road marking is reflected in all directions; thus, only a small portion of the light is reflected back towards the vehicle light source. In the case of a beaded line, much more light is reflected back towards the vehicle light source, and the line is therefore much more visible to the driver.
- 3 For the beads to refract and redirect light two properties are necessary:
 - (a) transparency; and
 - (b) roundness.

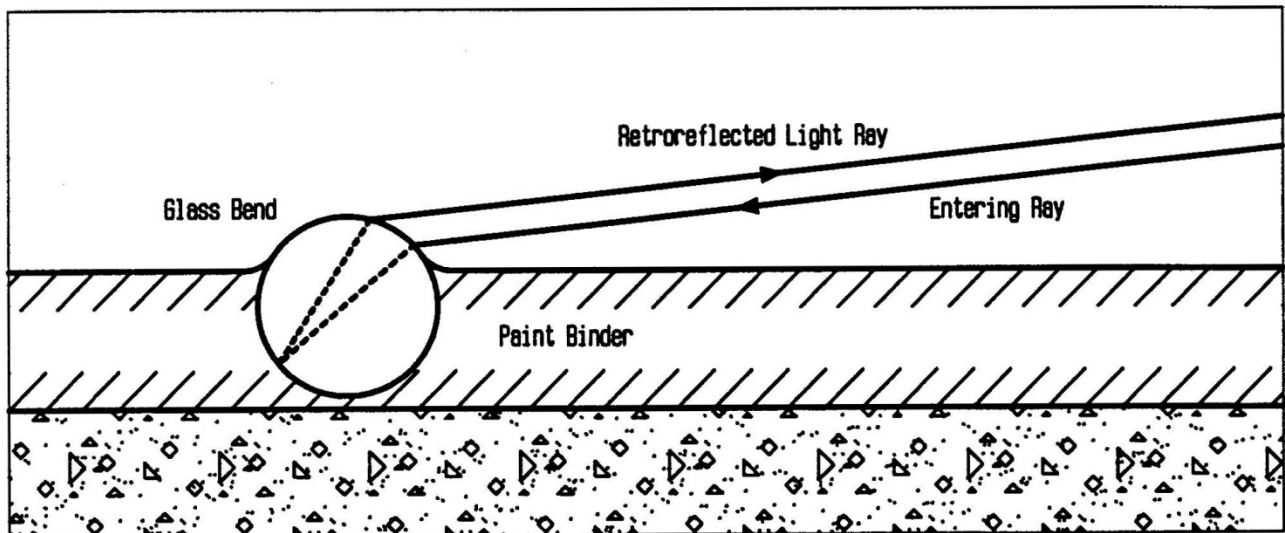
Glass beads meet both of these requirements. Early experiments in the use of crushed glass and aluminium or brass beads proved unacceptable because these materials failed to meet the above criteria.
- 4 The need for transparency and roundness can be explained by examining the path of light as it enters a single bead in a painted line. First, the glass bead must be transparent so that the light can pass through into the sphere. The light beam, as it enters the bead is bent (refracted) downwards by the rounded surface of the bead to a point below where the bead is embedded in the paint. Light striking the back of the paint-coated bead surface is refracted back towards the path of entry much like a mirror (Figure 18.2, Detail 18.2.2). If the paint were not present, the light would continue through the bead and scatter in many directions.

18.3.3 Refractive Index

- 1 When a headlight beam strikes thousands of these small spherical beads, the visibility of the line is greatly enhanced in terms of brightness. The degree of brightness depends on the Refractive Index (RI) which in turn, is a function of the chemical make-up of the beads. Commonly, beads used in road marking paint have an RI of 1.50. There are beads with an RI of 1.65, which are used in thermoplastic, and an RI of 1.90 for airport markings.
- 2 Each glass sphere works like a light-focusing lens and has a definite focal point outside the back of the bead. The closer the focal point is to the back surface of the sphere, the brighter the light return. For example, as shown in Figure 18.3, the 1.5 RI bead has a focal point further behind the back of the bead than the 1.65 RI bead. The focal point of the 1.90 RI bead is very close to the bead's back surface. Consequently, a painted line retroreflectorised with 1.90 RI beads will be brighter than those using 1.65 RI or 1.50 RI beads.
- 3 The chemical composition of glass beads differs for each reflective index. The 1.50 RI bead is a hard soda lime glass made from crushed scrap window pane glass, called cullet. This glass has a high silica content, which results in a chemically stable glass. Beads made from this glass will remain optically clear when exposed to strong acids, alkalies, moisture and salts for long periods.
- 4 Both 1.65 RI and 1.90 RI beads are produced from basic raw materials in a glass manufacturing tank. The 1.65 RI has 50% less silica, by weight, and an increase in weight per cent of calcium oxide, and consequently is less acid stable than 1.50 RI beads. The 1.90 RI glass beads have no silica or calcium as part of their formulation. The formulation is proprietary, but the major components, barium and titanium, are very stable so that the 1.90 RI beads are more acid resistant than the 1.65 RI beads.
- 5 The difference in acid resistance may not seem significant since reflectorised lines would not come into contact with concentrated acids. However, in the normal atmospheric environment, carbon dioxide and water vapour are present, forming a mild carbonic acid.
- 6 In industrialised areas, sulphur dioxide and moisture in the air combine to form a mild sulphuric acid which is even more corrosive. Thus, the 1.65 RI glass beads are potentially less durable than the 1.50 RI or 1.90 RI beads.
- 7 Because glass beads are purchased and used by weight, density becomes an important factor. Each RI category of bead has a different density; the higher the RI the higher the density. For example, to obtain the same bead population, the relationship of beads per litre for the three RI categories of bead is:
 - (a) 1.50 RI - 0,61 kg/litre;
 - (b) 1.65 RI - 0,74 kg/litre;
 - (c) 1.90 RI - 1.11 kg/litre.



Detail 18.2.1 Light Retroreflection/Reflection Characteristics



Detail 18.2.2 Glass Bead Retroreflection

Fig 18.2

Retroreflection and Reflection

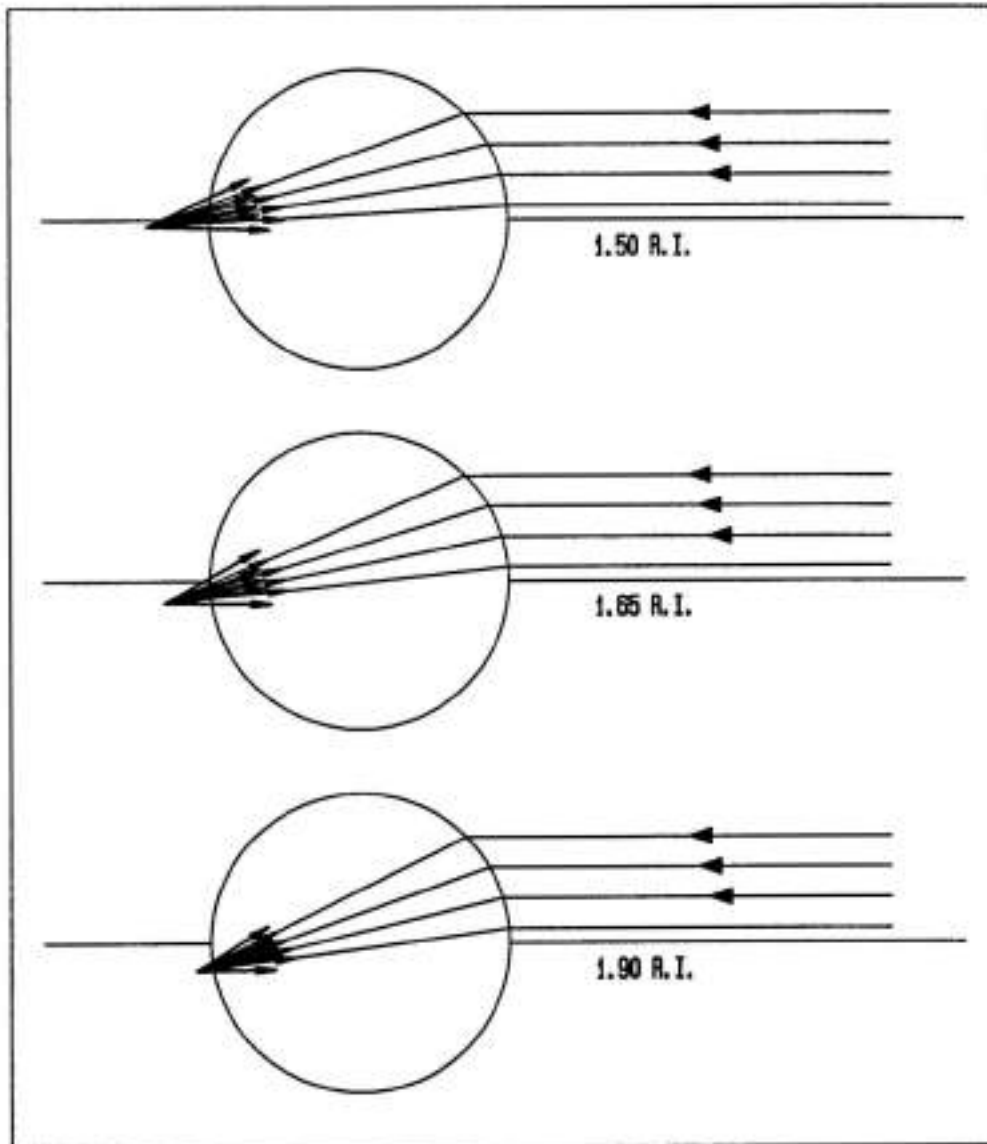


Fig 18.3

Focal Point for Commonly Used Glass Beads

18.3.4 Bead Size or Gradation

- 1 Glass beads are supplied in a range of sizes from the very small size of about 60 microns to larger sizes of 850 microns. The sizes of beads are usually expressed as a Standard Sieve Number, i.e. the size of a mesh that the bead will just pass through. For example, Standard Sieve 20 will permit all beads with a diameter of 840 microns or less to pass through the mesh. A 200 mesh will only allow beads of 74 microns diameter or less to pass through.
- 2 The size range or gradation is a variable that has a direct influence on both immediate and long term retroreflectivity. Maximum retroreflectivity occurs when approximately 50% of the bead diameter is embedded in the paint binder. Accordingly, larger beads with a diameter twice the dry paint thickness will provide excellent retroreflectivity as soon as they are dropped in the marking material. Since these beads are only partially anchored in the binder, they will be dislodged by traffic action within a relatively short period. As these larger beads disappear, the smaller spheres become effective as the paint film wears away. Figure 18.4, Detail 18.4.1, illustrates this principle.
- 3 The theoretical considerations of marking materials and bead size must be adapted to the reality of marking application operations and to the uncertainties of weather and control of materials. In addition, the drying time of the marking material affects the settlement of the beads into the binder.
- 4 The application rate (e.g. paint thickness), service life of the material, and the amount of beads applied must also be considered. For example, a paint-bead system based on wet paint thickness of 0,38 mm with a relatively long service life and a bead application rate of 0,6 kg/litre would probably call for a wide range of bead gradation. Conversely, for a system based on an 0,28 mm wet thickness and bead application of 0,4 kg/litre that is re-marked frequently, a narrower range of sizes would be indicated.

18.3.5 Flotation Beads

- 1 In seeking to improve the performance of conventional glass beads, manufacturers have developed a "flotation" bead. Flotation beads are standard glass beads treated with a special chemical substance that causes all beads, large and small to float to their diameter in wet paint rather than sinking completely into the paint film (see Figure 18.4, Detail 18.4.2). Since all beads are exposed, a brighter line or marking is obtained.
- 2 The two major advantages associated with flotation beads involve application and performance. Flotation beads will provide a more consistent level of brightness, regardless of large variations in film thickness, because all beads will float so that half the bead is exposed. With standard beads, a heavy application of paint will submerge a large proportion of the beads, thereby reducing initial brightness.

18.3.6 Application Techniques

- 1 Road markings can be retroreflectorised in three basic ways:
 - (a) the beads can be dropped on;
 - (b) the beads can be pre-mixed in paint or other marking materials before application; or

(c) a proportion of the beads can be dropped on pre-mixed materials.

- 2 The most commonly used technique is that of spraying (under pressure) or dropping (by gravity) a quantity of beads onto the wet material. The bead nozzle is located immediately behind the paint nozzle or extrusion shoe so that the beads are dropped almost simultaneously with the paint application.
- 3 One of the often cited problems in the application of drop-on glass beads is that in areas of high humidity, the beads tend to absorb moisture and lose their free flowing characteristics. This is due to the enormous surface area of the beads. When the beads agglomerate, they fall as a mass rather than as individual beads and create clumps on the marking film. It is not uncommon for beads to clog the dispensing equipment which must be cleared before marking can continue. To avoid this problem. Beads can be moisture-proofed by adding small amounts of moisture absorbing powders such as china clay or by coating with proprietary silicone-based material which effectively resists moisture.

18.3.7 Pre-mixed Marking Materials

- 1 To obtain greater durability and better distribution of beads, fine gradation beads (60 to 200 mesh) can be added to the paint formulation to produce a "retroreflective" paint. The initial reflectivity of pre-mix paint is subjected to traffic, the thin coating covering the beads is worn away and retroreflectivity results in improved visibility and this brightness is retained for a significantly long period of time. Initial retroreflectivity can be achieved by dropping coarser gradation beads on the applied pre-mixed material.

18.3.8 Volume of Beads Applied

- 1 As with the gradation of beads, the rate of beads applied for a given quantity of marking material is a matter of some controversy. It is generally agreed, however, that such factors as the size of beads, the thickness of the binder, the type of bead (flotation or non-flotation), and the service life expectancy of the retroreflective line or marking all exert an undeniable influence on optimum rate of application. Numerous research studies involving both field and laboratory tests have addressed the effect of each of these factors in terms of durability and cost effectiveness.
- 2 Traditionally, the paint-bead combination most often utilized has ranged from 0,38 mm to 0,43 mm wet paint thickness, with 0,6 kg/litre to 0,8 kg/litre of beads within 20 to 200 mesh sizes. In seeking to provide an equally efficient, but more cost effective retroreflectorised painted line, it has been demonstrated that 0,25 mm to 0,28 mm wet paint thickness, with 0,5 kg/litre of 40 to 80 mesh beads performs quite adequately.

18.3.9 Summary of Glass Bead Usage

- 1 The use of glass beads to provide night visibility of road markings is intimately related to the characteristics of the marking material (binder) used. The painted markings should be considered as an entity rather than as a combination of independent materials. For example, bead durability is tied in

with the life expectancy of the binder, which, in the case of paint is relatively short, but is relatively long for thermoplastic and other durable materials.

- 2 Current research findings, practices, and policies related to selecting the glass bead component of the road marking for typical delineation situations are summarised below:

(a) optical characteristics:

- (i) although higher index of refraction beads (RI 1,65 and 1,90) initially retroreflect more light, the difference is hardly visible to the human eye, although it can be measured with a photometer; these beads are also chemically and mechanically more unstable than beads with an RI of 1,50;
- (ii) the RI 1,65 and 1,90 beads have a higher density than the RI 1,50 bead; consequently, they must be applied at a higher weight rate to obtain the same bead population;
- (iii) for most situations, soda-lime based glass beads, with an RI of 1,50, provide adequate retroreflective properties, are extremely durable, and are more economical than the higher RI beads;
- (iv) beads with an RI of 1,65 or higher may be justified in situations requiring increased brightness, especially at long distances; one must consider, however, their inherent chemical and mechanical instabilities compared to beads with an RI of 1,50;

(b) bead gradation:

- (i) some evidence suggests that uniform smaller sized beads (40 to 80 mesh) produce a brighter, more durable marking; this is not true in wet conditions;

(c) flotation beads:

- (i) flotation beads are preferred by a number of road authorities because of their superior embedment;

- (ii) flotation beads are especially effective with a smaller, more uniform bead gradation and paint wet thickness of 0,28 mm ; this may require, however, more frequent re-marking and a lower wet night visibility;

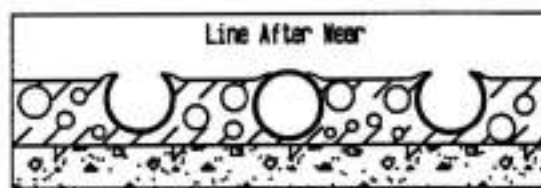
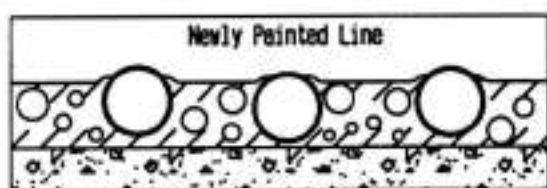
- (iii) in the smaller gradations, flotation beads provide more retroreflective surfaces per kilogram than standard beads; consequently, fewer kilograms are required, thus off-setting the additional cost of these specially treated beads at the expense of reduced wet night visibility;

(d) application techniques:

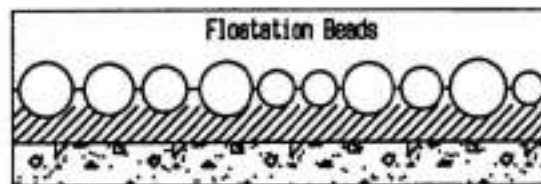
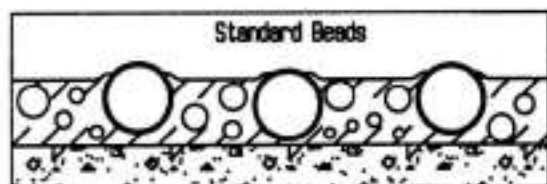
- (i) the drop-on application of glass beads is the most widely used technique for combining the beads with the paint film;
- (ii) beads pre-mixed in the paint provide poorer initial retroreflectivity but good long term brightness, where no drop-on beads are applied;
- (iii) smaller size beads are generally used in pre-mix paint to avoid the bead-settling problem in paint storage and wear and tear on the paint nozzle;
- (iv) road authorities using pre-mix paint apply drop-on beads (0,1 or 0,2 kg/litre) to provide immediate retroreflectivity;
- (v) moisture proof beads for drop-on applications are frequently specified for areas of high humidity and where beads are stored for long periods of time; moisture-proofing protects the free-flowing properties and provides for a more even dispersion when spray applied;

(e) volume of beads used:

- (i) optimum amount of beads to be applied depends on paint thickness, size of beads, expected service life of marking and the type of application and equipment;
- (ii) normal application is 0,7 kg/litre but 0,5 kg/litre has been reported to be effective.



Detail 18.4.1 Effect of Wear on Beaded Painted Line



Detail 18.4.2 Standard and Flotation-Type Beads

Fig 18.4

Retroreflective Beads for Road Markings

18.4 PAINTED MARKINGS

18.4.1 General

- 1 The use of painted lines on the road surface to divide the traffic stream and provide guidance to the driver has existed since the dirt roadway gave way to paved surfaces. Today, painted markings used alone or in combination with other devices comprise the most commonly used delineation technique. This section covers the various uses, materials, equipment, and installation procedures associated with painted road markings.

18.4.2 Uses

- 1 Basically, painted markings can be classified as either transverse markings or longitudinal lines which serve to provide "positive" guidance by defining the limits of a driver's field of safe travel (such as lane lines, dividing lines, edge lines or pedestrian crossings, STOP lines etc.). They are also used for "negative" guidance, namely to inform the driver where it is not safe (or permitted) to travel (e.g. gore areas, islands painted medians etc.).
- 2 The specific types of road markings are defined in Volume 1, Chapter 7: *Road Markings*, in terms of standard colour, widths, patterns and meaning or function. Chapter 2 of this volume gives in depth details of a wide range of road marking applications, and particularly how different types of marking may be used in conjunction with each other. Basic delineation concepts are provided here for convenience but the other references should be used for more precise information. (These application standards also govern the installation of other forms of pavement marking such as thermoplastic and raised pavement markers.)
- 3 Longitudinal lines generally include dividing lines, lane lines and edge lines and shall conform to the standard colours set down in the regulations. Standard colours include yellow, white and red. The use of black paint is permitted in combination with the three standard colours when the pavement surface itself is too light coloured to provide sufficient contrast.

18.4.3 Materials

- 1 Any discussion of the materials used in painted markings must consider the three interactive elements of the paint system, namely:
 - (a) the paint itself (pigment and binder);
 - (b) beads (retroreflecting glass spheres); and
 - (c) the pavement surface (substrate).

For example, different paints react differently on asphalt and concrete pavements. Glass beads reflect differently depending on the binder and its thickness.
- 2 Continual improvements have been made in paint composition and application techniques to provide increased cost-effectiveness. There are a number of interacting factors that affect the performance of the various types of traffic paint.
- 3 The following discussion provides a background for the subsequent discussion of the major factors influencing the selection of the most appropriate paint for a given situation. It includes a review of the categories of paint, essential properties and performance criteria.

18.4.4 Classification of Paint

- 1 There are several ways of classifying paint. The first basic description involves the retroreflectivity, i.e. whether or not glass beads have been added for night time visibility. "Retroreflective Paint" contains glass beads of specific size and volume, either inter-mixed, dropped on, or in combination. Paint without beads is generally used for markings not requiring night visibility such as parking bays, certain kerbs, etc.
- 2 Paint can also be classified by whether it is cold applied or hot applied. The temperature at which paint is applied has a direct relationship to the third area of classification, drying time. Drying time is influenced by the chemical composition, the temperature of the paint and of the pavement during application, wind velocity, and paint thickness. The categories of paint based on drying time are generally defined as follows:
 - (a) **Conventional:** cold applied paint of normal viscosity requiring over 7 minutes to dry, can require several hours depending on thickness of coat, atmosphere and road condition;
 - (b) **Fast Dry:** hot applied paint which will dry to no-track conditions within 2 to 7 minutes;
 - (c) **Quick Dry:** hot applied paint drying to no-track conditions within 30 to 120 seconds;
 - (d) **Instant Dry:** hot applied, heavily bodied paints which dry within 30 seconds.
- 3 Finally, paint can be classified according to the type or family of base material used in the paint composition. Some of the commonly used bases include:
 - (a) oil base (alkyd resin);
 - (b) rubber base (chlorinated rubber);
 - (c) oleoresinous (drying oil (dispersion) varnish, modified alkyd);
 - (d) water base.

18.4.5 Essential Properties of Paint

- 1 In general there are two basic criteria by which paint performance is judged:
 - (a) durability; and
 - (b) visibility.

Durability involves service life of the painted marking as a function of the material remaining on the pavement surface over time. Visibility concerns the brightness of the material, particularly at night.
- 2 Drying time is also a major performance consideration since the faster drying paints have the following benefits :
 - (a) they do not require coning off of the area for an extended drying period;
 - (b) they decrease the exposure of the paint crew to traffic;
 - (c) they lessen the disruption to traffic.

3 Other properties that are typically included when specifying traffic paint can be defined in terms of:

(a) Requirements before application:

- (i) the paint should be chemically stable with an adequate storage life;
- (ii) the paint should maintain a constant viscosity, resist caking, settling, gelling, skinning or colour changes;

(b) Requirements during application:

- (i) the paint should be adaptable to application by commercial marking equipment;
- (ii) the paint should permit uniform and easy spray application with economical and easy clean-up characteristics;
- (iii) the paint should have a strong wetting action to permit penetration of a contaminated substrate (dirt, oil, sand etc.) And thereby provide good adhesion;

(c) Requirements after application:

- (i) the paint should not bleed nor discolour on bituminous surfaces;
- (ii) the paint should resist chemical action of alkalines characteristic of concrete road surfaces (i.e. Portland Cement Concrete (PCC));
- (iii) the paint must withstand the abrasive action of sand and gravel;
- (iv) the paint must be flexible enough to expand and contract with day and night temperature changes;
- (v) the paint should be tough enough to resist the effects of traffic abrasion;
- (vi) the paint should be sunlight and water resistant, but sufficiently permeable to allow moisture to escape from the pavement surface.

4 The importance of these requirements and the form of their inclusion in the paint composition specification may vary among road authorities. Some of the site-specific considerations that may influence the essential properties built into a particular paint formulation include:

- (a) Pavement surface: certain formulations perform differently on asphalt and concrete surfaces;
- (b) Climate and weather: the range of temperatures to be expected during application and during the service life of the paint, as well as climatic conditions (rainfall, snow, blowing sand, extensive sun) create different requirements;
- (c) Travel characteristics: the traffic abrasion that a painted line must withstand is a function of AADT, the mix of vehicles (passenger cars, trucks etc.) And the type of marking (that is longitudinal lines last longer than transverse lines, and edge lines last longer than lane line because of fewer cross over traffic movements).

18.4.6 Paint Formulation

1 The major constituents of paint are:

- (a) the base vehicle (binder);
- (b) pigment;

(c) solvent.

The vehicle is the film former made up of drying oils, resins, or plasticisers in a formula which provides adhesion to the pavement surface and cohesion to hold the paint together. It also provides most of the resistance properties. The pigments give opacity, colour, hardness, and special weathering properties. Optimum pigment volume concentration for good durability lies in the 42% to 59% range. Solvents dissolve the film former, regulate the rate of film setting (drying) by controlling the rate of evaporation. It is also associated with adjusting film solids and with the ease of application.

18.4.7 Performance

- 1 A great deal of emphasis has been placed on the properties of traffic paint and on developing an optimum paint formulation that will produce increased durability, appearance and visibility. Such emphasis has resulted in a number of paint families that effectively meet specifications.
- 2 There are three basic reasons for the interest in evaluating the performance of paint. Firstly, it is necessary to assess the cost effectiveness of using painted markings rather than other forms of delineation. Next, if paint is indicated as the appropriate delineation medium, it is necessary to evaluate paint samples to determine the best product to purchase. Ultimately, it is necessary to determine how long a painted marking can be expected to provide adequate delineation so that re-marking operations can be planned and scheduled.
- 3 Research indicates that the precise composition of paint in use today has a relatively minor impact on the performance of the in-place road markings. It has been suggested that "a poor plate properly applied will out-perform a good paint improperly applied". It is also well documented that 90% of all paint failures are due to the type of pavement surface and the condition of the surface.
- 4 A number of terms are used by various road authorities to describe paint performance. Some of these terms such as "service life", "expected life", "life-span or useful life", "paint failure", etc., often have different meanings and care should be exercised in using these terms interchangeably. It is difficult to define these descriptors in quantitative terms as subjective judgement is frequently the sole determinant.
- 5 As mentioned earlier, the determination of service life is used in evaluating painted test lines and in computing the economic aspects of various materials. It is based on appearance, durability, and night visibility of sample materials placed on test sections. Each of these three characteristics is rated numerically on a scale from 0 to 10, where 10 indicates a perfect condition and 0 a complete failure i.e. no appreciable amount of paint remaining.
- 6 A factor of major significance is that performance is a function of numerous variables, not just the paint itself. That is, the performance of identical materials will vary as a result of:

- (a) traffic volumes;
- (b) traffic characteristics;
- (c) geographic and climatic conditions;
- (d) type of pavement surface;

- (e) condition of pavement surface;
- (f) method and circumstances of application.

18.4.8 Causes of Failure

- 1 The integrity of a road marking can suffer from at least three mechanisms, singly or in combination:
 - (a) loss of substance by abrasive wear on the upper surface;
 - (b) cohesive failure of the paint (i.e. failure within the paint layer); or
 - (c) adhesive failure at the interface with the road surface.

Another possible cause of failure, often overlooked, is failure within the concrete or asphalt region immediately below the paint-pavement interface. The stresses causing such failures arise from the reaction of the road surface to the forward forces of vehicles and the forces of the weight of vehicles.

- 2 Since single stresses apparently do not cause failure, failure may involve fatigue. Factors contributing to loss of strength of the paint, the interface, and the pavement may include temperature and humidity cycling, light radiation damage, chemical attack by salt and/or acids (from nitrogen and sulphur oxides in the air), and physical attack by solvents (including all those in petrol and oil).
- 3 With so many possible failure mechanisms and cause-and-effects relationships, it is not surprising that there is a great variation in the reported performance of the various types of materials. It is also the reason that abrasion tests have not been completely successful in predicting the useful life of painted markings.

18.4.9 Range of Service Life

- 1 Although the estimated life of painted markings is a function of numerous site-specific variables, AADT is the most commonly used variable in defining service life. Most road authorities consider a reasonable target to be 6 to 12 months under "normal" conditions. Three months service may be acceptable for roadways with very high density traffic, while some paints may last well over a year on roads with low AADT's. It should also be noted that paint wear is especially high in cold weather, therefore painted markings applied in the winter will have a shorter life expectancy than those painted in the spring.
- 2 In summary, the service life of paint depends primarily on:
 - (a) traffic density and type;
 - (b) position of marking (dividing line, edge line, lane lines, transverse markings);
 - (c) composition of material and pavement surface;
 - (d) thickness of paint film; and
 - (e) season of the year when paint is applied.

The position of the marking will determine the amount of traffic that usually passes over the marking. For example, longitudinal lines in general have a longer life than transverse markings and edge lines last longer than lane lines.

- 3 Some paints are formulated to be more durable than normal, but tend to be more costly. The type and condition of the pavement surface also affect service life. That is paint normally lasts longer on asphalt than on concrete. On average, dividing lines placed

on concrete may require re-painting each year, whereas dividing lines painted on asphalt may require re-painting only every two years. It has also been found that paint laid over paint will perform better than on new installations, provided that the base layer of paint is in moderately fair condition on a stable pavement.

- 4 Thicker paint films on stable pavement surfaces will usually provide increased durability. This is not however, a linear relationship. The additional life of a line thicker than 0,4 mm is not in direct proportion to the additional thickness used.
- 5 Because of the great variations in the parameters associated with the service life of paint, each road authority should develop its own estimated service life based on local conditions and experience. An "average" service life based on a compilation of nationwide experience has little meaning from an operational standpoint.

18.4.10 Application

- 1 The equipment, procedures and policies involved in the application of the paint have a profound influence on the ultimate performance. This is equally true for all forms of road delineation treatments. Among the major concerns is compatibility of materials and equipment, size and capabilities of crew, protection of crew, and traffic control during the application process.
- 2 While it may be assumed that the preferred material will dictate the type of equipment, in actual practice, the opposite is usually true. That is, the material used is frequently based on the capabilities of available equipment. For example, it may be determined from laboratory and field tests and from economic analysis that a rapid dry hot-laid paint will provide the necessary durability and is economic from the standpoint of crew safety and traffic disruption. If the road authority's equipment is compatible only with cold-laid paint, most authorities will opt to use the cold-laid materials. Capital expenditure for new equipment for the use of the contractor are often beyond the available budget.

18.4.1 Equipment

- 1 Painted markings can be applied with a variety of equipment. Selection of the proper equipment will depend on the size of the community, kilometres of roadway, geographic characteristics, pavement surfaces, and the types of markings.
- 2 Equipment basically falls within two broad categories. The first is a small, self-propelled, manually-controlled low capacity paint marker and the other is the heavy duty, multi-lane truck-mounted unit. The smaller applicator is generally used for marking pedestrian crossings and other transverse markings, symbols, arrows and legends. Commercially developed units may have several unique characteristics. One type may be self-contained including a small engine to propel and operate air-compressors, paint and bean tanks, spray gun, and bead dispenser. In other types, the compressor may be an auxiliary unit with a connecting hose to the spray unit.
- 3 The larger truck mounted unit is almost always used for longitudinal markings. These units are available commercially or can be customised based on specifications. While the specifications may differ, heavy-duty units typically have the

following characteristics:

- (a) the truck bed must be large enough to carry all of the necessary marking equipment;
 - (b) the truck should have enough power to maintain speed up grades so that the spray equipment can continue to produce a uniform line marking;
 - (c) the truck should be protected by special warning lights, or should be preceded and followed by support trucks;
 - (d) arrow signs should be provided to warn traffic and to direct passing movements;
 - (e) the front of the truck should be equipped with a device that will enable the driver to follow a target on the roadway ("cat tracks"), or to follow a previously placed line (this device should be retractable so that it can be lifted free of the roadway when the marking operation is discontinued or the device is not in use).
- 4 Two different methods are used to supply the traffic paint to the spray guns. In one, the paint drums are lifted from the supply truck to the paint truck by a hoist and the paint is then pumped directly from the drums to the paint guns. A valved T in the hose may be used to permit pumping from either of the two drums. In the other method, paint tanks are located on the paint truck. These may be filled from drums or tankers by either mechanical pumps or air pressure. In either method, the paint screens that must be used in the lines must be freely accessible so that they may be cleaned frequently. Additional screens should be located close to the paint spray guns. The hoses that connect fixed parts of the paint spray equipment to the movable parts must be resistant to the cleaning solvent being used and to the solvent used in the paint. The painting truck should be equipped with an accurate speedometer so that the truck speed is known. A volume meter for each paint supply is a valuable addition to monitor the quantity of paint supplied.
 - 5 An air pressure system transports the paint to the spray guns at a pressure determined by the quantity of paint to be delivered. It also supplies air at a lower pressure to an air-jet at the paint nozzle to atomise the paint. Air also moves the glass beads from the bead tank to the gravity-type bead dispensers. (When hot paint is used, the glass beads are pneumatically applied.) Air is again used in the control valves for the paint guns, etc. Some road authorities use an air blast just ahead of the paint gun to blow loose paint chips and other debris from the area being sprayed.
 - 6 The air supply comes from an air compressor driven by a petrol or diesel engine, which is mounted on a skid frame bolted to the truck bed. Controls should be provided so that the engine power matches the load of the compressor. Protective devices are desirable to shut down the engine in the event of a malfunction.
 - 7 The air pressure is also connected to the cleaning system, which consists of a tank of paint solvent that can be connected to the paint lines and nozzles by suitable valves. The lines, nozzles, and screens must be cleaned daily after use. The cleaning solvent is returned to a drum on the painting truck.
 - 8 The paint spray guns and bead dispensers are mounted on carriages underneath the truck bed just behind the rear axle. The carriages can be moved laterally by the spray gun

operator. A positive placement of the carriage is required. If edge lining is done at the same time as dividing lining, two carriages are needed.

- 9 The paint spray guns and bead applicators are synchronised so that the bead applicators start at the appropriate time after the paint spray gun starts. All spray guns and bead applicators are controlled by an intermittent timer containing a timing mechanism driven by a ground contact wheel.
- 10 Heating the paint prior to application has proved effective in terms of achieving more uniform consistency under changing temperature conditions and in reducing drying time. Low heat (up to about 49°C) can be obtained by using a heat exchanger in the paint supply tank. This uses hot water from the truck radiator or from the compressor radiator. If higher temperatures are required, it is necessary to jacket the paint supply lines and to supply hot water to the jackets.
- 11 Temperatures above 82°C generally require an external heating system to supply heated liquid (a coolant or special fluid) to the heat exchanger and to the paint lines. Some road marking truck for quick drying heated paint have a compressor located behind the driver and a heat exchanger mounted on the truck bed.

18.4.12 Line Protection and Safety

- 1 Although heated paints and a few quick drying cold applied paints do not require protection of the freshly applied painted line from traffic, there are still a number of slower drying paint materials that require some form of protection. The type of protection required dictates the size of the crew.
- 2 The most common form of protection is traffic cones. The road marking truck may be equipped with an apparatus that sets the cones or with a platform at the rear or side of the vehicle to accommodate a crew member who sets the cones manually. In other operations, the cones are placed from a following truck equipped with an illuminated arrow board.
- 3 For the most part, the cones are placed in the skip protection of the broken line or are offset to the side of, or on alternating sides of, a continuous line. Machines for picking up cones have been developed by some road authorities in the USA. Most road authorities pick up cones manually.
- 4 On well-travelled roads, some road authorities may use one or more following trucks equipped with arrow boards for directing traffic away from the crew and equipment, and to protect the line from traffic. Extreme care and caution in these situations are required to protect the working crew.

18.4.13 Crew Size

- 1 The size of the crew depends on the nature of the operation and on road authority policy. If edge lines are applied at the same time as dividing lines and no overtaking lines, two spray gun operators are needed. Thus, considering that the road marking truck has a driver and an assistant, a crew of four is required. A supply truck and operator is also generally required for most operations. If cones are needed, another crew-member is required. The crew foreman co-ordinates the operation and generally follows the road marking truck. The cones must be retrieved by another truck with two or three crew. The trucks supporting the road marking truck are used for the protection of

the line if cones are not needed, and generally follow at about 150 m intervals.

- 2 The simplest marking operation requires a crew of about five and two trucks plus the road marking truck. Considerable planning and co-ordination is needed to attain an efficient and low-cost operation. Because the marking operation is often seasonal, it is necessary that the crew should place markings as early in the morning as possible, but not before conditions are suitable. Because of rigid working hours, marking is often started in the morning before the road surface has dried.
- 3 Good workmanship is often sacrificed because of the constant push for increased production. Short cuts in application are seldom cost-effective. Materials can be wasted, machinery clogged, and the quality of the line jeopardised if proper attention to detail is abandoned in favour of a few added kilometres of marking.

18.4.14 Maintenance

- 1 In the case of painted markings, maintenance involves repainting when the markings lose their contrast, base film and/or retroreflectivity. The decision to repaint and the scheduling of the activity is usually based on established policy and is a function of the road authority's maintenance superintendent. The availability of materials, equipment, and crews are also important considerations from a maintenance standpoint. Materials must be selected, purchased, and stored. Equipment must be serviced and maintained to assure proper operations and to prevent on-the-road breakdowns. Trained crews must be available and appropriately scheduled.

18.4.15 Scheduling of Re-marking Activities

- 1 Some road authorities have predetermined schedules which identify sections of the roadway to be periodically re-marked. Such re-marking programmes involving a large number of streets and highways can be computerised to assure a cost-effective allocation of equipment, crew, and materials. When a smaller road length is involved, a manual scheduling process is commonly used. In either case, past experience and road authority policies define which roadways must be re-marked once, twice or three or more times a year.
- 2 Other road authorities may prefer to schedule re-marking based on night inspection of the various facilities. In some cases, residential streets and other low ADT facilities are scheduled on an "as needed" basis.
- 3 Determining when to replace painted markings is, at best, an inexact science vulnerable to subjective judgement and budgetary expedience. Several road authorities have reported that overtime costs for night inspection cannot be justified, especially since the resulting evaluation is based on the individual's opinion without a precise scientific technique. Local knowledge of traffic and climatic conditions, coupled with experience with the various delineation materials is considered an equally effective technique for scheduling these activities.
- 4 Another factor that should be considered in scheduling repainting activities is co-ordinated with major improvement programmes and with other maintenance activities. Resurfacing, realignment, or changes in traffic patterns which would require new or repainted markings may render previously scheduled re-marking unnecessary. If these activities are not adequately

co-ordinated, significant expense of removing a newly marked line could be incurred. While road authorities hesitate to report such lapses, it is a relatively common occurrence.

- 5 This is not to suggest that re-marking should be indefinitely postponed because of planned changes or improvements, particularly if the markings are significantly degraded in a hazardous location. The type of paint, the thickness laid, or the use of temporary markings should be carefully considered when changes are anticipated. The option to postpone re-marking must be balanced against the possible cost of removal and the potential safety and legal ramifications should the lack of adequate delineation create an unsafe condition.

18.4.16 Spotting

- 1 it is generally necessary to spot or cat track the road surface before applying a new road line marking. The customary method of spotting is to use a rope and make spots approximately every 1 m to 2 m. When working in traffic, the workers applying cat tracks must be protected by signs, flagmen and lane closures as required. Another procedure is to mark the pavement with a dribble line using a striping machine. It permits rapid placing of a guide line with a minimum number of control points.
- 2 Another method frequently used for resurfacing jobs is to place a temporary offset line on the shoulder beyond the paved area before the overlay is placed. After the new surface has been placed, the marking machine then paints the line using the offset line as a guide on the new surface directly over the old line. This method has proved very satisfactory.
- 3 Where a traffic lane has been obliterated by re-surfacing, re-marking should be in place before the roadway is opened to traffic. The practice of placing heavy cat tracks or dribble lines to serve traffic until the surface has cured and the standard marking can be painted is used by some road authorities, but should be discouraged. However, when cat tracks are used they should not be applied more than 75 mm in width, so that they can be completely covered when the line is painted.

18.4.17 Pre-treatment of the Surface

- 1 Earlier experience with traffic paints suggested that better adhesion with the pavement might be achieved by some form of pre-treatment. It was fairly well documented that re-painted lines performed better than the initial application on a bare pavement. It was therefore hypothesized that pre-treatment, particularly on concrete surfaces would lengthen the life of the paint.
- 2 Several forms of pre-treatment have been used without significantly increasing durability. Some states in the USA, however, have followed the practice of applying a light coating of paint without beads as a sealer on the new surface. This first or primer coating, laid at 9,4 l/km to 11,8 l/km dries rapidly and seals the pavement. This eliminates the de-colouration which sometimes occurs from the solvent action of the traffic paint on asphalt pavement, and provides better adhesion on concrete surfaces.
- 3 One of the major concerns has been that paint is most frequently applied to a dirty road surface. Laboratory tests have indicated that cleaning of the surface prior to application substantially improves adhesion. A field study was undertaken in the USA to assess the effectiveness and economic feasibility

of various types of surface preparation techniques. The techniques that could be used for this purpose include air-blasting, sand-blasting, grinding, burning, washing (hydro-blasting), acid etching and wire brushing.

- 4 Of the different methods wire brushing appeared best suited to the subject application. It was easy to use, worked well over irregular surfaces, did not damage the surface, had no logistics or time lapse problems, and removed the road film. The methodology involves a wire brush assembly which is mounted forward of the dividing line spray gun, and is controlled by the same circuit that operates the gun thus activating and de-activating simultaneously.

18.4.18 Removal of Paint Markings

- 1 Every road authority maintenance facility needs to provide a capability for removing existing markings that no longer define the safe path of travel. The difficulties involved in the removal of markings have been compounded by the increasingly successful effort to improve paint durability and adhesion.
- 2 Traditionally, methods of removal include grinding, burning, chipping, appropriate chemical treatment, and sand-blasting. Over-painting of markings with black paint and bituminous solutions is no longer appropriate, and is specifically disallowed. This treatment has proved unsatisfactory as the

original line eventually reappears as the overlying material wears away under traffic. In addition, lines which have been covered in this way are still visible under certain conditions (i.e. low angles of illumination) due to the preferential reflection from two contrasting surfaces - the painted line and the adjacent road surface.

- 3 A prime requisite in determining the best method for line removal is that the treatment should have a minimum effect on the roadway surface i.e. it will not materially damage the pavement surface or texture. Chemical treatment may cause damage to the pavement surface, drainage channels or pipes, and is consequently is seldom considered satisfactory. Removal of markings by grinding is not considered totally successful as some remnants of the marking usually remain. Generally, sand-blasting has been the preferred method of treatment.
- 4 Sand-blasting is particularly effective when the surface is rough and porous. This technique will do little damage to asphalt and the resulting scar will barely be noticeable. Sand deposited on the pavement accumulates and might interfere with drainage, and should therefore be removed. Hydro-blasting has also been used successfully under certain conditions.

18.5 THERMOPLASTICS AND OTHER DURABLE MARKINGS

18.5.1 General

- 1 The use of thermoplastic and other highly durable marking materials as an alternative to conventional traffic paint has been under study for over 15 years in the USA and Europe, but there has been limited application in South Africa mainly due to the perception of high cost. The growing popularity of thermoplastic, epoxy, or polyester installation has been attributed to readiness for immediate use, superior durability, and the potential for long term economy and traffic safety. While the initial cost of these highly durable markings can range as high as five to fifteen times the cost of paint markings, their long service life and improved visibility makes an attractive alternative in many situations.

18.5.2 Uses

- 1 Thermoplastic and other durable markings have the same uses as traffic paint. Specifically, thermoplastic can be used as dividing lines, lane lines, edge lines, pedestrian crossings, stop lines, gore markings, no overtaking lines, parking lines, and on-street regulatory, warning and directional arrows, symbols and legend.
- 2 Field tests and operating experience have shown that the characteristics of various types of highly durable markings serve some uses better than others. Moreover, as with most delineation techniques, the most effective usage in terms of cost and safety is a function of a particular combination of site-dependent variables. Consequently, the decision whether to use plastic-based markings in a given installation must be weighed-up in terms of the advantages and disadvantages associated with the site characteristics, as well as those of the materials *per se*.

18.5.3 Materials

- 1 Hot extruded and cold laid thermoplastic materials have been in use for many years and are considered a cost-effective alternative to conventional paint markings when durability is a prime criterion.

18.5.4 Properties of Thermoplastic

- 1 Hot-laid thermoplastic are generally defined as synthetic resins which can be heated and then harden without changing the inherent properties of the material. The formulation of thermoplastic road markings includes three basic components:
 - (a) plastic and plasticisers (binder);
 - (b) pigment and fillers; and
 - (c) glass spheres.
- 2 The exact chemical composition varies considerably. Formulae of commercially available materials are proprietary and continually change as the price of chemical components fluctuates. For this reason, composition is usually specified in terms of minimum percentage weight of each basic component.
- 3 Although the percentage by weight of the components varies from one specification to another, a typical range may be as follows:

- (a) binder 15% to 35%;
- (b) glass beads 14% to 33%;
- (c) titanium dioxide (TiO_2) 8% to 12%;
- (d) calcium carbonate 48% to 50%;
- (e) other inert filler to 100%.

- 4 Formulations differ for materials to be applied by the extrusion or hot spray process. They also differ for use in hot or cold climates. For example, one manufacturer supplies an alkyd base (synthetic resin) material for use in areas subject to harsh winter temperatures, and applied by extrusion. A hydrocarbon base (organic compound) material is recommended for applications in areas with warmer climates. Most material suppliers will formulate the thermoplastic compound in response to road authority specifications, although they may recommend some minor variations.

18.5.5 Use and Properties of Cold-Applied Thermoplastics

- 1 The discussion to this point has centred around hot melt thermoplastic materials. The temperature necessary to achieve a molten state for application requires expensive installation equipment and experienced operators. Cold plastic lining material eliminates this requirement, requires no hardening time, and under certain circumstances exhibits a high level of durability.
- 2 These materials are most frequently used for pedestrian crossings, stop lines, arrows, symbols and words, and other specialised markings. Some road authorities have also indicated a preference for the cold-applied tape for dividing lines and lane lines in areas of low traffic density. As with the hot-applied thermoplastics, these plastics are reported to perform better on bituminous asphalt surfaces than on concrete surfaces.
- 3 There are two basic forms of cold-applied plastic materials. The first range of materials are extruded cold flow plastic tape with embedded glass beads, with or without a top surface dressing of beads. This material is generally used in thicknesses of 2,3 mm or 1,5 mm, and is either pre-coated with pressure sensitive adhesive for self-bonding or an adhesive for application to the road surface can be supplied. The second range of materials include preformed plastics that can be somewhat more pliant than the cold extruded type. A top dressing of beads is recommended for areas where immediate retroreflectivity is required. Standard thicknesses of these films are 0,76 mm and 1,5 mm, and they can be supplied pre-coated for self-bonding or can be supplied with a contact adhesive cement.
- 4 A special type of the preformed plastic has been recently introduced for use as temporary road markings in roadworks zones. The major advantage of this material is easy removability. The markings can be removed intact (or in large pieces) from either asphalt or concrete pavements manually or in a roll-up device without the use of heat, solvents, grinding or sand-blasting.

18.5.6 Application

- 1 The various categories of thermoplastic installations require very different application techniques. In selecting the most appropriate thermoplastic materials the application procedure for each category should be carefully considered from the standpoint of the physical requirement to achieve a proper bond, as well as the equipment and manpower requirements.
- 2 The type of road marking (transverse or longitudinal), type of facility (urban/rural etc.), type of pavement, magnitude of the installation, and other project characteristics will influence the method of application. For example, a small intersection project to install pedestrian crossings or stop lines will differ from a major improvement project in which delineation markings are a line item in the construction contract.
- 3 In almost all cases, thermoplastic, hot or cold laid, can be applied with small manually operated equipment, or can be applied mechanically with large, fully automated equipment. The exception is the application of cold preformed arrows, symbols or legend, which must be applied by hand. This is however, a relatively simple operation. The major characteristics of the basic application procedure are reviewed in the following subsections.

18.5.7 Application Thickness

- 1 The matter of application thickness is the subject of some controversy. If durability is a function of thickness, the thicker markings would naturally have a longer life, but would require more materials, and would therefore cost more. It can be argued that this extended life may outlast the retroreflective properties, and in some cases, the roadway surface itself. Therefore, the value of the expected life of six to ten years could be meaningless if the pavement is subject to re-surfacing, or if the bead loss (retroreflectivity) renders the markings ineffective at night.
- 2 The thicker markings, in the range 2,3 mm to 3,1 mm, provide better wet night visibility when the beads are still in place. In practice, the thicker application continues to be specified so that either the extrusion or spray process can be used. The extrusion process is more compatible to thick applications, especially if 3,1 mm is desired. The spray is best suited to applications of 2,3 mm or less. These lighter coatings have generally performed well and are more cost effective.
- 3 Proponents of thinner applications, 1,0 mm to 1,8 mm, report acceptable durability and retroreflectivity over a 3 to 4 year life span, with lower material costs and faster application. The average wear of thermoplastic materials as a result of traffic abrasion has been estimated at 0,25 mm loss per year. Thus, a line of 1,0 mm thickness could be expected to survive three to four years. Even these thinner applications provide limited wet night visibility since a moderate surface water film does not cover the marking and therefore does not completely inhibit retroreflectivity.

18.5.8 Installation of Hot Applied Thermoplastics

- 1 Molten thermoplastic can be extruded or sprayed on the pavement surface by means of a manually operated device for small runs, or by large automated equipment for major construction projects. Typically, 907 kg of thermoplastic

materials, supplied in granular or block form, will yield approximately 2110 metres of line with a width of 100 mm and a thickness of 2,3 mm.

18.5.9 Application Equipment

- 1 The manual applicator usually consists of a melting pot holding a manual mixing paddle to keep the plastics from segregating or scorching, the extrusion spigot and die, and a bead hopper and dispenser. In one design, the machine is equipped with a propane tank and regulator to fuel the burner under the melting pot. Another type of equipment utilizes an auxiliary unit for heating the materials which are then transferred to the dispensing unit. An infra-red burner over the extension die can be used to maintain the temperatures during application. For hot-spray manual application, the road marking unit draws its compressed air supply through a long hose from a small truck mounted machine.
- 2 Truck or skid mounted thermoplastic road markers are self-contained units consisting of large melters with automatic agitators, heaters, electronic controls, intermittent interconnected timers to control the flow or spray to form continuous or broken lines, materials dispensing unit (extrusion die or spray nozzle), and bead hoppers and bead dispensers.
- 3 Applications utilizing these large machines are frequently contracted out. The equipment costs can exceed R 1 000 000 and local staff are seldom experienced in the operation of such complex machines. Some authorities maintain a small mobile unit for maintenance jobs or small installations such as new pedestrian crossings or stop lines. Large installations are either bid separately (for existing pavements) or are included as part of a new construction or re-surfacing contract. There are, however, a number of authorities who prefer to purchase medium sized equipment and carry out their own road marking activities, often with assistance from the materials supplier. Crew sizes range from two men for manual application to up to five for the largest equipment (excluding following vehicles or other protection and traffic control personnel).

18.5.10 Storing and Field-Handling of Materials

- 1 Hot melt thermoplastic materials are available in block and granular form. These are packaged in cardboard containers or heavy duty bags with weights of from 9 kg to 23 kg. The containers (or bags) should be stacked flat and stored on pallets in a dry place. Water or dampness will not harm the materials, may weaken or otherwise damage the cardboard containers. The manufacturers suggest that cardboard containers should be stacked not more than 13 boxes high. In periods of extremely hot weather, it is suggested that stacks be limited to 10 containers.
- 2 Dirt residue from the cardboard or the polyethylene liner will contaminate the material. Consequently, care should be exercised to protect the materials so that none of these pollutants are inadvertently loaded into the melting kettle.

18.5.11 Conditioning the Road Surface

- 1 The operational procedures for the application of hot melt thermoplastic markings is quite similar to the application of paint.

Where no previous markings exist, the roadway must be marked with guidelines (cat tracks) using the same method as has been described for paint markings (see Subsection 18.4.16). The roadway should be dry with no surface dampness, dew or subsurface wetness. The ambient temperature should be above 10°C or the temperature recommended by the manufacturer.

- 2 The type and condition of the road surface during installation is a critical factor in ensuring the best possible bond between the thermoplastic film and the roadway. Experience to date, shows that better adhesion, is generally achieved on asphalt surfaces than on concrete. (It has been suggested that the improved bond results from the bituminous surface softening due to the heat emitted from the road marking equipment and the molten material, thus fusing more completely with it.) Preparation of the surface may involve cleaning and/or the application of a primer-sealer to promote adhesion.
- 3 Although practices amongst road departments differ, most call for applications on dry and clean pavement surfaces. The appropriate degree of dryness is usually a subjective judgment of the engineer in charge. Early morning dampness is suspected as being the cause of early failures.
- 4 The techniques for removing dirt, old paint, oils etc., to provide the required clean surface include sandblasting, air-blasting, hydro-blasting, brooming, acid etching or grinding. Some authorities report no pre-cleaning requirements for bituminous pavements. The appropriate technique depends on the condition of the surface and whether any residual paint must be removed. Sandblasting and acid etching are usually restricted to concrete. Better adhesion is reported for installations in which the concrete was subjected to light grinding before application.
- 5 There appears to be clear cut consensus on the pre-treatment by primer or by cleaning of the pavement surface prior to application. There is also little agreement on the optimum application rate of primer. Basically, the relevant factors are the age, porosity, and texture of the pavement as well as the active solid contents of the epoxy solution used. The wet film thickness of primers ranges from 0,3 mm to 0,13 mm, and is normally based on manufacturer's recommendations. Recent studies, however, indicate that 0,5 mm is adequate.
- 6 The proper handling and application of rapid-dry epoxy primer coatings is necessary for good bonding. For example, evidence suggests that the thermoplastic materials should be applied when the primer is still tacky. Failures have been reported when the primer has been either too dry or too wet. One specification requires that the spray-applied primer should be of a type that remains tacky for at least 10 minutes at 23°C. One form of epoxy (with linseed oil) requires 24 hours of curing time.
- 7 Similarly, there is little agreement on whether thermoplastic should or should not be applied over paint. There is evidence to suggest that a better bond is achieved on bare pavements. Those road authorities that maintain their own equipment and use their own labour for day-to-day applications appear to have evolved methods compatible to their unique requirements. In some instances, neither concrete nor asphalt surfaces are primed or cleaned despite recommendations from suppliers. Yet the authority will confidently estimate an 8 to 10 year life expectancy based on experience.

- 8 The documented differences in opinions, procedures, and experiences tend to reinforce the assumption that the performance and life expectancy of thermoplastic markings is directly tied in with a multitude of site-dependant variables. This reinforces the frequently repeated caution that findings, conclusions, and recommendations emerging from research projects be tempered by judgement and local experiences of local personnel.

18.5.12 Installation of Cold-Laid Plastics

- 1 Cold-laid plastic road markings are supplied in continuous rolls of various lengths and widths for yellow and white markings, and in pre-cut shapes to form standard lengths of arrows and symbols. They are also provided in sheets from which special shapes, forms or letters can be customised.
- 2 Line markings can be installed by an inlay method or the overlay method, depending on the condition of the pavement. With either of these methods, the markings are ready to receive traffic immediately after installation.
- 3 The inlay method is used with new construction or re-surfacing of asphalt concrete surfaces. While the asphalt is still warm (at least 54°C) the pressure sensitive, self-bonding tape is positioned in place and is tamped firmly into the asphalt during the final compaction. For longitudinal markings, a tape applicator device is available which follows the breakdown rollers and lays broken lines, double white lines, and continuous yellow edge lines. This applicator is powered by a 12 volt battery with a compressed air cut-off mechanism. The tape, when in position, is securely bonded to the pavement by the finish roller following behind. Pre-cut shapes and letters must be positioned manually before compaction. The rolling tends to bevel the plastic strip into the pavement, thus enhancing the bond and sealing out moisture.
- 4 The overlay method is employed on existing pavements. Pressure sensitive film works well on good asphalt surfaces. Better bond is achieved on concrete pavement or old asphalt when contact adhesive cement is applied prior to the installation. In such instances, manufacturers may recommend two coats on the pavement and one on the film, particularly for intersection markings subjected to heavy turning movements. The markings can be tamped by simply stepping on them, but most authorities prefer to use a light hand roller to ensure good placement until the continuous tyre pressure of traffic can securely bond the film to the pavement.
- 5 For construction or maintenance jobs which require temporary delineation of new or altered travel lanes through the work zone, a thinner, self-adhesive tape can be applied directly to the pavement. Two forms of temporary marking tape are available. One form is intended for use in those types of construction projects where removable markings will not be required. The other form is designed for easy removability. Major advantages of the latter type of material are that it is highly retroreflective, it is quickly installed by a two-man crew, and can be removed easily when the construction project changes configuration or is completed, and traffic flow changes to a new or original configuration.

18.5.13 Service Life

- 1 Although thermoplastic markings have been in use for a number of years, there is little agreement on their service life.

The longevity and durability of the plastic film, *per se*, has been fairly well established. The problem arises in attempting to establish an expected service life of a particular material as installed on a given roadway. There are too many factors influencing performance to permit an average life to be predicted with any confidence.

- 2 The remaining thickness and/or the percentage of longitudinal area retained are the most common measures of service life. For example, it is assumed that the line is no longer effective when the thickness falls below 0,25 mm to 0,38 mm. The longitudinal loss of thermoplastic is most often used to determine terminal service life.

18.5.14 Maintenance

- 1 One of the advantages of thermoplastic markings is its durability. Depending on the material used and the roadway characteristics, thermoplastics can provide virtually maintenance free delineation for a number of years. Some of the maintenance concerns related to thermoplastics are discussed in subsequent subsections.

18.5.15 Staining

- 1 In very hot climates, thermoplastic markings can become discoloured or badly stained by tyre tracks, particularly on bituminous pavements. This degrades the day-time contrast and visibility. Thermoplastics are, however, somewhat self-cleaning during rainy weather as a result of tyre action on the wet markings. In hot dry areas it may be beneficial to consider cleaning markings with a mild detergent.

18.5.16 Patching

- 1 The nature of thermoplastic, especially the thicker extruded installations, is such that pieces of the markings can be chipped away if the bond to the pavement is faulty, or if the internal cohesion of the pavement itself is unstable. Almost all of the thermoplastic materials, hot and cold applied, can be patched by placing a thin overlay of compatible material over that portion of the old marking. This is usually accomplished with a manual applicator.

18.5.17 Replacement

- 1 When the thermoplastic markings are no longer effective and must be replaced for safe operations, it is common practice to renew the lines with overlays of compatible material. This can be treated as a scheduled maintenance activity, a separate project, or as part of a larger improvements programme. Depending on the size of the installation, or road authority policy, the work can be undertaken by road authority staff or can be contracted out.

- 2 In some cases, thermoplastic markings outlive their retroreflective properties. One road authority in USA has experimented with the overlaying of the thermoplastic with paint and retroreflective beads to obtain night-time visibility. The paint was used as a binder to retain the beads since much of the thermoplastic material was still in place. If the paint adheres to the thermoplastic and if the thermoplastic base is securely bonded to the pavement, this could represent an inexpensive method of upgrading markings with inadequate retroreflectivity. However, there is no available information on the performance of this combination.

18.5.18 Removal

- 1 Thermoplastic markings are intended for life-long installations. As such, they are relatively difficult to remove. Those properties which enhance durability (thickness, integral bond with pavement) serve as deterrents to easy removal.
- 2 On either bituminous or concrete surfaces, the removal of a thermoplastic marking will leave some degree of scarring of the pavement surface. The extent of the scar will depend on the method of removal employed. Sand-blasting is frequently used for large removal jobs. One operation features a high-pressure water jet used in conjunction with sand-blasting. This minimises the residual sand left on the pavement and enhances the effects of the sand-blasting.
- 3 The excessive oxygen paint removal equipment described in Section 18.4 has also been used to remove hot-spray applied thermoplastic. In this case, the hot flame melts the plastic which is then removed with a straight spade. Subsequently the residual marking is re-burned and the burned residue is brushed away leaving only a slight indication of where the marking had been. This will disappear with traffic wear.
- 4 For smaller jobs, an air hammer and chipping blade may be used, although on asphalt surfaces this requires extreme care to prevent inordinate damage to the road surface. To remove an occasional arrow, symbol or legend, a hand hammer and chisel can do a satisfactory job.
- 5 Because of the long life and inherent difficulty in removing permanent thermoplastic markings, care should be exercised in their application to ensure that changes in marking patterns are kept to a minimum. Road maintenance programmes, future permit work and utility repair programmes should also be considered to avoid installing thermoplastic on a roadway that will be resurfaced during the early life of these markings.

18.6 RAISED PAVEMENT MARKERS – ROADSTUDS (RPM's)

18.6.1 General

- 1 The use of glass beads in paint was the first breakthrough in providing low-cost day and night visibility. Unfortunately, these retroreflective painted markings disappear from view when the surface of the roadway becomes wet. This loss of visibility occurs when visibility is most needed - during adverse weather conditions, particularly on rainy or foggy night.
- 2 During the past several decades, a significant emphasis has been placed on continuing research to develop a durable marking device that could provide both day and night visibility under adverse conditions. Raised pavement markers (RPM's), retroreflective and non-retroreflective, have emerged from this research as highly effective delineation devices.

18.6.2 Uses

- 1 Essentially, raised pavement markers can be used in place of, or as a supplement to painted road markings, in particular, longitudinal markings. RPM's are covered in Volume 1, Chapter 7, Section 7.5.
- 2 In effect, the same general principles governing the use of painted markings apply to RPM's in terms of colour, configuration and application. Chapter 2: *Road Marking Applications*, addresses RPM or roadstud application location and patterns.

18.6.3 Functional Applications

- 1 There are several different types of RPM. The characteristics of the particular categories of RPM are directly related to their functional application. Non-retroreflective markers are used in some installations to completely replace painted longitudinal line markings (dividing and lane lines). Retroreflective markers are most commonly interspersed with painted markings to enhance night-time visibility where there is no overhead lighting. The higher initial cost of a complete raised pavement marker system is justified on the basis of the long service life and increased wet weather visibility. More frequently, road authorities tend to use retroreflective RPM's in conjunction with painted lines for a general improvement in longitudinal delineation. Because RPM's provide increased visibility at night, especially during rainy conditions, retroreflective RPM's are particularly desirable at high hazard locations such as freeway exit ramps, bridge approaches, lane transitions, horizontal curves, and in roadworks environments.
- 2 There are three basic colours of markers in use:
 - (a) white;
 - (b) yellow; and
 - (c) red.

The white and yellow markers are used alone or in combination with painted lines to convey the same messages as the painted lines. Red retroreflective markers are used to convey the message "wrong way". Blue markers are being used on an individual basis by some authorities to indicate the presence of fire hydrants/water valves.

18.6.4 Considerations for Application

- 1 Raised pavement markers have certain advantages over painted markings:
 - (a) retroreflective RPM's provide increased retroreflectivity under wet weather conditions;
 - (b) both retroreflective and non-retroreflective RPM's have a durability and life much greater than painted lines; therefore replacement is much less frequent than for paint lines and hazardous re-painting under heavy traffic conditions can often be avoided;
 - (c) the vehicle vibration and audible tone produced by vehicles when running over or crossing the markers creates a secondary warning;
 - (d) the capability of providing directional control of retroreflective colour permits their use in conveying "wrong way" messages;
 - (e) non-retroreflective RPM's can be used as transverse "rumble strips".
- 2 A principle disadvantage of RPM's is the high initial cost. In order to recover the high initial investment and realise the full benefit of the durable long life materials in raised pavement markers, their application tends to be limited to more important roadways, hazardous locations, and roadways having a surface that will not soon be subject to major repair, replacement, or excavation activity.

18.6.5 Materials

- 1 A number of concepts have been applied to developing a low cost, durable raised pavement marker. A primary goal has been to produce a RPM that will:
 - (a) provide both day and night visibility at least equal to that of a retroreflective painted line; and
 - (b) be highly visible under wet night conditions.
- 2 Commercially available RPM's are quite varied and provide a wide range of capabilities. No one type of marker satisfies all of the capabilities mentioned above. The size, shape, retroreflective properties and materials used are selected to fulfil the widest range of delineation requirements at the lowest cost. While there is a trade-off between higher visibility at higher cost and lower visibility at lower cost, this is not a linear relationship, and RPM's should be selected on the basis of site requirements.
- 3 In addition to the several types of off-the-shelf markers in general use, there are a number of experimental configurations still under development, and others which have been investigated and abandoned. The following subsections cover highlights of:
 - (a) the more commonly used markers;
 - (b) special-use markers; and
 - (c) markers in the planning stage.

18.6.6 Physical Characteristics of RPM's

- 1 The fore-runner of the raised pavement marker was a convex button with glass beads suspended in a flexible polyester resin. Referred to as "Botts Dots" after the name of the developer, these markers were introduced in California in 1954. These retroreflective markers were cemented to the road surface with an epoxy adhesive, one each in the centre of the 4,5 metre gap in the broken painted "centre" line marking.. In theory, these elevated markers "shed the water" and were not readily submerged. They were used as auxiliary devices to provide delineation during darkness and wet weather. The service life of the markers was estimated to be 20 years on concrete pavements.
- 2 A number of variations of this round-headed button have been developed, but the original convex configuration has been maintained. For example, a non-retroreflective ceramic button is used today for day visibility as a low-cost alternative to painted lines. In this case, the buttons should be used in combination with retroreflective markers to provide both day and night visibility. Another variation of the convex configuration in general use is the ceramic button with a glass or plastic retroreflective insert utilising glass beads.
- 3 The rectangular wedge shaped marker was developed shortly after the "Botts Dot", around 1955, to improve durability on asphalt surfaces. These early wedges utilised the same concept, that is polyester resin base with glass beads as the retroreflective element. The wedge shed water and extended above the water film usually encountered during wet weather. This configuration also allowed one - and two-way delineation.
- 4 Subsequent advances in precision moulding technology made possible the application of a trihedral angled mirror retroreflection (corner cube) principle to the wedge shaped marker. In this system, three mirrored surfaces are arranged at a proper angle to receive the light rays from headlights on one of the three mirrors. From there the rays are reflected to a second mirrored surface, and then to a third, and finally outwards on a line parallel the path of entry. These tiny tri-mirrored surfaces are arranged as shown in Figure 18.5 to provide the retroreflective unit for use in RPM's. Approximately 360 retroreflective corner cubes are contained in the face of a marker measuring 91,4 mm by 25,4 mm.
- 5 Prismatic corner cube retroreflective markers are available in a combination of colours:
 - (a) silver (white);
 - (b) yellow; and
 - (c) red.

They come in one-way and two-way configurations combining any of the three standard colours. Generally, these retroreflective units are encased in a plastic shell. In one version, the retroreflective surface covers the entire sloping face of the wedge. In another version, the face is divided into two retroreflective surfaces bounded by the base material.
- 6 The basic difference between these two variations involves daytime visibility. The full face retroreflective element, usually encased in a silver grey housing, produces brilliant delineation

on both clear and rainy night conditions, but is almost invisible in daylight. The dual element retroreflectors cover a smaller area of the face and are encased in white or yellow plastic thereby being somewhat visible in daylight.

18.6.7 Adhesion Characteristics

- 1 The service life of any roadway delineation material is a direct function of the bond or adhesion between the delineation material and the road surface. Ideally, the bond strength between the two should be equal to, or greater than, the strength of the pavement itself. The physical strengths of the epoxy resins used today far surpass the internal physical strength of either concrete or asphalt pavements. Since road films, laitance in concrete, and other conditions encountered in the field often interfere with the direct access of the epoxy resin bonding material to the main structure of the pavement surface, it is often necessary to undertake some form of surface preparation to achieve a proper bond.
- 2 Good adhesion is particularly critical in the use of RPM's as roadway delineation devices. The major factors that impact on good adhesion between the marker and the pavement surface are:
 - (a) the properties of the bonding agent;
 - (b) the design of the marker's bonding surface;
 - (c) the type of pavement;
 - (d) the temperature; and
 - (e) the care exercised in application.
- 3 In general practice, RPM epoxy adhesives are proportioned, mixed and extruded by automatic mixing equipment. Flow properties of the adhesive (i.e. its viscosity) at various temperatures are important not only for the proportioning, mixing and extruding, but also to prevent excessive flow of the extruded adhesive from the marker when placed in position.
- 4 There are numerous formulations of epoxy bonding agents used to fix RPM's to the pavement surface. These formulations generally fall into two classifications:
 - (a) **Standard Set** - which may take up to several hours to cure: and
 - (b) **Rapid Set** - which may be ready to receive traffic in 10 to 15 minutes.

Manufacturers of RPM devices recommend and supply epoxy adhesives compatible to their individual product.
- 5 There are some forms of RPM's that are pressure sensitive and do not require a special epoxy adhesive. They do require that a primer be applied to the pavement surface and be allowed to dry before placing the marker. The marker is then immediately ready for traffic. This type of RPM is generally used by smaller municipalities and for roadworks zones and detours, and other applications.
- 6 The adhesion characteristics of RPM devices differ as a function of the base material. That is, ceramic materials do not bond as well as the acrylic shell. For this reason California, USA, specifies that their ceramic markers have a textured surface to increase the bond with the pavement, as follows:

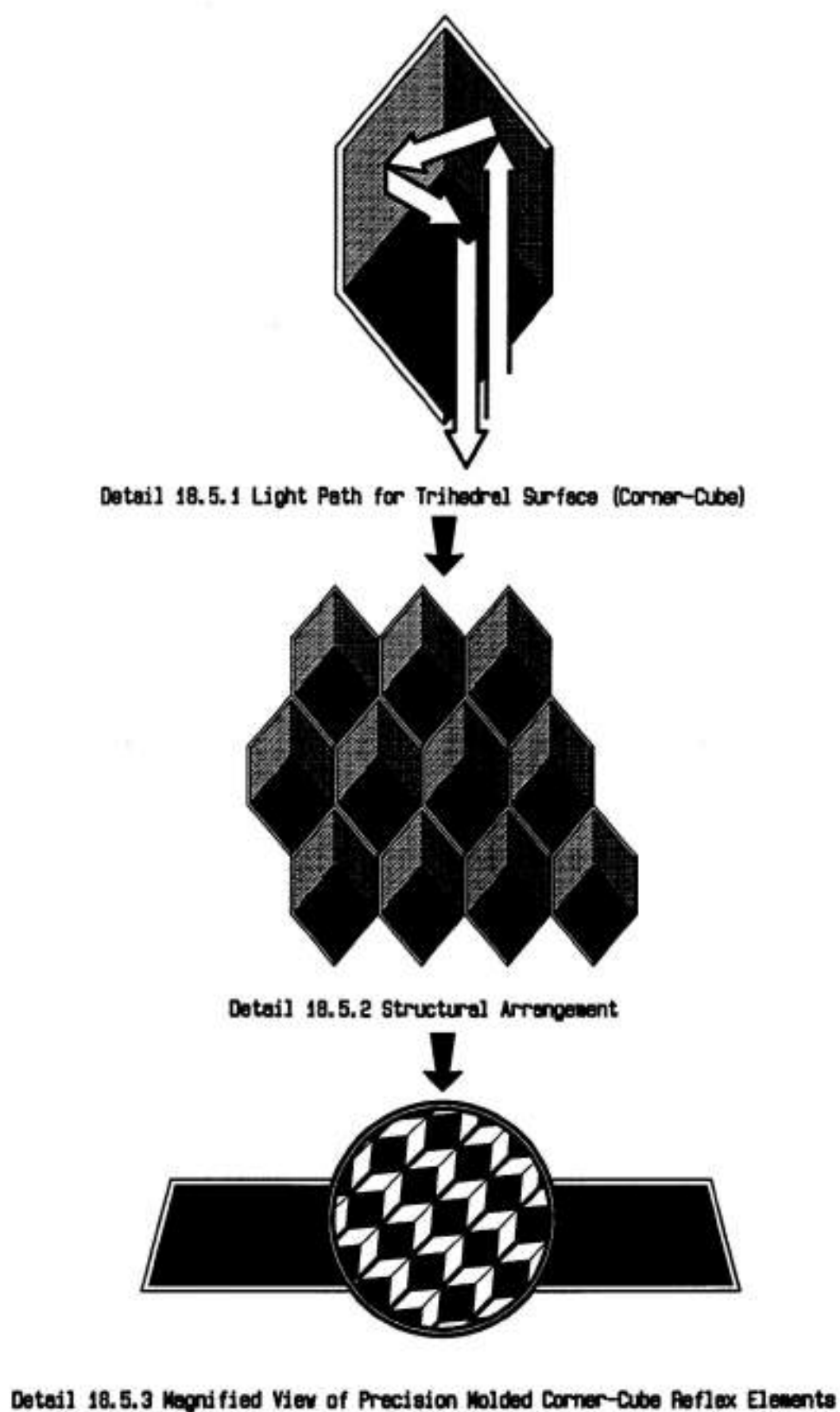


Fig 18.5

Principle and Structure of Corner-Cube Retroreflector

- (a) the bottoms of the ceramic markers shall be free from gloss or glaze and shall have a number of integrally formed protrusions approximately 1,27 mm projecting from the surface on a uniform pattern of parallel rows;
 - (b) each protrusion shall have a flat surface parallel to the bottom of the marker; the area of each parallel face shall be between 65,2 mm² and 41,9 mm², and the combined areas of these faces shall be between 1419 mm² and 2581 mm²;
 - (c) the protrusions shall be circular in section;
 - (d) the number of protrusions should be not less than 50 nor more than 200;
 - (e) to facilitate forming and mould release, the sides of each protrusion may be tapered; this taper shall not exceed 15° from the perpendicular to the marker bottom; markers manufactured with protrusions whose diameter is less than 3,8 mm may have an additional taper not exceeding 30° from the perpendicular to the marker bottom and extending no more than one-half the total height of the protrusion;
 - (f) the overall height of the marker shall be between 17.2 mm and 20.3 mm.
- 7 There is some considerable difference in some physical characteristics of asphalt materials made from various crude stocks which still meet specifications for paving asphalt. Some of these properties can be expected to affect the ability of a fresh asphalt or concrete mix to retain raised pavement markers. Consequently, some road authorities may adopt a waiting period before placing markers. Similarly, it is clear that some agents soften asphalt so that good marker retention cannot be expected. The softened asphalt will, however, harden again with time. It is, therefore, recommended that no installation of RPM's be made for one year after the application of a rejuvenating agent.

18.6.8 Temporary Delineation Using RPM's

- 1 The problem of safely carrying traffic through construction and maintenance zones, especially on high-speed, high-volume roadways, requires that the contractor maintain normal traffic flow and provide positive guidance so that potential accident situations are kept to a minimum. To maintain safe traffic flow, the contractor has several alternatives, depending on the number of factors such as:
 - (a) normal traffic;
 - (b) peak traffic;
 - (c) percentages of trucks;
 - (d) speed;
 - (e) geometry;
 - (f) seasonal aspects;
 - (g) urgency etc.
- 2 A system of RPM's is one alternative that will provide effective day and night delineation. RPM's are easy to install and remove, and, after removal, do not leave a misleading indication to confuse drivers. Despite the apparent safety benefits, the relatively high cost of these devices has retarded their use. Accordingly, the Federal Highways Administration, in the USA, conducted a comprehensive study of the use of

RPM's for roadworks delineation. Specifically, the objective was to evaluate the costs, spacing, case of application and removal, and the ability of the markers to guide traffic and produce public acceptance.

- 3 The major findings and recommendations based on the experience in 9 states in USA are that the markers are effective and provide positive day-time and night-time guidance through both wet and dry periods. The additional safety, improved operations, reduced vandalism, and unanimous favour of the public, government and construction personnel justify their expanded use. On an economic basis, the cost of the markers and paint was equal to or less than the cost of paint marking and removal. Most significantly, the study found that the use of retroreflective RPM's on roadworks detours tended to reduce the number of accidents.

18.6.9 Application of Self-Adhesive Markers

- 1 The "self-adhesive" marker with a pressure sensitive butyl backing provides a satisfactory bond with the pavement. These retroreflective devices are well suited to detour-type applications. They are easy to install and maintain since no epoxy formulation or special application equipment is necessary. These markers are far less labour intensive in terms of actual installation time as well as time required for traffic control since they are virtually ready for traffic as soon as they are installed.
- 2 The "self-adhesive" markers have proved to be surprisingly durable under normal traffic conditions. There is no significant difference in the loss rate between markers placed with epoxy and those placed with butyl pads in this type of usage. It should be noted, however, that the butyl padded ceramic marker does not perform as well as the acrylic shell marker. It should also be noted that lower temperatures (below 9.4°C) seem to reduce the bonding capability of the butyl pads. The basic installation procedure is to mark and sweep the location of the marker. Using a marker-sized cardboard template, an adhesive primer is applied with a paint brush to each pre-marked location. The paper backing is removed from the marker and the marker is placed on the cured primer. A following car then sets the marker by slowly driving over it. An applied mass of 700 kg for 6 seconds is required.

18.6.10 Performance

- 1 As with other forms of delineation, the performance of RPM's is usually expressed in terms of durability and visibility. The various types of markers provide different forms of visibility. For example, non-retroreflective ceramic markers are used to provide day-time visibility and to supplement retroreflective markers in providing night-time visibility. The corner-cube retroreflective marker provides excellent night-time visibility (especially in adverse weather conditions), but is virtually ineffective in daylight. These conventional markers, when combined for day and night visibility, perform exceptionally well.

18.6.11 Conventional Markers

- 1 The experience of authorities who use RPM's will vary widely, depending on the roadway characteristics and conditions. Findings and observations compiled from experience of these authorities are included below for non-retroreflective ceramic markers and for conventional

retroreflective RPM's:

(a) raised ceramic markers :

- (i) white and yellow ceramic markers may be expected to last in excess of 10 years;
- (ii) the ceramic marker system gives good day-time visibility when clean, and when wet it supplements the corner cube retroreflective marker in producing good night-time delineation; alone, the white ceramic marker provides night delineation only in dry weather;
- (iii) in hot dry months, considerable road film can accumulate on the ceramic markers and the visual delineation is less than desired in daytime and almost non-existent at night; this condition is usually reversed after periods of wet weather; it can also be controlled in urban environments where mechanical street cleaning is used;
- (iv) poor bonding accounts for most marker losses; the use of a textured base creates a better adhesion with the pavement surface;

(b) raised retroreflective markers;

- (i) within a few months, the retroreflectivity of the corner cube marker is reduced to 80% to 50% of its original value due to surface abrasion of the retroreflective element; this retroreflectivity however, is adequate and tends to remain fairly constant for the life of the marker ;
- (ii) expected service life for retroreflective markers varies from 2 years under severe conditions to up to 8 years on most freeway locations and up to 10 years on rural low density roads.

The high retroreflectivity corner cube lens, even when partially obscured or damaged will still provide some level of retroreflective performance unless the lens face has been completely destroyed.

18.6.12 Installation Procedures

- 1 Although the installation of RPM's is not a difficult procedure requiring neither special complex equipment nor specialised staff capabilities, new installations are commonly part of a construction or improvement contract. Maintenance (replacement), on the other hand, is usually performed by road authority work crews. General practice and individual procedures related to the various types of markers are covered in following subsections.

18.6.13 General Practice

- 1 On two-way roads, RPM's should be installed within traffic control conditions like any other operation on the travelled way.
- 2 Cleaning the surface of concrete and old asphalt pavements should be undertaken prior to the application of the devices. Clean, newly placed asphalt need not be blast cleaned unless the surface contains an abnormal amount of asphalt or the surface is contaminated with dirt, grease, paint, oil, or any other material which would adversely affect the bond of the adhesive.
- 3 The adhesive should be placed uniformly on the cleaned pavement surface or on the bottom of the marker in a quantity sufficient to result in complete coverage of the area of contact of the marker, with no voids present and with a slight excess after the marker has been pressed into place. The marker

should be placed in position and pressure applied until firm contact is made with the pavement.

- 4 Excess adhesive around the edge of the marker, on the pavement, or on the retroreflective surface of the markers should be removed. A soft rag moistened with mineral spirits or kerosene can be used, if necessary, to remove any excess adhesive. The marker must be protected against traffic impact until the adhesive has hardened. Traffic control and protection of the markers is similar to other road marking operations.
- 5 Retroreflective markers should be placed so that the retroreflective face of the marker is perpendicular to a line parallel to the roadway centre line. No pavement markers should be placed over longitudinal or transverse joints in the pavement.
- 6 When the RPM's are used to supplement a continuous painted or thermoplastic road marking they are generally offset 50 mm from the edge of the line. This permits repainting the line without degrading the retroreflective properties of the markers. Some special road marking patterns, commonly those used in high risk potential conflict areas (merges and diverges) may require that the RPM's be located within the road marking. Special attention must then be paid to protecting the RPM's when such lines are being re-marked. For example, when a 300 mm channelising line is used such an arrangement is normally specified.

18.6.14 Using Epoxy Adhesives

- 1 As described in Subsection 18.6.7, there are numerous formulations of epoxy bonding agents. The proper proportioning, mixing, extruding and handling, are, in general, the most critical parts of the application procedure.
- 2 Essentially, all two-part epoxies require that the mixing operation and the placement of the marker on the pavement be carried out quickly. Whether hand mixing or machine mixing is used, most standard types of epoxy require that the marker be coated, aligned, and pressed into place within minutes after mixing is started. Consequently, no more than a litre of adhesive should be hand mixed at one time.
- 3 Rapid set adhesive is usually mixed by a two component automatic mixing and extrusion apparatus. For a typical large scale installation, a crew member is positioned on a platform located low on the side of the truck between the front and rear axles. The mixing and extruding apparatus is installed nearby. A predetermined amount of the mixed epoxy is expelled onto the bottom surface of the marker which the operator then positions on the pavement well within the 40 to 60 seconds allowed.
- 4 To achieve a proper bond, care should be exercised to ensure that the adhesive is used in accordance with the manufacturer's instructions. For example, some standard set type adhesives require that the pavement and air temperatures be above 10°C. Rapid set can usually be applied at temperatures as low as 1°C. Normally, no marker should be set if the relative humidity is over 80% or if the pavement surface is not dry.

18.6.15 Maintenance

- 1 The routine maintenance of RPM's is almost always a function of the road authorities maintenance teams. No complex equipment or special crew capabilities are needed for the replacement of conventional RPM's. The only critical element

involves the proportioning and mixing of two-component epoxy as discussed in Subsection 18.6.14. Contractors will normally install such markers as part of resurfacing or other types of rehabilitation or construction contract that requires the replacement or new installation of RPM's. The following subsection address some RPM maintenance practices and developments that have proved effective or show promise for future use.

18.6.16 Routine Maintenance Levels

- 1 As in maintenance functions, there are two basic categories of maintenance:

- (a) periodic or preventative maintenance (routine); and
- (b) immediate or emergency repairs (as-and-when needed).

In the context of delineation, the former is performed to maintain the system at a safe operational level commensurate with established policy or standards. The latter function usually involves returning a hazardous condition to a safe condition shortly after it occurs or is identified.

- 2 The approach to routine maintenance varies among road authorities. If expected service life is adopted as the primary determinant for routinely scheduling marker replacement, the history of brand name marker performance and the traffic characteristics of individual roadway sections must be known. For example, if experience or field tests have indicated that a particular type of lane line marker can be expected to remain effective for 6 years on long sections of high speed multi-lane freeway, and 3 years in areas of heavy turning movements such as near ramps and merge and diverge areas, then replacements of markers can be scheduled accordingly. This is not always a cost effective procedure even though the practice does not require night inspection. The number of markers that must be replaced, may not warrant the effort, or the marker system may have deteriorated below safe levels.
- 3 A more commonly used criterion for replacement is based on the number of missing markers that can be tolerated without seriously degrading driver's visibility, particularly under adverse weather conditions. For example, it can be specified that markers should be replaced when 8 or more non-retroreflective markers are missing in a 30 m section, and when 2 or more successive retroreflective markers are missing.
- 4 The determination of the acceptable level of missing or damaged markers is based on the spacing, pattern, whether painted markings are present, and the roadway geometry. Once the level is specified, inspections must be conducted, usually at night, to identify areas where missing markers exceed the acceptable level. Such night inspections are usually scheduled near the end of the expected service life. In some cases, spot checks are conducted annually prior to the onset of adverse weather cycles. Inspection of roadway markings may also be included as part of regularly scheduled traffic control device inventories.

18.6.17 "As Needed" Maintenance

- 1 This form of immediate maintenance is important from the standpoint of legal responsibility. Although not a frequent occurrence under normal circumstances, care must be exercised to ensure that appropriate delineation is not interrupted by major accidents or natural disasters, which may have damaged or removed RPM's.
- 2 This type of maintenance is most commonly associated with

roadworks zones and unexpected storms. In areas accustomed to heavy seasonal rainfall with the possible coverage of the road surface by mud or gravel inspection and maintenance of the markers after the rainy season is usually considered routine maintenance.

- 3 When self-adhesive markers are used for temporary delineation on roadways through, or adjacent to, roadworks zones, inspection and maintenance are critical safety considerations. In particular, areas of heavy truck or construction traffic should be carefully monitored and missing markers replaced to ensure that the temporary travelled way is clearly delineated. This is often either a shared responsibility with the contractor, or the sole responsibility of the contractor.
- 4 Whilst not applicable to all situations, authorities could develop several interesting shortcuts in marker replacement. For example, on some freeways where two successive retroreflective markers are badly damaged another retroreflective marker could be placed immediately in front of the defective marker. This can be achieved quickly since time is not spent removing the damaged marker.
- 5 Replacement on long sections over several kilometres of freeway is often scheduled for early Saturday or Sunday morning when coning will not be too disruptive to traffic. Whenever possible other site maintenance should be scheduled for the same period, in order to take advantage of the lane closure and other protective measures. The simplest form of operation consists of a crew member walking along-side the epoxy dispensing truck and indicating which markers are to be replaced. The "applicator", who is located in the well of the truck, activates the epoxy dispenser which extrudes a measured quantity of the mixed epoxy onto the bottom of the new marker which is then firmly placed next to the damaged marker or near the location of where a missing marker used to be. A following crew member removes the old marker by hammer and chisel with one or two taps and disposes of it in a hopper in the back of the truck. Cones and following vehicles are used as needed to protect the crew and the markers from traffic. This operation can move at from 2 km/h to 5 km/h depending on the number of markers to be removed and/or replaced.
- 6 Semi-annual night inspection of sections containing markers nearing the end of their expected service life are conducted by the maintenance engineer and staff to determine the scheduling priority. This type of replacement operation is normally scheduled when 50% or more of the markers are defective or missing.

18.6.18 Cleaning RPM's

- 1 It has been noted that during hot dry periods, road film, oil, grease and other debris will seriously degrade the retroreflective performance of markers. It is also noted, that tyre marks can stain non-retroreflective ceramic markers to the point that they are no longer visible, either by day or night. Most of the commonly used markers are self-cleaning to some extent when wet. Loss of delineation from staining is not a critical problem in geographic areas that normally experience summer rains. It can become significant in hot dry areas. The cleaning of stained markers is not easily accomplished using any of the more common organic solvents, but can be achieved with a cleanser containing a fine abrasive.

VARIABLE MESSAGE SIGNS

SECTIONS

- 19.0 Contents
- 19.1 Introduction
- 19.2 Terminology
- 19.3 Planning
- 19.4 Warrants
- 19.5 Design Considerations
- 19.6 VMS Elements
- 19.7 Applications of VMS
- 19.8 Specifications
- 19.9 Maintenance
- 19.10 Testing and Measurement

MAY 2012



SARTSM – VOL 2

CHAPTER

19

TITLE SOUTH AFRICAN ROAD TRAFFIC SIGNS MANUAL Volume 2 Chapter 19			
ISBN	STATUS Digitised Version	DOT FILE 000/0/0/0	DATE Digitised May 2012
DIGITISING CARRIED OUT BY Transport and Traffic Technology Africa (Pty) Ltd P O Box 1109 SUNNINGHILL 2157			
COMMISSIONED BY Department of Transport Private Bag X193 PRETORIA 0001			
ORIGINAL AUTHOR J J Prinsloo		PUBLISHER ENQUIRIES Director-General: Transport Private Bag X193 PRETORIA 0001	
It is impossible for a publication of this nature to free of errors. It would be appreciated if errors be brought to the notice of - Director-General: Transport Department of Transport Infrastructure Network Management Private Bag X193 PRETORIA 0001			
COPYRIGHT This publication is protected by copyright under the Bern Convention. In terms of the Copyright Act No. 98 of 1978, no part of this publication may be produced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording or by any information storage or retrieval system, without permission in writing from the publisher. © National Department of Transport 1999, 2012			
KEYWORDS ROAD SIGN, ROAD MARKING, REGULATORY, WARNING			
COST: VOLUME 2			
VOLUME SET		R	
Chapter 1	R	Chapter 11	R
Chapter 2	R	Chapter 12	R
Chapter 3	R	Chapter 13	R
Chapter 4	R	Chapter 14	R
Chapter 5	R	Chapter 15	R
Chapter 6	R	Chapter 16	R
Chapter 7	R	Chapter 17	R
Chapter 8	R	Chapter 18	R
Chapter 9	R	Chapter 19	R
Chapter 10	R		

CHAPTER 19: VARIABLE MESSAGE SIGNS

CONTENTS

19.0.1 Sections and Subsections

Number	Title	Page No.
19.0	CONTENTS	19.0.1
19.0.1	Sections and Subsections	19.0.1
19.0.2	Figures	19.0.2
19.0.3	Tables	19.0.3
19.1	INTRODUCTION	19.1.1
19.1.1	Background	19.1.1
19.1.2	Objectives of VMS	19.1.1
19.1.3	What is a VMS System?	19.1.1
19.1.4	Typical Applications of VMS	19.1.1
19.1.5	References	19.1.2
19.2	TERMINOLOGY	19.2.1
19.2.1	General	19.2.1
19.3	PLANNING	19.3.1
19.3.1	VMS: Part of an Overall System	19.3.1
19.3.2	Types of Display	19.3.1
19.3.3	Light Reflecting Displays	19.3.1
19.3.4	Light Emitting Displays	19.3.1
19.3.5	Hybrid Types	19.3.1
19.3.6	Control Systems	19.3.2
19.3.7	Surveillance Systems	19.3.2
19.3.8	Communication Systems	19.3.2
19.3.9	Fields of Application of VMS	19.3.2
19.3.10	Classification	19.3.2
19.3.11	Positioning of VMS	19.3.2
19.3.12	Flow of Data Through Control Centre	19.3.6
19.3.13	Checklist	19.3.6
19.4	WARRANTS	19.4.1
19.4.1	General	19.4.1
19.4.2	Warrant 1 - Traffic Volumes	19.4.1
19.4.3	Warrant 2 – Traffic Accident Statistics	19.4.1
19.4.4	Warrant 3 – Level of Congestion	19.4.1
19.4.5	Warrant 4 - Other	19.4.1
19.4.6	Checklist	19.4.1
19.5	DESIGN CONSIDERATIONS	19.5.1
19.5.1	General	19.5.1
19.5.2	Conspicuity	19.5.1
19.5.3	Legibility and Readability	19.5.1
19.5.4	Comprehensibility	19.5.1
19.5.5	Credibility	19.5.1
19.5.6	Colours	19.5.2
19.5.7	Sign Display Mounting	19.5.2
19.5.8	Checklist	19.5.2

Number	Title	Page No.
19.6	VMS ELEMENTS	19.6.1
19.6.1	General	19.6.1
19.6.2	Pixel Characteristics	19.6.1
19.6.3	Module Characteristics	19.6.1
19.6.4	Text Display	19.6.1
19.6.5	Symbolic Display	19.6.1
19.6.6	Symbols to be Used on Non-Matrix VMS	19.6.1
19.6.7	Symbols to be Used on Matrix VMS	19.6.2
19.6.8	Characteristics of Messages	19.6.2
19.6.9	Types of Information Displayed	19.6.2
19.6.10	Deviation from Standards	19.6.2
19.6.11	Checklist	19.6.2
19.7	TYPICAL EXAMPLES OF VMS	19.7.1
19.7.1	General	19.7.1
19.8	SPECIFICATIONS	19.8.1
19.8.1	General	19.8.1
19.8.2	Photometric Performance of VMS	19.8.1
19.8.3	Light Reflecting VMS	19.8.1
19.8.4	Light Emitting VMS	19.8.1
19.9	MAINTENANCE OF VMS	19.9.1
19.9.1	General	19.9.1
19.9.2	Typical Maintenance	19.9.1
19.9.3	Checklist	19.9.1
19.10	TESTING AND MEASUREMENT	19.10.1
19.10.1	General	19.10.1
19.10.2	Subjective Measures of Performance	19.10.1
19.10.3	Objective Measures of Performance	19.10.1
19.10.4	Actual Performance	19.10.2
19.10.5	Evaluation and Testing of Optical Characteristics	19.10.2
19.10.6	Test Modules	19.10.2
19.10.7	General Optical Test Requirements	19.10.2
19.10.8	Luminance Ratio Measurement – General	19.10.2
19.10.9	Luminance Ratio Measurement – Test Area	19.10.2
19.10.10	Luminance Ratio Measurement – Multiple Light Sources	19.10.5
19.10.11	Luminous Intensity (or Luminance) Half Angle	19.10.5
19.10.12	Luminance or Luminous Intensity Uniformity	19.10.6
19.10.13	Colour	19.10.6

19.0.2 Figures

Figure No.	Title	Page No.
Fig 19.1	Elements of a TOMS	19.3.3
Fig 19.2	Types of Mechanical VMS	19.3.4
Fig 19.3	Types of Electro-Mechanical VMS	19.3.5
Fig 19.4	Types of Electric or Electronic VMS	19.3.6
Fig 19.5	Hybrid VMS	19.3.7
Fig 19.6	Typical Location of VMS	19.3.9
Fig 19.7	Typical Flow of Data Through the Control Centre	19.3.10
Fig 19.8	Sign Mounting	19.5.3
Fig 19.9	Positioning of VMS	19.5.4
Fig 19.10	Effect of Interference from the Sun	19.5.5
Fig 19.11	Typical Symbols for Pictograms	19.6.3
Fig 19.12	Module Layout – Matrix Arrays	19.6.4
Fig 19.13	Display Layout	19.6.5

Figure No.	Title	Page No.
Fig 19.14	Font for a 7 x 5 Module	19.6.6
Fig 19.15	Minimum Reading Times for Short Word Messages	19.6.7
Fig 19.16	Typical Messages to be Displayed	19.6.8
Fig 19.17	Example of Fibre Optic VMS (Limited Message)	19.7.2
Fig 19.18	Example of Overhead-Mounted LED VMS (Multi-Message)	19.7.3
Fig 19.19	Example of Overhead-Mounted Fibre Optic Lane VMS (Limited Message)	19.7.4
Fig 19.20	Example of Horizontal Rotating Prism VMS (Limited Message)	19.7.5
Fig 19.21	Example of Vertical Roatating Prism VM<S (Limited Message)	19.7.6
Fig 19.22	Example of Overhead-Mounyed Text/Graphics LED VMS (Multi-Message)	19.7.7
Fig 19.23	Chromaticity Chart of Light reflecting Displays	19.8.2
Fig 19.24	Luminance and Irradiation Compensation for Light Emitting Displays	19.8.3
Fig 19.25	Luminous Intensity Distribution for VMS	19.8.4
Fig 19.26	Measurement of Luminance Ratio	19.10.3
Fig 19.27	Measurement of Test Area – 1	19.10.4
Fig 19.28	Measurement of Test Area (Text Matrix) - 2	19.10.7

19.0.3 Tables

Table No.	Title	Page No.
Table 19.1	Limits of Contrast	19.10.5

CHAPTER 19: VARIABLE MESSAGE SIGNS

19.1 INTRODUCTION

19.1.1 Background

- 1 Developments in the field of electronics over the last few years have been dramatic compared with any similar preceding period. It is evident that we are experiencing an electronic revolution similar to or even greater than the industrial revolution at the turn of the nineteenth century.
- 2 The provision of information today is a major industry. The more information one has at one's disposal, the better decisions one can take in managing people, a business, a vehicle or a road network.
- 3 With the ever growing congestion on our roads and the decline in the availability of land, it is becoming more and more important to make maximum use of the existing road network capacity.
- 4 Variable Message Signs (VMS) provide road authorities with an instrument to supply up-to-date information to the road user making use of all the latest electronic equipment in this field. A variety of types of VMS are available ranging from the simplest folding type sign to the fully remote controllable matrix display type sign.
- 5 This chapter introduces the concepts, functions and criteria related to VMS and basic warrants for their provision (see also Volume 1, Chapter 9).
- 4 Provision should be made during the design of the system to collect traffic data by:
 - (a) facilitating an assessment of the current state of the system;
 - (b) using the data to assist decision-making for the optimisation of the system;
 - (c) developing new or revised strategies to be used to improve the system in the future.
- 5 The achievement of these objectives could be furthered by one or more of the following:
 - (a) advising road users on speed requirements under adverse conditions (e.g. mist, fog, smoke, wet, accidents);
 - (b) detection and interpretation of disruptions in traffic flow;
 - (c) adequate advance warning of road and traffic conditions;
 - (d) deviation of traffic around incidents or congested road sections;
 - (e) the design and implementation of a flexible, expandable system able to accommodate technological upgrades.

19.1.2 Objectives of VMS

- 1 The introduction of Variable Message Signs should be aimed at achieving one or more of the objectives in the following paragraphs. The primary objective should be to strive for greater safety by:
 - (a) reducing the risk of primary accidents;
 - (b) giving advance warning of conditions which may result in traffic queues so that the increased likelihood of secondary accidents is reduced.
- 2 The next important objective should be to promote the improved utilisation of road capacity and subsequent reduction in congestion by:
 - (a) preventing bottle-necks by better distribution of traffic;
 - (b) achieving stable traffic flow conditions.
- 3 A further objective is to assist road and law enforcement authorities to fulfil their respective duties, with a minimum delay to road traffic, by:
 - (a) providing the means for rapid and effective action for incident management;
 - (b) assist in enabling roadworks to be carried out more safely, quickly, efficiently and with minimal disruption to traffic.

19.1.3 What is a VMS System?

- 1 A VMS system is a traffic control aid to relieve congestion, enhance traffic safety, improve mobility and collect and display traffic related information. It consists of a number of building blocks which will be dealt with later in this chapter.
- 2 The most important building blocks for a VMS system are the following:
 - (a) variable message display signs;
 - (b) traffic condition detection system;
 - (c) a control centre;
 - (d) a communications network.

19.1.4 Typical Applications of VMS

- 1 VMS has already been applied in a variety of fields and this list is growing every day. The following are some of the better-known applications which will be discussed in more detail in Subsection 19.3.3 with examples of some of the VMS provided in Section 19.7:
 - (a) traffic management:
 - (i) roadway information;
 - (ii) roadway incident management;
 - (iii) special events;
 - (iv) adverse road and weather conditions;
 - (v) variable speed control;

- (vi) following distance control;
- (vii) lane control/ management;
- (viii) safety management;
- (ix) construction/maintenance management;
- (x) ramp metering;
- (xi) demand management;
- (xii) priority access control;
- (xiii) ride sharing control;
- (xiv) high occupancy vehicle (HOV) control;
- (b) control at crossings:
 - (i) bridge management;
 - (ii) tunnel management;
 - (iii) toll gate management;
 - (iv) mountain pass management;
 - (v) weigh bridge control;
- (c) other applications:
 - (i) parking control/management;
 - (ii) public transport management;
 - (iii) intelligent vehicle highway systems (IVHS);
 - (iv) road navigational systems;
 - (v) park-and-ride.

19.1.5 References

The following documents represent a limited additional reading list. Many have further reference listings.

- 1 International Commission on Illumination. Variable Message Signs. Technical Report CIE 111 - 1994.
- 2 Dudek, Conrad L. Guidelines on the Use of Changeable Message Signs. Federal Highway Administration. U.S. Department of Transport. Publication No. FHWA-TS-90-043, July 1991.
- 3 Service d'Etudes Techniques des Routes et Autoroutes. Panneaux de signalisation à messages variables. Guide technique. Centre de la Sécurité et des Techniques Routières. December 1994.
- 4 Bundesanstalt für Strassenwesen. Richtlinien für Wechselverkehrszeichen-anlagen an Bundesfernstrassen (RWVA). April 1994.
- 5 Department of Transport. Optical Performance Functional Specification for Discontinuous Variable Message Signs (Draft 6). Report TR2136. Traffic Control and Communications Division, Department of Transport. United Kingdom. October 1993.
- 6 Department of Transport. Road Sign Note No. 10 - Variable Message Signs (VMS) - Draft. South Africa.
- 7 Automobile Association of South Africa. Relief Measures for Urban Traffic Congestion. World Traffic and Safety Foundation Research Report. 1993.
- 8 Stanway Edwards Associates Inc. Traffic Operations Management System : Masterplan for Johannesburg. Johannesburg City Council. March 1994.
- 9 McCormick Rankin Consulting Engineers. Technology Evaluation for Changeable Message Signs. Ontario Ministry of Transport. May 1989.
- 10 Jenkins S.E. Optical and Photometric Standards for Variable Message Signs. Research Report ARR 216. Australian Road Research Board - Vicroads.

19.2 TERMINOLOGY

19.2.1 General

- 1 The following terms are relevant to any discussion on Variable Message Signs. They are included here to assist readers. A more complete road traffic sign "Glossary of Terms" is given in Volume 1, Chapter 10.

"Pixel" - the smallest dot-like unit of a graphic display unit providing a light emitting or reflective source".

"Reflective sign" - a sign whose legend(s) and/or legend background is made visible by reflective light from daylight or other sources" (see Volume 1, Chapter 10 for descriptions of the terms "retroreflective" and "reflective").

"Special event" - an irregular event (usually associated with large concentration of people) involving a large amount of traffic (vehicular or pedestrian) affecting the normal flow of traffic on a road network".

"Light emitting sign" - a sign using light emitting devices in the display surface, with the purpose of displaying a legend(s) and/or a legend background(s)".

"Toll gate control" - the regulation of traffic at or in the vicinity of a toll gate with the purpose of improving the performance of the toll gate".

"Sign background" - the part of environmental scenery which immediately surrounds the face of a sign".

"High occupancy vehicle (HOV)" - vehicles carrying more than a preset number of occupants; such vehicles often include buses and taxis, but can also include motor cars".

"V/C ratio" - the ratio of the demand flow rate to the capacity of a traffic facility".

"Matrix" - a reference grid whose intersections may hold the centre of the elements used in a sign or in a legend background or in a legend; a matrix may be extended to a whole display surface or to part of it".

"Freeway" - a multi-lane divided highway having a minimum of two lanes for exclusive use of traffic in each direction and full control of access and egress".

"Level of service (LOS)" - a qualitative measure describing operational conditions within a traffic stream, generally described in terms of factors such as speed and travel time, freedom to manoeuvre, traffic interruptions, comfort and convenience, and safety".

"Variable message sign (VMS)" - a sign for the purpose of displaying one of a number of legends that may be changed or switched off, either manually or automatically at the site or remotely, as required".

"Tunnel/bridge control" - the regulation of traffic in/on or in the vicinity of a tunnel/bridge with the purpose of improving the throughput of traffic through the facility".

"Public transport management" - the preparation and management of a transport management plan covering all aspects of the available and possible future public transport systems".

"Transport demand management" - a process for the modification of the trip-making behaviour and habits of the

motoring public to reduce the use of single occupant modes of travel and at the same time encourage the use of multi-occupant modes of travel to enhance transport efficiency and minimise the negative effects of congestion".

"Ramp monitoring/control" - a system through which the entry of vehicles onto a limited access facility (usually a freeway) from a ramp is metered by manual or automatic traffic control devices, which can allow traffic onto the facility at intervals, or the closing off of on-ramps, dependent on traffic conditions on the facility".

"Ride-sharing management" - the development of methods of increasing the number of high occupancy vehicles (HOV) on the urban freeway and arterial network by providing cost effective incentives for using such modes of travel".

"Safety management" - consists of a process of timeous identification, investigation, setting of priorities and correction of hazardous or potentially hazardous roadway locations and features".

"Incident management" - a pre-planned set of procedures to deal with any incident with the main aim of restoring traffic to normal operation. The procedure consists of six steps i.e. detection, response, on-site management, clearance, follow-up and driver information".

"Motorist/driver information system" - the collection and analysis of road and traffic information followed by the interpretation thereof, to supply the road user with the necessary information to take timeous action to avoid congested areas, and thereby reduce driver frustration and secondary congestion levels".

"Parking information system" - the collection and analysis of parking facility occupancy levels to establish the availability of parking and the supply of such information to the road user to minimise unnecessary parking-seeking trips, thereby reducing driver frustration road user costs".

"Parking control" - the regulation of vehicle movements at parking facilities through a variety of activities to maximise the utilisation of parking facilities and at the same time optimise the flow of traffic in and out of such facilities".

"Parking guidance" - the timeous provision of information to the road user on the availability of parking spaces with the main purpose of minimising unnecessary parking seeking trips".

"Route planning systems" - the timeous provision of information to the road user to assist in the decision-making process in reaching the destination in the shortest length of time or along the least congested route".

"Incident" - the occurrence of any extraordinary condition or event which results in the reduction in road capacity, or creates a hazard for the road users for a sustained period of time".

"Construction management" - a set of pre-planned procedures complemented by the scheduling of activities to minimise the effect of construction and scheduled maintenance".

19.3 PLANNING

19.3.1 VMS: Part of an Overall System

- 1 VMS forms part of what is termed a Traffic Operations Management System (TOMS). A TOMS is the total operational system whereby the co-ordinated and pre-planned use of human, electrical and electronic resources are applied to manage and improve traffic flow and safety conditions on the road network. All the elements identified in Subsection 19.1.4 apply to a TOMS and are shown in Figure 19.1.
- 2 A vast amount of transportation, traffic and environmental information is required for a fully operational TOMS since it comprises a wide variety of control parameters. The TOMS elements can be grouped into two major focus areas, namely Congestion Management and Vehicle Highway Systems.
- 3 Congestion Management deals mainly with the identification of locations of congestion and the improvement of congestion levels on the road network. The following components are included in a Congestion Management System:
 - (a) incident management;
 - (b) construction management;
 - (c) safety management;
 - (d) ride-sharing management;
 - (e) demand management.
- 4 On the other hand Vehicle Highway Systems provide the means for real-time traffic management which has proved to be very cost effective. The components which are included in such systems are the following:
 - (a) freeway and arterial management systems;
 - (b) motorist/driver information systems;
 - (c) other advanced technologies, e.g. intelligent vehicle highway systems (IVHS).

19.3.2 Types of Display

- 1 Three types of displays are being used for VMS:
 - (a) light reflecting;
 - (b) light emitting;
 - (c) hybrid.
- 2 The application of the various types varies in level of sophistication of all types. The lowest level of sophistication is found with light reflective displays (ordinary road signs used as VMS). The light reflective as well as light emitting displays also represent the opposite side of the scale with regard to the highest level of sophistication. Hybrid displays are a mixture of both these technologies at any level of sophistication. Examples of the different types of displays are shown in Figures 19.2 to 19.5 (see also Volume 1, Chapter 9).

19.3.3 Light Reflecting Displays

- 1 The following are the various types of light reflecting displays in order of increasing cost and level of sophistication, many of which may be retroreflective:
 - (a) fixed with flashing beacons;
 - (b) cloth;

- (c) removable panels;
- (d) blank-out;
- (e) fold-out;
- (f) scroll;
- (g) rotating drum (prism);
- (h) rotating triangle;
- (i) electromagnetic flip disk;
- (j) electromechanical flap matrix;
- (k) electrostatic vane matrix.

19.3.4 Light Emitting Displays

- 1 The various types of light emitting displays are listed below in order of increasing cost and level of sophistication:
 - (a) flashing beacons;
 - (b) neon;
 - (c) fibre optics;
 - (d) incandescent lamp matrix;
 - (e) electromagnetic shutter;
 - (f) liquid crystal display (LCD) shutter matrix;
 - (g) light emitting diode (LED) matrix;
 - (h) liquid crystal display (LCD) matrix (back-lit);
 - (i) cathode ray tube (CRT) signs (colour video).

19.3.5 Hybrid Types

- 1 The following are the various types of hybrid displays:
 - (a) static sign combined with VMS;
 - (b) electromagnetic flip disk with light source.

19.3.6 Control Systems

- 1 Control systems are used to manage VMS networks consisting of non-manual types of VMS. Apart from allowing for the change of messages, the management of a VMS network also requires a message from the sign to the control centre confirming the message that has been sent to the sign.
- 2 For any network to operate efficiently, knowledge of the status of the network is of paramount importance. The selection of messages can be achieved through:
 - (a) fixed message selection - a matrix of message elements is set up from which the operator can select elements to build up an applicable message to be displayed; similarly pictograms can be selected from a data bank of pre-prepared pictograms; this control system has a number of access levels which are all password-controlled to ensure security of the system; change to, or addition of, message elements should only be done by the systems manager; or
 - (b) variable message selection - with this type of control system messages can be created freely by the operator using appropriately developed software.

19.3.7 Surveillance Systems

- 1 Surveillance forms the backbone of the system. The better the surveillance network, the better the service provided to the road user through the VMS will be.
- 2 Surveillance, however, consists not only of the detection and reporting of incidents, but also of the validation of such information. False or invalid information is one aspect which can bring a VMS network into discredit very rapidly. The following represent the more important detection, reporting and validation systems available:
 - (a) detection and reporting:
 - (i) public response;
 - (ii) radio broadcast monitoring;
 - (iii) regular ground patrols;
 - (iv) aerial patrols;
 - (v) loop detectors;
 - (vi) environmental detectors;
 - (vii) video imaging detection (CCTV);
 - (b) validation - information has little value if it has not been validated; for VMS networks the following methods of data-validation are used:
 - (i) visual/manual;
 - (ii) electronic/automatic.

19.3.8 Communication Systems

- 1 A VMS network, however simple or sophisticated, is useless without a communication system. Manually operated VMS networks have to rely on verbal messages sent between the control centre and the operator (person who changes messages on signs) via radio (general broadcast or two-way), telephone or visually.
- 2 Automated systems require a higher level of communication systems. Cable and radio provide such communication as follows:
 - (a) cable: cable communication of the following types has proved, over the years, to be the most popular:
 - (i) owned cable network;
 - (ii) leased utility telephone cable;
 - (iii) leased utility private data cable;
 - (b) radio:
 - (i) owned radio frequency;
 - (ii) FastNet (Telkom);
 - (iii) radio paging systems;
 - (iv) cellular telephone.

19.3.9 Fields of Application of VMS

- 1 VMS, due to its versatility, can be applied in a very wide variety of fields ranging from freeway management to parking control and public transport information systems, as follows:
 - (a) freeway traffic management:
 - (i) congestion management;
 - (ii) incident management;

- (iii) construction management;
 - (iv) safety management;
 - (v) transport demand management;
 - (vi) ride-sharing management;
 - (vii) ramp monitoring/control;
- (b) lane control - information applicable to a specific lane is presented on an overhead sign above each individual lane; displays are either simple, showing an arrow or a cross, or compact but more complex, showing an appropriate pictogram;
- (c) driver information:
 - (i) motorist information system;
 - (ii) parking information system;
 - (iii) route planning systems;
- (d) parking management:
 - (i) parking guidance;
 - (ii) parking control;
- (e) other:
 - (i) public transport management system;
 - (ii) tunnel/bridge control;
 - (iii) environmental information;
 - (iv) toll gate control;
 - (v) special event.

19.3.10 Classification of VMS

- 1 The four major classes of VMS -Regulatory, Warning, Guidance and Information - are similar to those of standard fixed signs. Depending on the type of VMS, light reflecting or light emitting, the signs shall have a similar appearance to their standard counterparts or there may be a slight variation in colour code to accommodate the technology used (see Subsection 19.4.6).
- 2 The function of the different classes of VMS are as follows:
 - (a) **Regulatory Sign** - the function of these signs is to inform road users of the regulation applicable on the facility they are using; such signs are legally enforceable by the relevant authorities;
 - (b) **Warning Signs** - the purpose of these signs is to warn road users of dangerous situations or conditions ahead;
 - (c) **Guidance Signs** - the role of guidance signs is to provide the road user with information to assist in navigation to reach a specific destination;
 - (d) **Information Signs** - information signs are used to provide the road user with important information to make the journey safer, more relaxing and more efficient.

19.3.11 Positioning of VMS

- 1 The placing of VMS is very important for the success of VMS systems and their level of efficiency. A number of factors play an important role in the establishment of the preferred location of VMS. These factors can only
(continued on page 19.3.8)

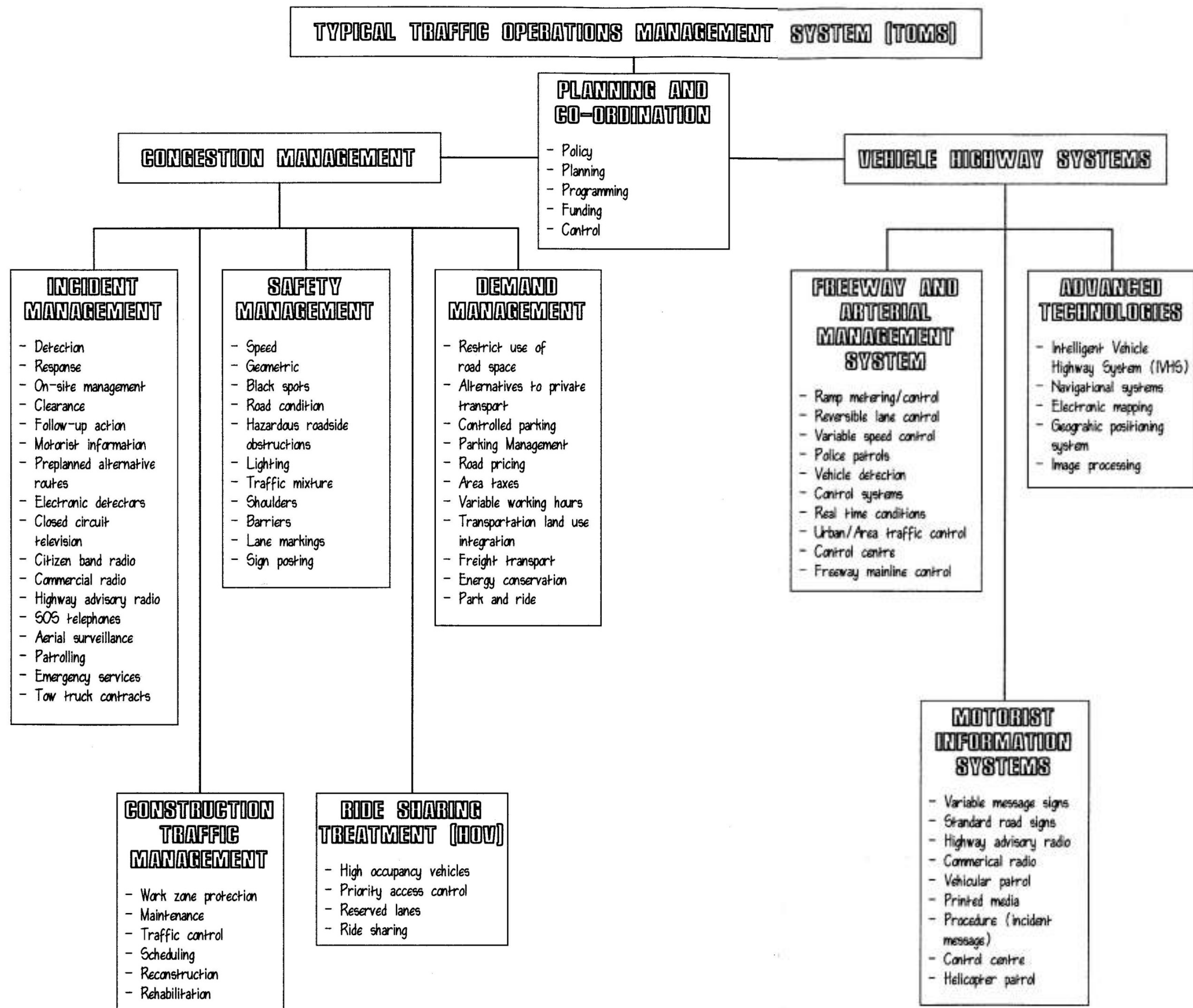
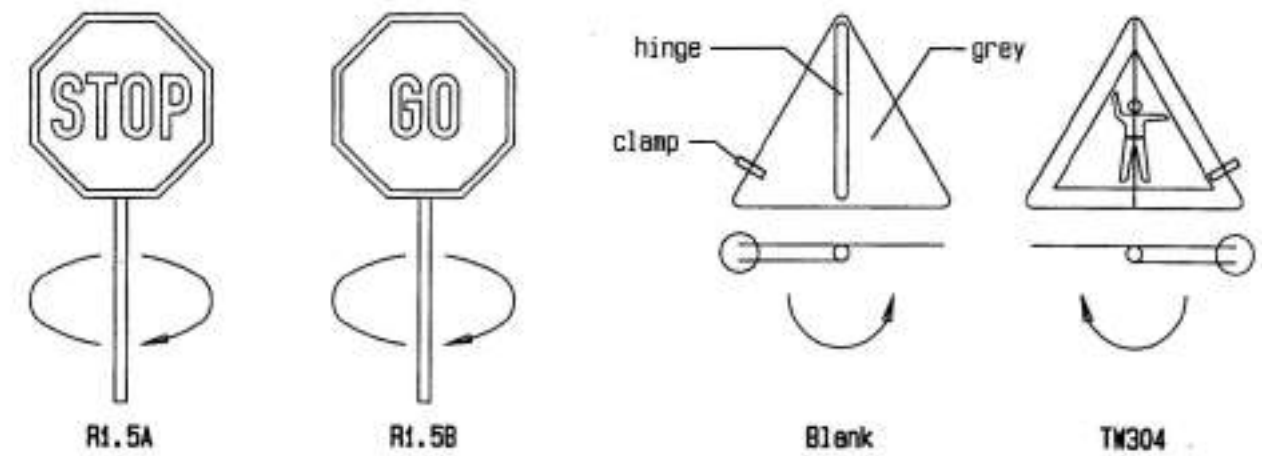


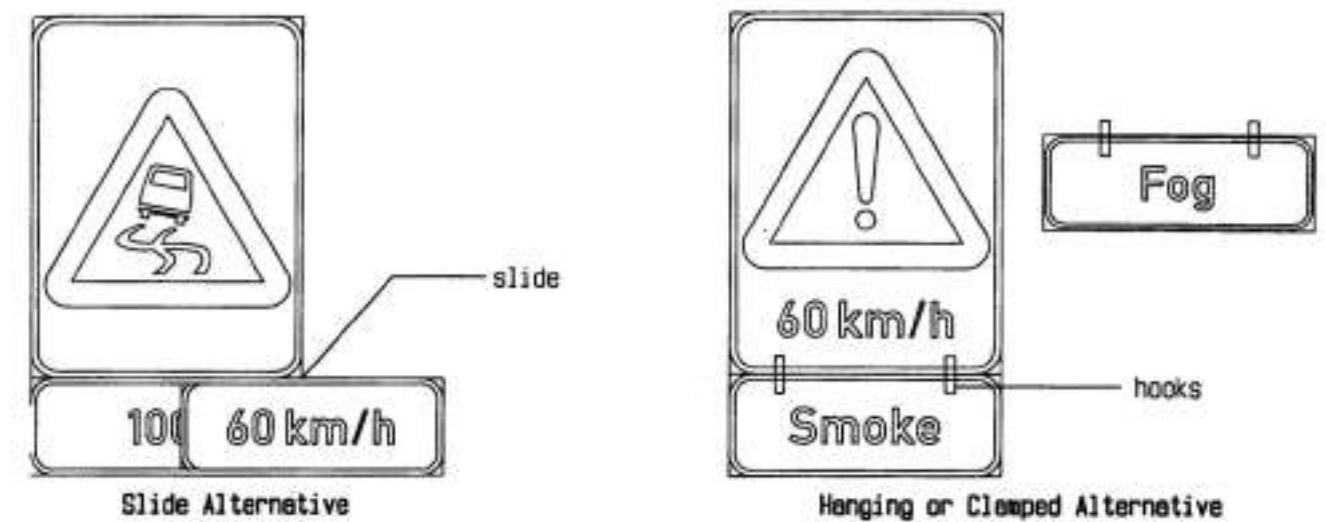
Fig 19.1
Elements of a TOMS



Detail 19.2.1

Back - to - Back Rotating Signs

































Detail 19.2.2 Flip Sign



Detail 19.2.3 Options to Vary High Visibility Warning Signs

Fig 19.2

Types of Mechanical VMS

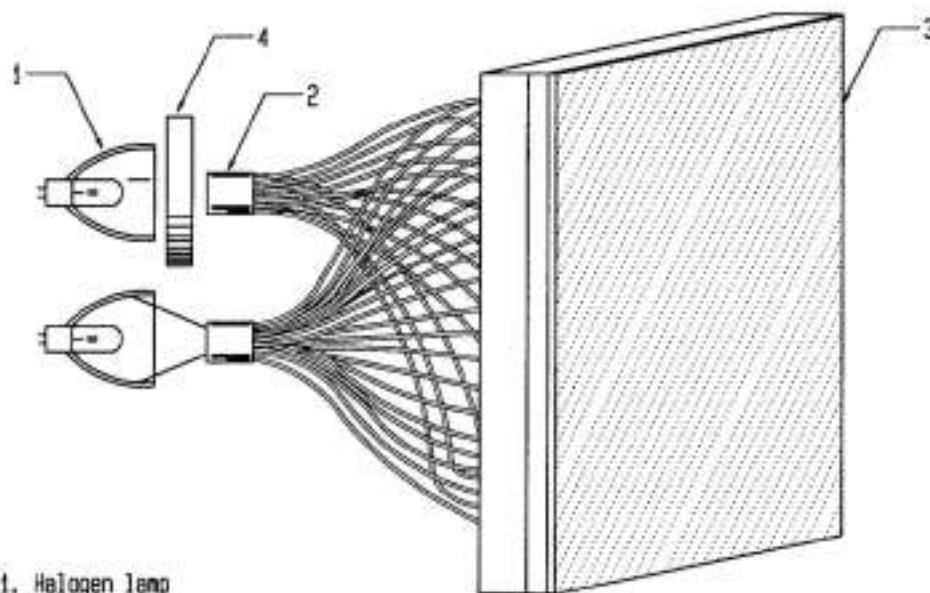
BELT	CHANGEABLE		ROTATING PLATES	ROTATING LAMINA	ROTATING PRISM
  B ₁	  E ₁	  E ₅	  Of ₁	  Of ₁	  P ₁
  B ₂	  E ₂	—	—	  Of ₁	  P ₂
  B ₃	  E ₃	—	—	  Of ₃	  P ₃
—	  E ₄	—	—	  Of ₄	—

B₁ Continuous belt
 B₂ Roller
 B₃ Multiple continuous belts
 E₁ Single roller
 E₂ Continuous belt roller
 E₃ Simple plate
 E₄ Spilt plate
 E₅ Lamina plates

Of₁ Rotating shutter
 Of₁ Single flip-over plank
 Of₂ Multiple flip-over plank
 Of₃ Rotating planks
 Of₄ Matrix sign
 P₁ Three-sided rotating prism
 P₂ Four-sided rotating prism
 P₃ Multi-sided rotating prism

Fig 19.3

Types of Electro-Mechanical VMS



1. Halogen lamp
2. Multi-branched, flexible light guides
3. Screen
4. Filter

Fig. 19.4.1
Fixed Grid Fibre Optic Module

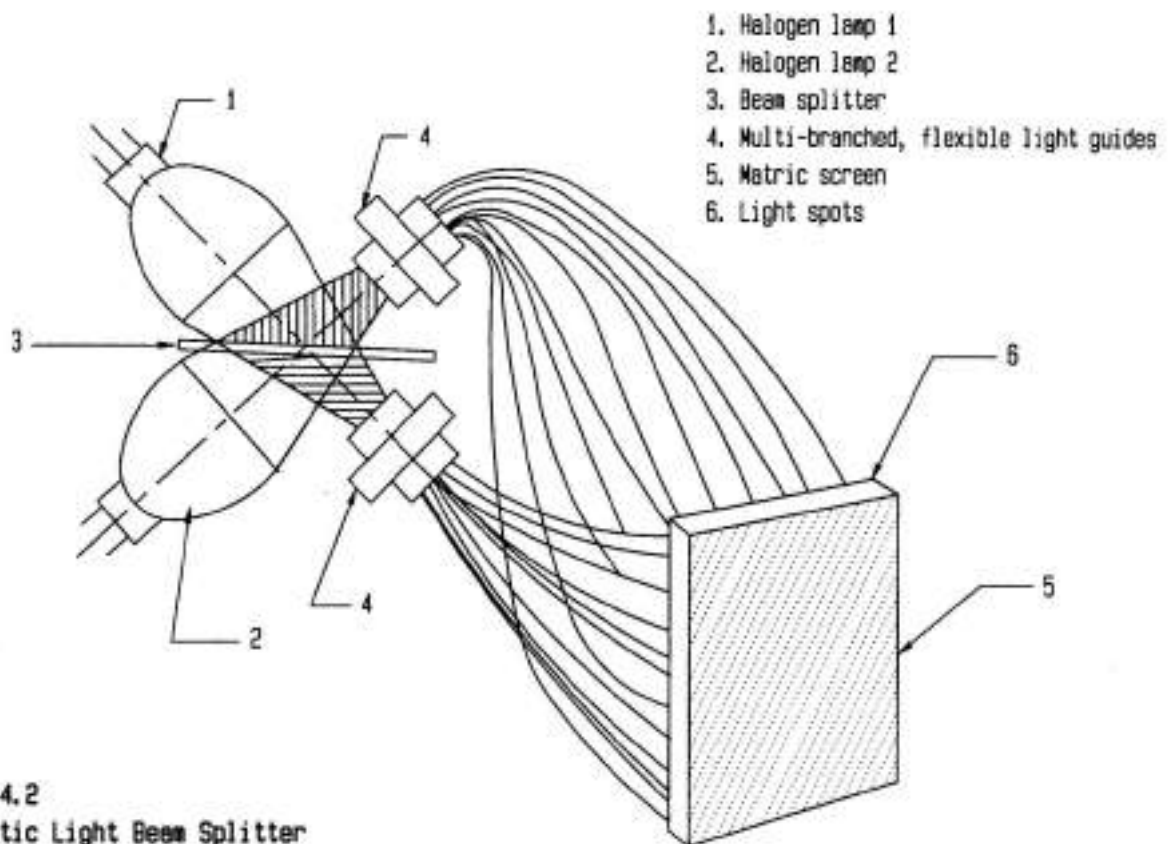
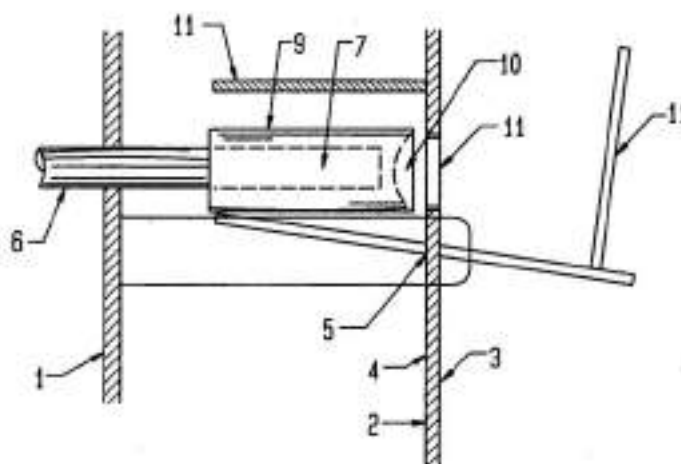


Fig. 19.4.2
Fibre Optic Light Beam Splitter

Fig 19.4

Types of Electric and Electronic VMS



1. Back plate
2. Reflective disk, black side (off position)
3. Reflective disk, reflective side (on position)
4. Disk
5. Disk pivot point
6. Fibre optic cable
7. Fibre optic bundle
8. Fibre optic lens
9. Supporting socket
10. Aperture (through disk)
11. Shroud

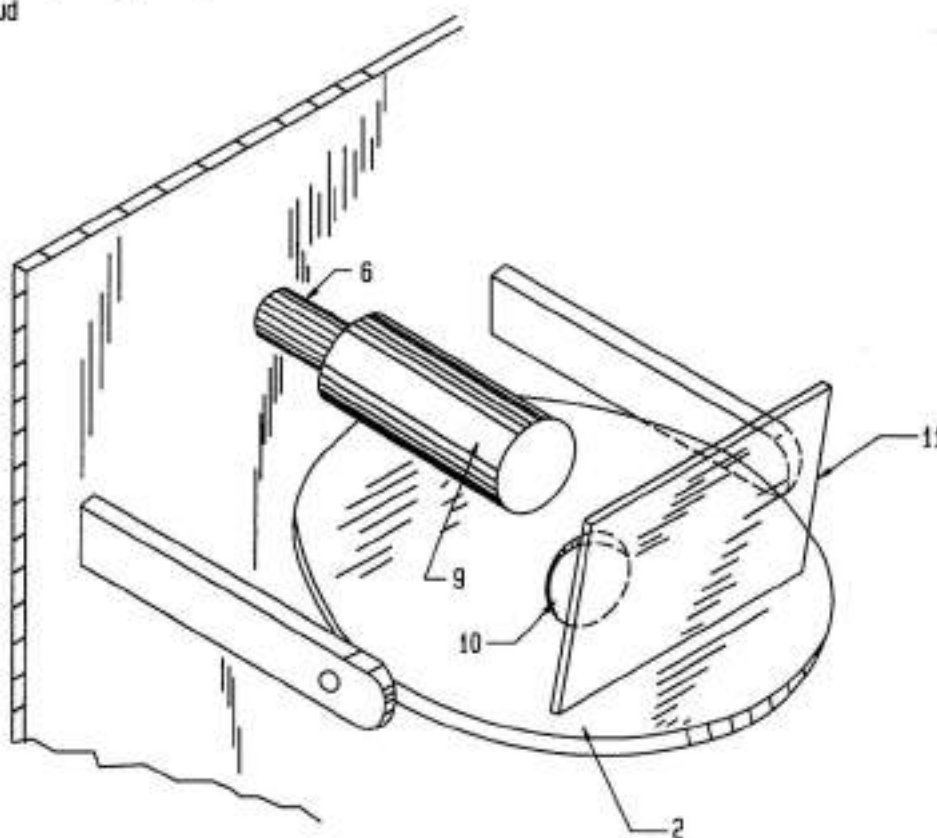


Fig 19.5

Hybrid VMS

(continued from page 19.3.2)

be applied with a sound knowledge of the relevant environment. The following information about the traffic in the area where implementation will take place is required:

- (a) traffic volumes;
- (b) traffic accident statistics;
- (c) location of congested road sections;
- (d) road sign inventory;
- (e) future road improvements;
- (f) area-specific traffic policies;
- (g) incident detection procedures.

- 2 Typical locations of where VMS should be positioned, or should be expected to be positioned, are shown in Figure 19.6.

19.3.12 Flow of Data Through Control Centre

- 1 The flow of data throughout the system should be well co-ordinated and well-structured to ensure accuracy and security (prevention of conflicting, non- applicable or unauthorised messages).
- 2 The procedure from the moment an incident occurs until the moment the message is displayed on the VMS, is as follows:
 - (a) receive data through available relevant detection process;
 - (b) verification of data for authenticity;
 - (c) design the message/s to be displayed;
 - (d) select VMS to be utilised;
 - (e) convert data into electronic format;
 - (f) send data to VMS and/or Emergency Reaction Units (ERU's);

- (g) monitoring of the sign and system (has message been displayed and is system performing correctly);
- (h) discontinuation of message display when no longer required.

- 3 A flow diagram of the flow of data through the control centre is shown in Figure 19.7.

19.3.13 Checklist

- 1 The questions listed below provide a checking process designed to assist planners:
 - ☐ do displayed messages vary according to time-of-day, road and environmental conditions and/or traffic conditions?
 - ☐ what funds will be available for VMS?
 - ☐ is power available in the vicinity of the VMS locations?
 - ☐ what power consumption can be handled by the available power distribution network?
 - ☐ what technology is available in a reasonable distance from the location of installation?
 - ☐ how many messages need to be displayed?
 - ☐ is a VMS system required (central control) or will stand-alone VMS suffice?
 - ☐ how will surveillance or detection of conditions be done?
 - ☐ how will the validation of detected or reported conditions be undertaken?
 - ☐ what data communication network will suit the local conditions best?
 - ☐ how extensively will the system be used?
 - ☐ is the necessary information available for locating VMS?
 - ☐ will VMS improve the safety conditions where it is intended to be used?

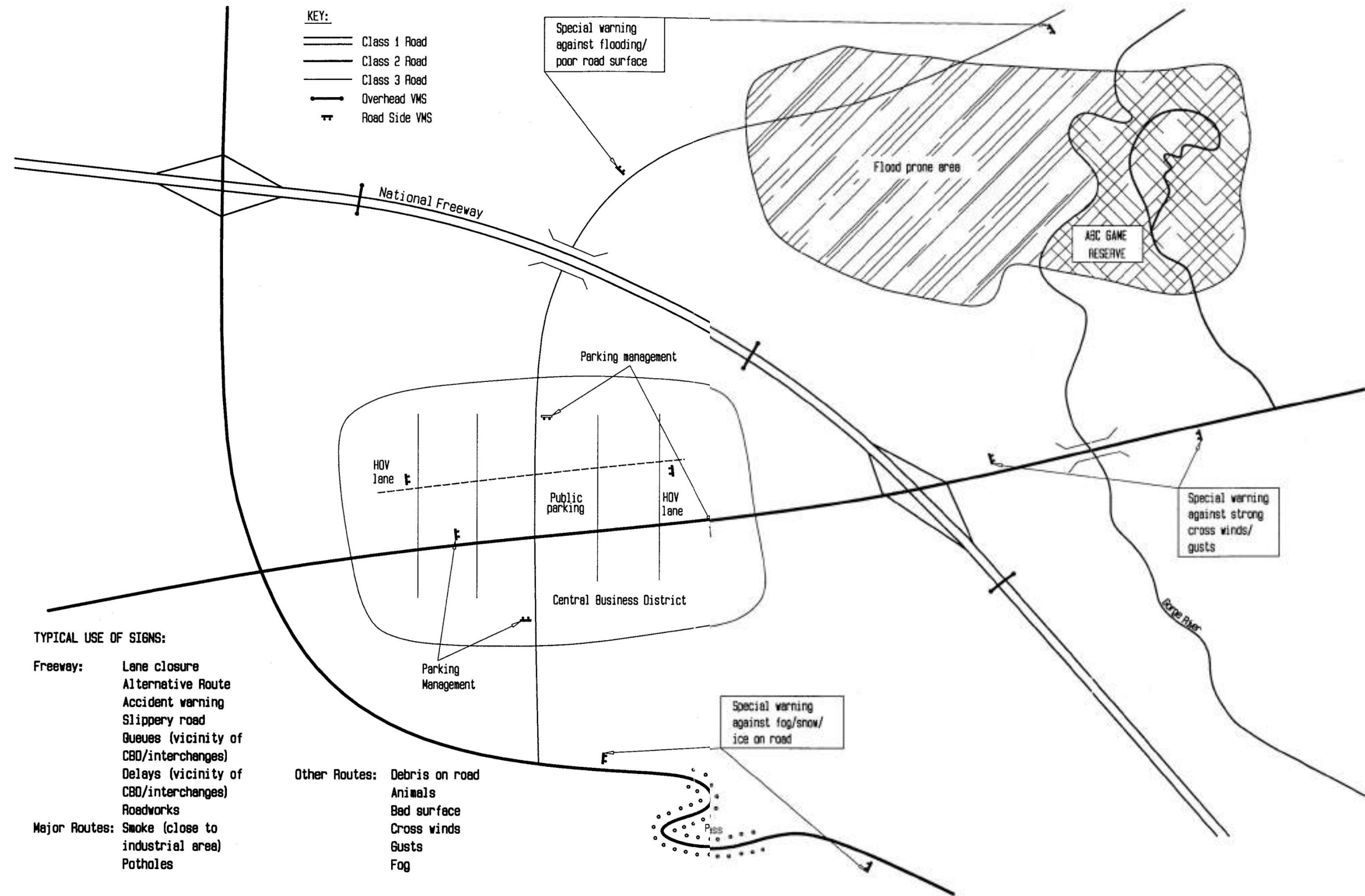


Fig 19.6
Typical Locations of VMS

19.4 WARRANTS

19.4.1 General

- 1 As with any other system, the feasibility of the system depends on a number of warrants. These warrants define the minimum standards applicable which will make the implementation of a VMS system feasible and affordable in terms of savings on decreases in accidents, delays and congestion levels. **A VMS system is warranted if any one of the four warrants discussed below is met.**

19.4.2 Warrant 1 - Traffic Volumes

- 1 When the traffic volume on any road exceeds 1600 passenger car units per hour per lane (pcuphpl) for more than five hours per day, or when traffic densities exceed 30 passenger car units per kilometre per lane (pcupkmpl), VMS should be considered as a traffic management measure.

19.4.3 Warrant 2 - Traffic Accident Statistics

- 1 VMS should be considered on roads where the accident rate is in excess of one accident per million kilometres travelled or 15 accidents per kilometres of road length per year.

19.4.4 Warrant 3 - Level of Congestion

- 1 VMS should be considered on roads when the volume-capacity (V/C) ratio exceeds 0,90 or when a level of service (LOS) "D" is

experienced on more than 70% of the road or for more than four hours during a 12-hour period.

19.4.5 Warrant 4 - Other

- 1 Under special circumstances when unfavourable weather conditions are a major problem causing regular traffic congestion or accidents, and when a proper incident management system is operational or is to be installed.

19.4.6 Checklist

- 1 The questions listed below provide a checking process designed to assist planners and designers:
 - ☐ has the necessary allowance been made on the budget for a VMS system?
 - ☐ have the necessary feasibility studies been undertaken?
 - ☐ are the necessary traffic volumes available on the selected routes?
 - ☐ are accident statistics available?
 - ☐ are there any specific prevailing environmental conditions against which motorists need to be warned?

19.5 DESIGN CONSIDERATIONS

19.5.1 General

- 1 The photometric and geometric (dimensional) requirements for VMS are based on a number of functional requirements which are covered in more detail below. These requirements, which are as follows, are relevant to all road traffic sign design:

- (a) conspicuity;
- (b) legibility and readability;
- (c) comprehensibility;
- (d) credibility.

These aspects can be expressed in values of the required visibility distance, provided details of the observer population are known.

19.5.2 Conspicuity

- 1 Conspicuity of a sign is the extent to which the sign stands out from its background regardless of the location of the sign in relation to the point of fixation. This is also referred to as the target value of the sign. The priority value of a sign relates to certain attributes which determine the order in which signs of equal target value are noticed.
- 2 The following are the most important factors affecting conspicuity of a sign:
 - (a) luminance contrast;
 - (b) size of the sign;
 - (c) luminance of the sign;
 - (d) flashing lights on sign corners;
 - (e) colour of the sign;
 - (f) placement of the sign;
 - (g) standardisation of signs.
- 3 Contrast between the foreground and background is the major determining factor for target value or conspicuity. A further contributing factor to improve conspicuity of a sign is to use beacons on, or near, the sign face. Beacons used in this regard should emit a yellow light and be located at, or near, each of the four corners of the sign face or part of the sign to which they relate. The minimum separation of any such beacons from the edge of the display area (text or graphics) should be twice the character height.
- 4 Although the flashing of a sign or part of it may improve the conspicuity of a sign, it has a detrimental effect on the legibility of a sign at distance, and should therefore be applied with caution.
- 5 The conspicuity of a sign can be significantly improved by using a border around the outside of the sign, especially if retroreflective material or a light emitting source is used. The width of such a border has to relate to the spacing between the characters and the edge of the sign face which should be approximately 1,1 times the character height.
- 6 Various signs have various levels of conspicuity, depending on the position in the hierarchy of signs. Thus regulatory and warning signs will have a higher conspicuity than guidance or information signs.

19.5.3 Legibility and Readability

- 1 Various factors affect the legibility or "the ease with which something may be read" of a message. Of these the most important factors, in no specific order, are:
 - (a) visual acuity of driver;
 - (b) reading time available;
 - (c) number of other simultaneous driver tasks;
 - (d) character size;
 - (e) character width to height ratio;
 - (f) dot size (matrix-type messages);
 - (g) spacing between characters.
- 2 Legibility is usually measured in the threshold distance at which the sign becomes legible. In a comparative study done by the Human Sciences Research Council (HSRC), it was found that the visual acuity of South African drivers is lower than that of drivers in the United States or the United Kingdom. For this reason, standards with regard to factors affecting legibility should allow for this.
- 3 Readability is the reading and recognition of what was observed. The measuring unit is time related and can be applied to the road sign environment as the time required to read and understand a displayed message. The following factors have been found to affect readability:
 - (a) extent of message;
 - (b) character size;
 - (c) character width to height ratio;
 - (d) spacing between characters.

19.5.4 Comprehensibility

- 1 The comprehensibility of a sign is the extent to which the sign is understood and responded to by all drivers.
- 2 South Africa is a multi-lingual country with many of its people not conversant in English, Afrikaans, Zulu or Xhosa (the more widely spoken languages). It will be confusing and not viable to have a message displayed in all four languages simultaneously or one after the other. A single language, English, should be used for the sake of getting drivers used to a less confusing terminology (instead of using more than one language) and because a substantial portion of the South African population has an understanding of English.
- 3 The use of pictograms (graphical signs) will overcome this problem to a large extent. It may not, in all cases, be possible to display the same sign as the static sign and the colour coding might not be the same due to technological and financial constraints, but this should not pose too serious a problem.

19.5.5 Credibility

- 1 The credibility of a sign is the value the message displayed on the sign has to the driver. Factors that influence the credibility of a sign are as follows:
 - (a) information accuracy;
 - (b) information reliability;

- (c) information not up-to-date;
 - (d) information/sign pollution;
 - (e) legality of sign.
- 2 A speed limit set at roadworks, experienced by road users to be too low, will often be disregarded. If this happens frequently at roadworks, even valid speed restrictions in future at such locations will also be regarded as having a low, or no credibility at all.

19.5.6 Colours

- 1 The colours displayed on VMS should conform to the colour coding as prescribed in the Road Traffic Act, Act 93 of 1996. If this is not practised, law enforcement will not be possible based on the road traffic signs or information displayed on VMS.
- 2 The colour code for standard fixed signs as specified in Volume 1, Chapter 1, Subsection 1.4.4 will, due to the limitation of certain technologies and the cost involved with others, not always be possible to adhere to. Light reflecting VMS shall conform to the colour code of standard fixed road signs. In cases where it is financially not viable to reproduce the standard colours for light emitting VMS, the sign face colours of the symbol and its background may be reversed. This has the effect that the background, which is by far the largest area on road signs, need not be illuminated, hence reducing running costs. The border of regulatory and warning VMS shall be illuminated and shall be of the same colour as used for a standard fixed sign. These colour requirements are covered by Regulation 409(11) of the Road Traffic Act, Act 93 of 1996 so that any sign complying with them will be enforceable.

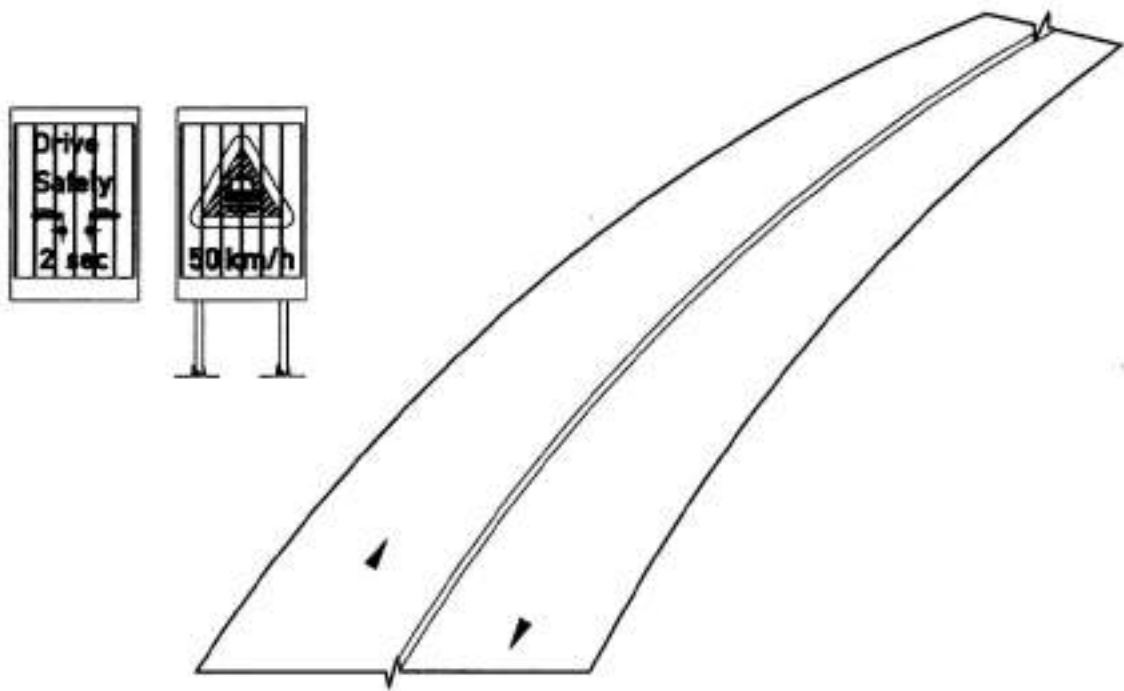
19.5.7 Sign Display Mounting

- 1 The types of sign mounting which proved to be most effective and popular are roadside and overhead mounting (see Figure 19.8). Roadside mounting is not recommended for three, four and other multi-lane roads and should be avoided at all times for dual carriageway roads.
- 2 The lateral and vertical displacements of signs are shown in Figure 4.26 of Volume 1, Chapter 4. The positioning of the signs in relation to the road user, is shown in Figures 19.9 and 19.10. Signs should always face the oncoming traffic directly. Depending on the technology used for sign displays, slight vertical and horizontal deviations could be necessary to accommodate geometric road layouts and signface materials, but a thorough assessment will be required before implementation.

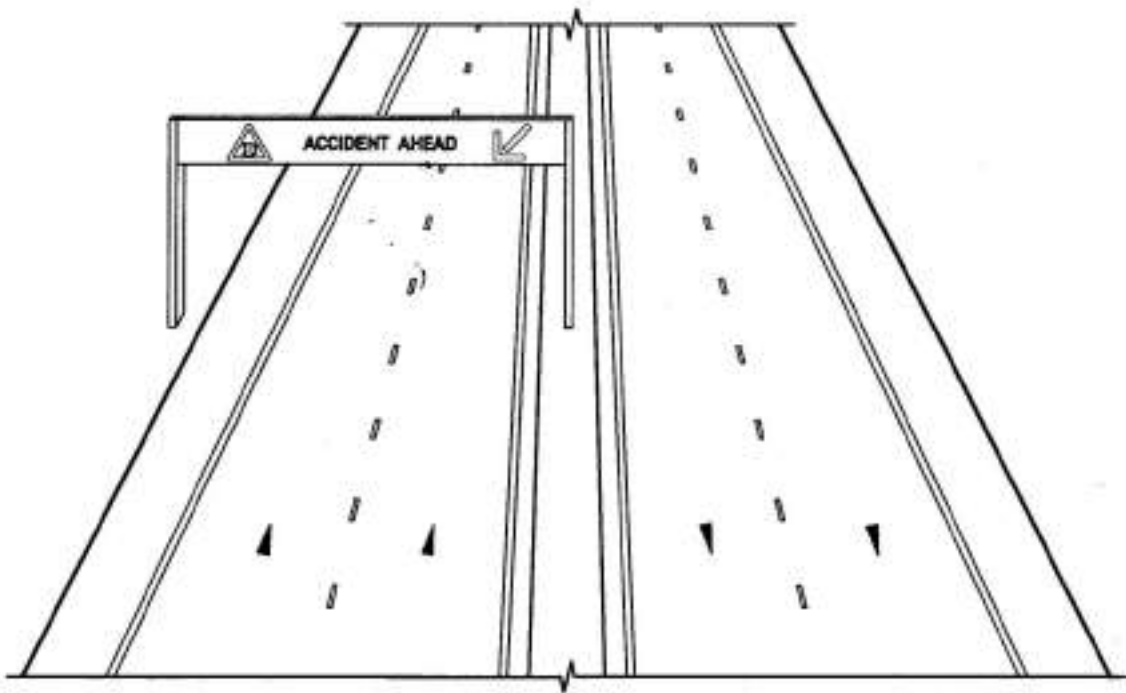
- 3 Overhead signs could be mounted on overpass bridges if structurally possible. Mounting on decks of bridges not crossing the road at right angles, requires thorough assessment of moments and torsion created by forces acting on the sign.
- 4 Interference by the sun (shining from behind the sign) should be avoided as far as possible. In Figure 19.10 the sun interference zone is shown as being 20° on either side of the sign. VMS facing east or west could experience interference from the sun all year round and while these conditions usually coincide with the morning and afternoon peak hours, special care should be taken to address this problem.
- 5 VMS facing the south will experience similar problems during the winter months. This is due to the sun being behind or facing the VMS. Special provision should be made depending on the type of VMS technology used to accommodate interference from the sun (e.g. variable illuminance levels, larger back-boards, front illumination by day and horizontal and/or vertical deviations).

19.5.8 Checklist

- 1 The questions listed below provide a checking process designed to assist designers.
 - ☐ will the sign stand out clearly against the background during day and night time?
 - ☐ does the sign need front illumination?
 - ☐ is the sign intended for law enforcement?
 - ☐ are the sign characteristics standard?
 - ☐ are any additional measures required to make the sign more legible at any time?
 - ☐ what is the educational background of the average road user?
 - ☐ can the message be kept as short as possible?
 - ☐ beware of sign pollution - can the amount of information on the sign be read and understood by drivers?
 - ☐ can the message be enhanced through the use of pictograms?
 - ☐ are the messages important enough to distract the attention of the motorist from the road?
 - ☐ if the sign is to be mounted with the sun behind, have the necessary precautions been taken to ensure that the message can still be read?



Detail 19.8.1 Side Mounting



Detail 19.8.2 Overhead Mounting

Fig 19.8

Sign Mounting

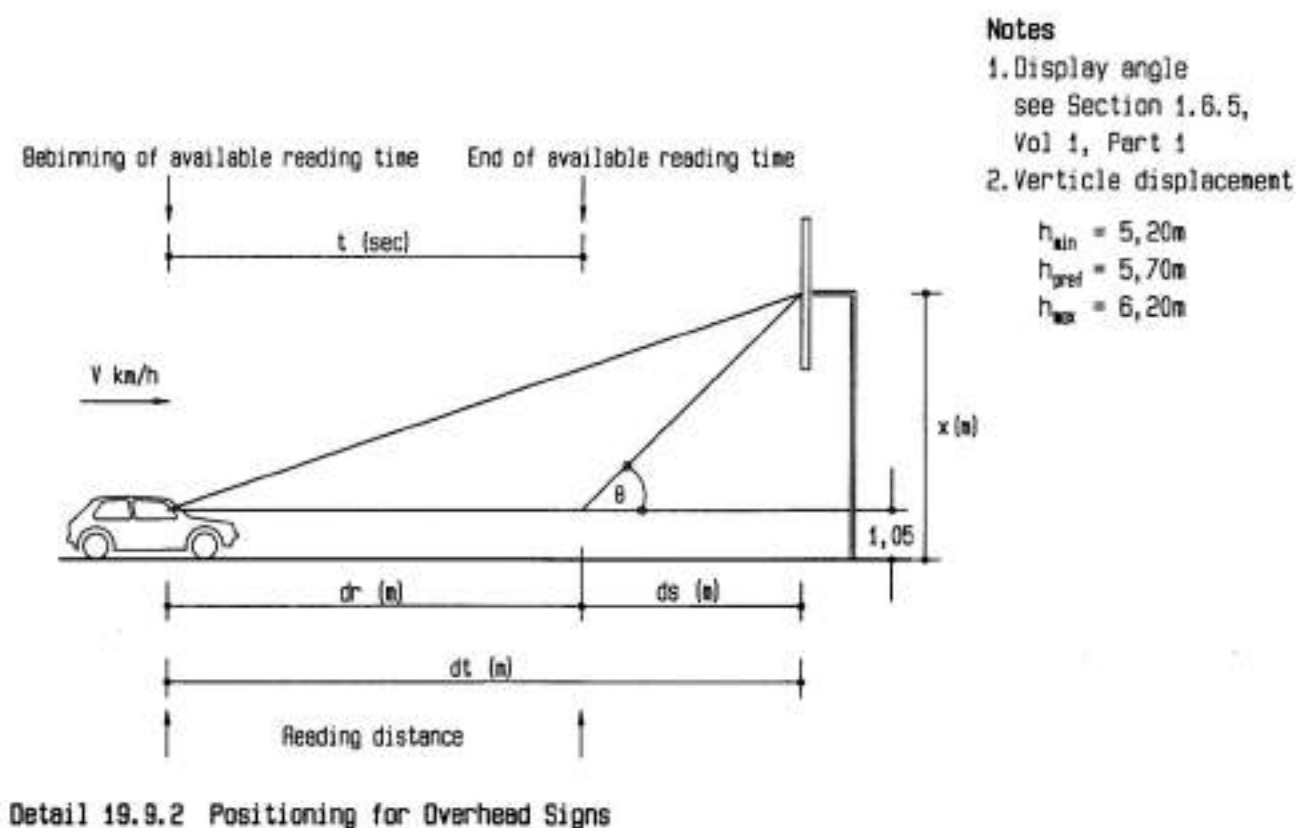
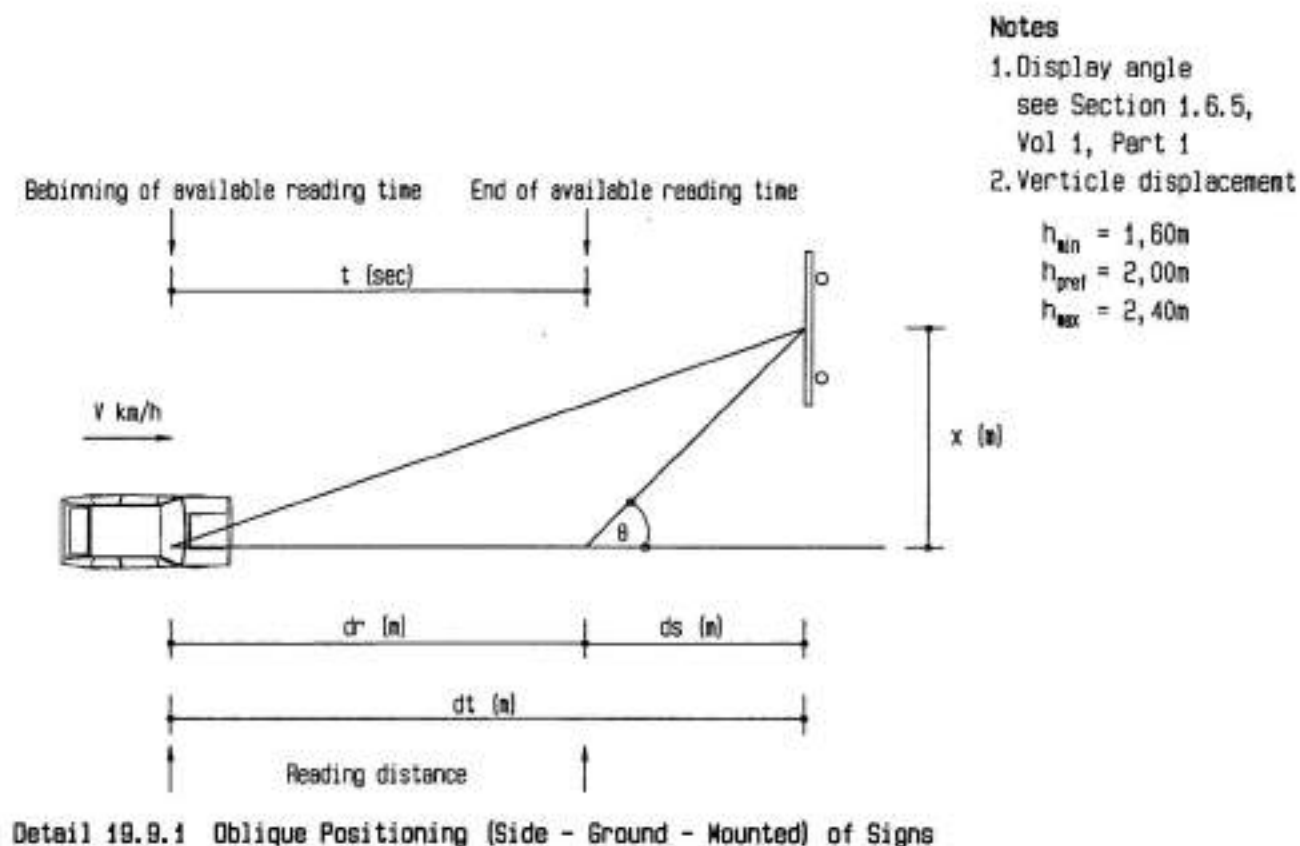


Fig 19.9

Positioning of VMS

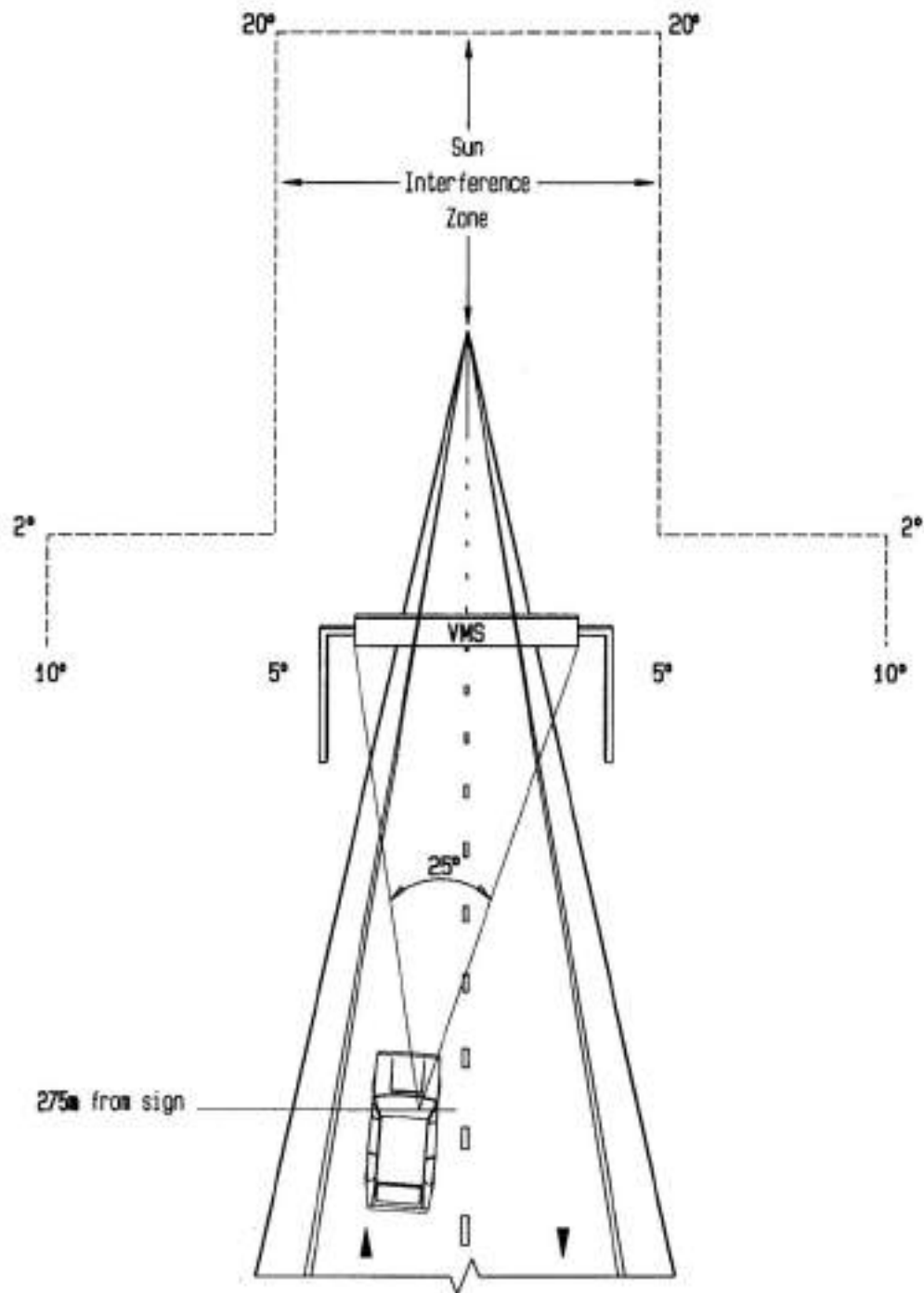


Fig 19.10

Effect of Interference from the Sun (Ref.9)

19.6 VMS ELEMENTS

19.6.1 General

- 1 VMS graphic displays are commonly arranged in a modular manner, particularly those that are of the light emitting type. This modular approach helps to standardise design, manufacturing and maintenance procedures. The design of a graphic display is affected by:
 - (a) pixel characteristics;
 - (b) module characteristics.
- 2 The message in a VMS graphic display can be given as:
 - (a) a text message;
 - (b) a symbolic or pictogram message; or
 - (c) a combination of symbol and text.

19.6.2 Pixel Characteristics

- 1 In the case of light reflecting displays the shape of the pixel (smallest unit forming a light emitting or reflective source) should be round. The reflective material used on the pixel should comply with the relevant SABS specifications.
- 2 Pixel sizes of light emitting displays will affect the spacing between characters. The minimum spacing between characters should be the width of one column. More than one light source can be used to produce a pixel, however, care should be taken to ensure that glare and irradiation caused by a combination of light source strength, number of light sources and pixel spacing do not cause characters to become illegible.

19.6.3 Module Characteristics

- 1 Modules can be characterised in terms of size, form and spacing. These factors are comparatively simple to define for text messages, but may require extra care if the truest possible representation of a regulatory or advance warning sign is to be incorporated into the range of displays which a specific VMS is designed to cover (see Subsection 19.6.5 and Figure 19.11 for details of standard pictograms).
- 2 The size of a module which accommodates a single character should be made up of seven pixels vertically by five pixels horizontally (7 x 5 module). The minimum physical size of the module depends on the size of the character required. This is mainly dependent on the operating speed of the traffic in the vicinity of the sign location. The size of characters, based on operating speed alone, varies between 90 mm and 500 mm for speeds between 60 km/h and 120 km/h respectively. The factors affecting module/letter size are as follows:
 - (a) traffic operating speed;
 - (b) sign environmental background;
 - (c) sign position (roadside/overhead);
 - (d) length of message displayed.
- 3 The form and spacing of modules should be such that they are rectangular, consisting of 7 x 5 matrices. No slanting of characters is permitted. Characters should be separated by at least one blank column of pixels. The spacing of words should be a minimum of two columns of blank pixels. For continuous displays at least three rows of blank pixels should separate text lines.

19.6.4 Text Display

- 1 Text can be displayed on a VMS in a number of ways. Factors such as policies of road authorities, traffic condition requirements or financial constraints will have an influence on the display layout.
- 2 Displays can be in the form of continuous arrays or modular arrays (rectangular 7 x 5 modules) as can be seen in Figure 19.12. Figure 19.13 provides typical display layouts for various applications.
- 3 The layouts which are used vary in size and composition and could be in the form of the following:
 - (a) block layout;
 - (b) separate lines (continuous or block);
 - (c) continuous display (able to display text as well as graphics);
 - (d) text combined with graphics section;
 - (e) graphics section alone.
- 4 The font to be used on all VMS, is shown in Figure 19.14. Only upper case characters should be used on VMS since lower case characters cannot be properly displayed on a 7 x 5 matrix.
- 5 The minimum spacing between characters should be equivalent to a single column of inactive elements (pixels) or 15% of the letter height.
- 6 To distinguish clearly between word and letter separation, words should be separated by a minimum of two columns of inactive elements (pixels).
- 7 The minimum vertical line separation should be three lines of inactive elements (pixels).
- 8 The character height is dependent on the nominal legibility distance, and the operating speed of the relevant road. The following table allowing for all applicable factors, should be used to establish the applicable character heights:

(a) 60 km/h	- 250 mm;
(b) 60 km/h - 80 km/h	- 330 mm;
(c) 80 km/h - 100 km/h	- 420mm;
(d) 100 km/h	- 500 mm.

19.6.5 Symbolic Display

- 1 If pictograms (Figure 19.11 provides typical examples) are displayed either on a separate graphics display area or in the main display area (continuous matrix displays) the minimum size of such an area should be 40x40 pixels, however, a 64 x 64 graphic display is preferable.

19.6.6 Symbols to be Used on Non-Matrix VMS

- 1 All signs used on non-matrix displays should be in accordance with the standard fixed road signs as provided in the SARTSM and current Road Traffic Act.

19.6.7 Symbols to be Used on Matrix VMS

- 1 Symbols (examples shown in Figure 19.11) used on matrix-type displays could differ slightly from their standard fixed counterparts due to certain hardware and other technological

constraints. These constraints should not be permitted to over-rule the symbol size guidelines given in Subsection 19.6.5.

19.6.8 Characteristics of Messages

- 1 To keep in line with international standards only messages in English should be used. This will furthermore have a positive effect on the cost involved with VMS and will also accommodate the problems associated with the multi-language situation existing in South Africa.
- 2 The length of a message is limited to the amount of information which could be read and understood by drivers in a maximum of eight (8) seconds (see Figure 19.15). The maximum number of bits of information allowed per message can be calculated (one bit equals one word of less than eight letters see Volume 1, Chapter 4, Figure 4.27).
- 3 In overseas studies it has been found that the length of lines should not be longer than 18 characters and with a maximum of eight words. It has been found that longer lines on signs cause reading and interpretation problems, thus causing signs to lose their impact and effectiveness. Messages longer than 18 characters should be accommodated by using a multi-line display (not more than three lines), vertical scrolling of data or by alternating pages (maximum two pages per message). The maximum of eight words should under no circumstances be exceeded. It is important that information should be displayed long enough to be read and understood. This has been found in studies to be at least one second per word (see Figure 19.15).

19.6.9 Type of Information Displayed

- 1 Information displayed should only be of a traffic related nature. Traffic slogans (e.g. buckle up, drive safely, etc.) should not be displayed as these are recognised by drivers as advertising.

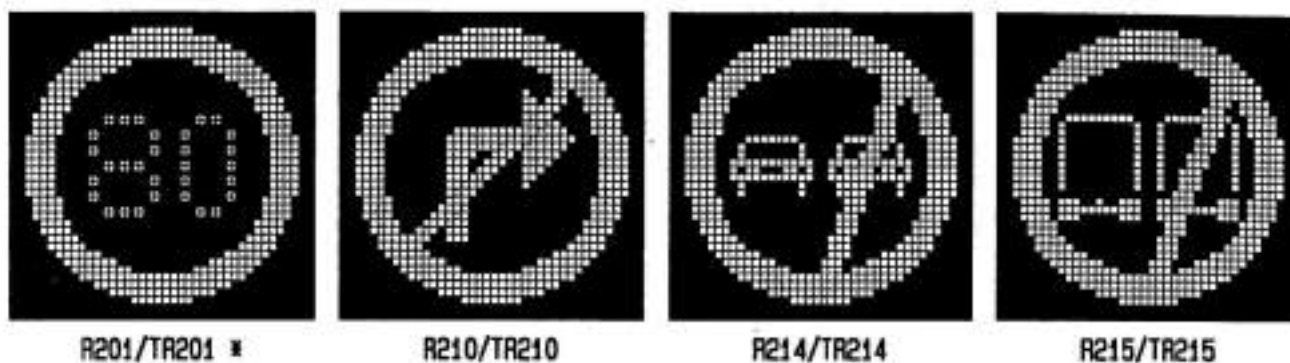
Any message not in line with this specification will lead to VMS losing their credibility. Typical words/messages which are permitted on VMS are shown in Figure 19.16. No advertising of any kind should be displayed on VMS. This includes the display of logos, etc. Advertising on VMS of any kind reduces the credibility of road signs.

19.6.10 Deviation from Standards

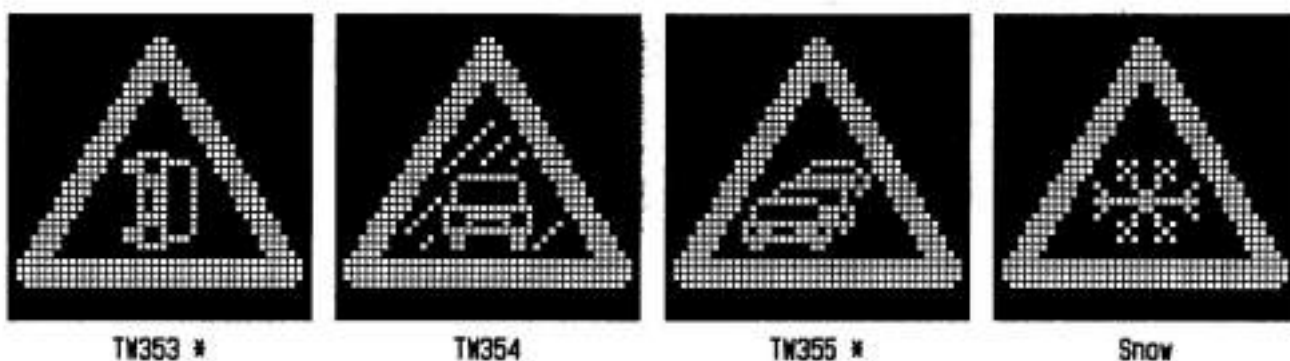
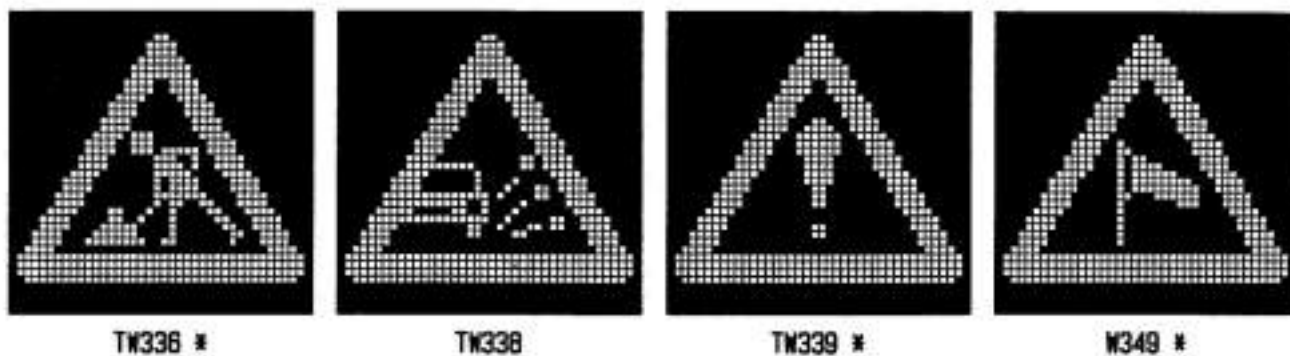
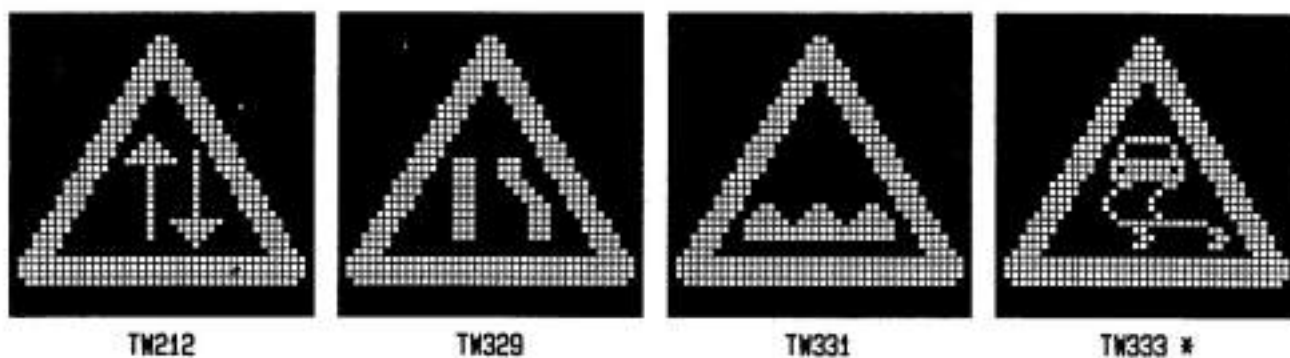
- 1 Deviation from the standards set in this chapter could only be allowed if adequate proof of the need for, or effectiveness of, the proposed deviation can be supplied.

19.6.11 Checklist

- 1 The questions listed below provide a useful checking process:
 - ☐ how many messages need to be displayed?
 - ☐ what is the operational speed in the vicinity of the sign location?
 - ☐ do the symbols used on VMS conform to the laid down specifications?
 - ☐ where possible, is text only being used to enhance the message conveyed by pictograms?
 - ☐ are messages being kept short?
 - ☐ have messages which could be perceived as advertisements or logos been used - remember, deviation from standards causes confusion which creates a hazard?
 - ☐ will the message be legible, specific and understood?
 - ☐ will motorist be able to take the required action safely and timeously?



Detail 19.4.1 Regulatory Sign Symbols (Prohibition)

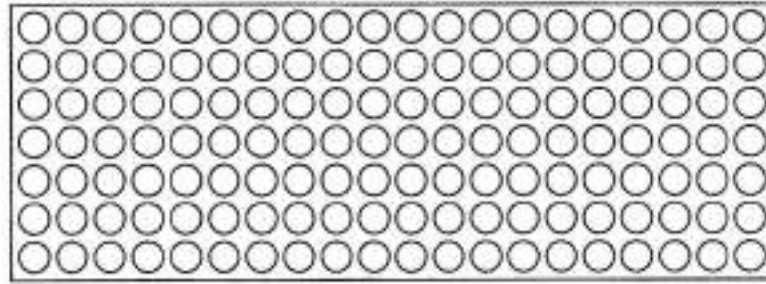


Detail 19.4.2 Advance Warning Sign Symbols

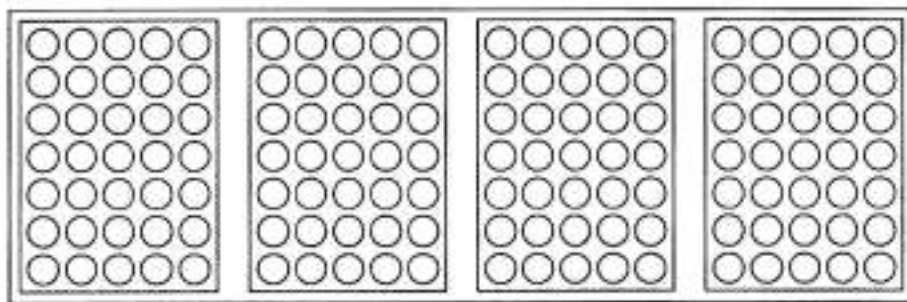
* = International

Fig 19.11

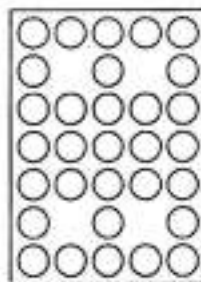
Typical Symbols for Pictograms



Detail 19.12.1 Continuous Array



Detail 19.12.2 Modular Array (5x7 Rectangular Modules)



Detail 19.12.3 31-Bulb Figuregram

Fig 19.12

Module Layout – Matrix Arrays

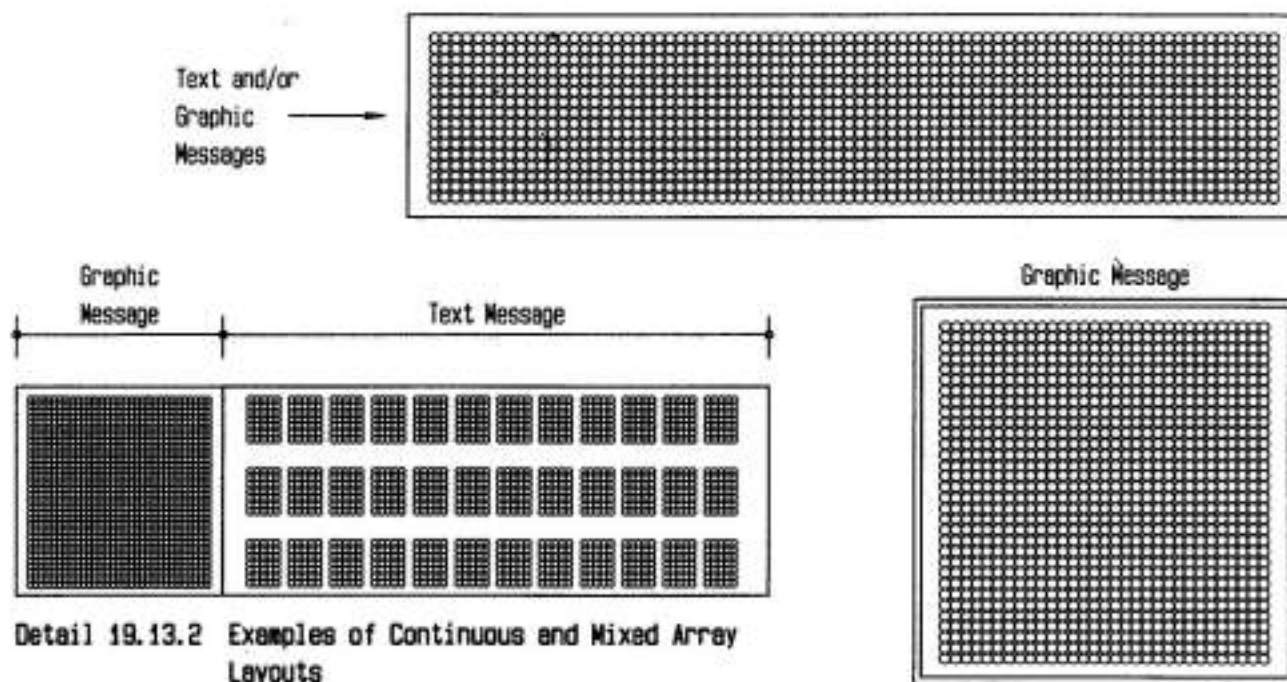
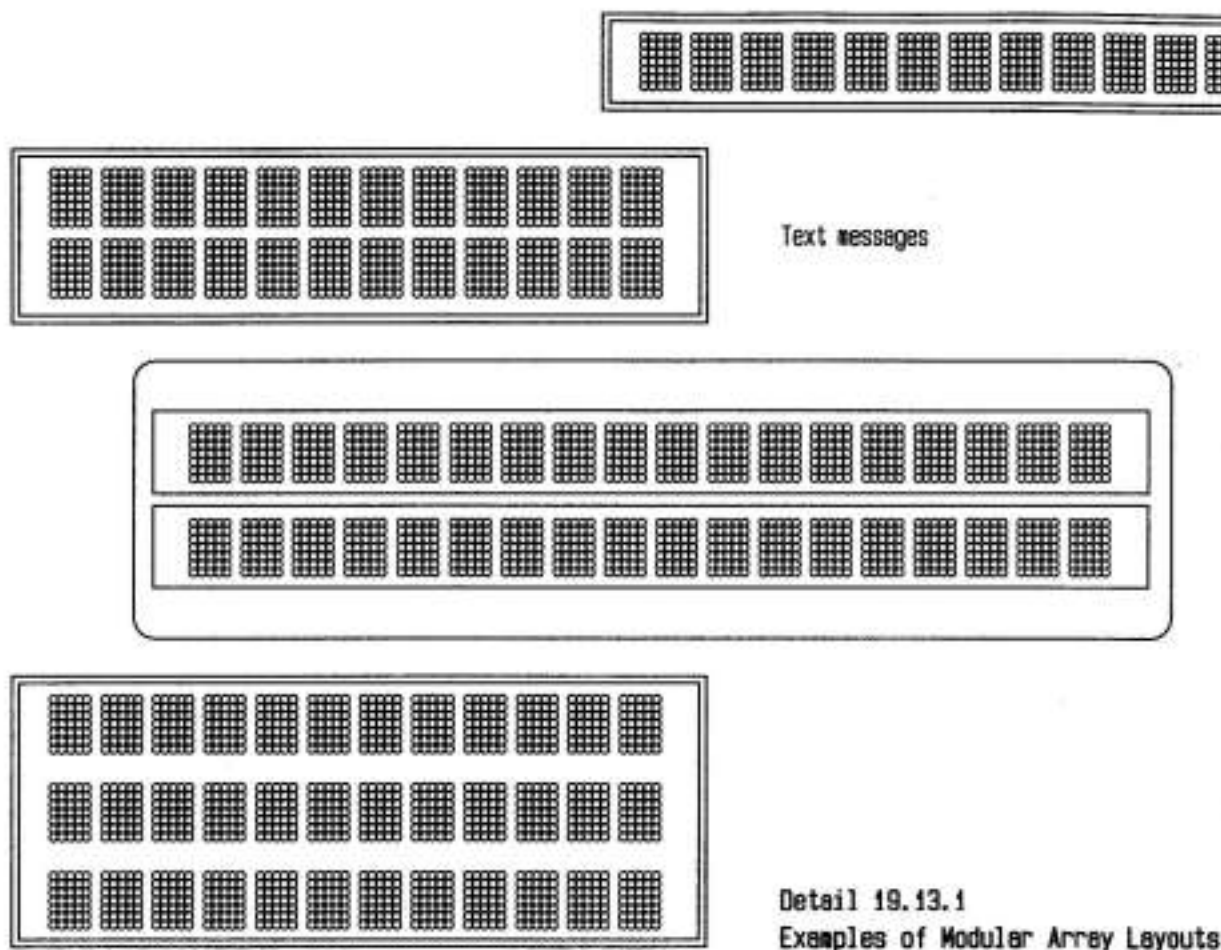


Fig 19.13

Display Layouts

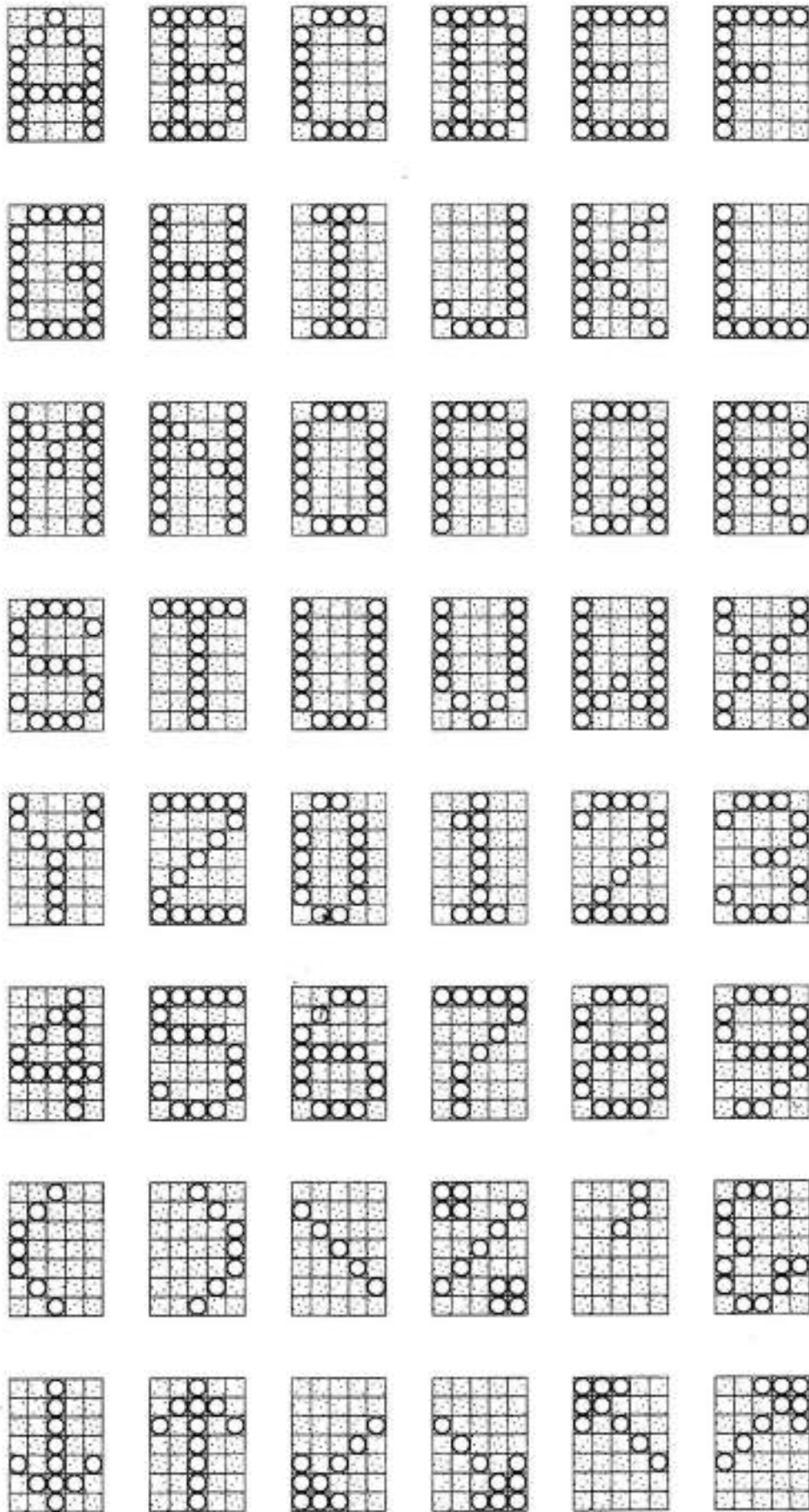


Fig 19.14

Font for a 7 x 5 dot Module

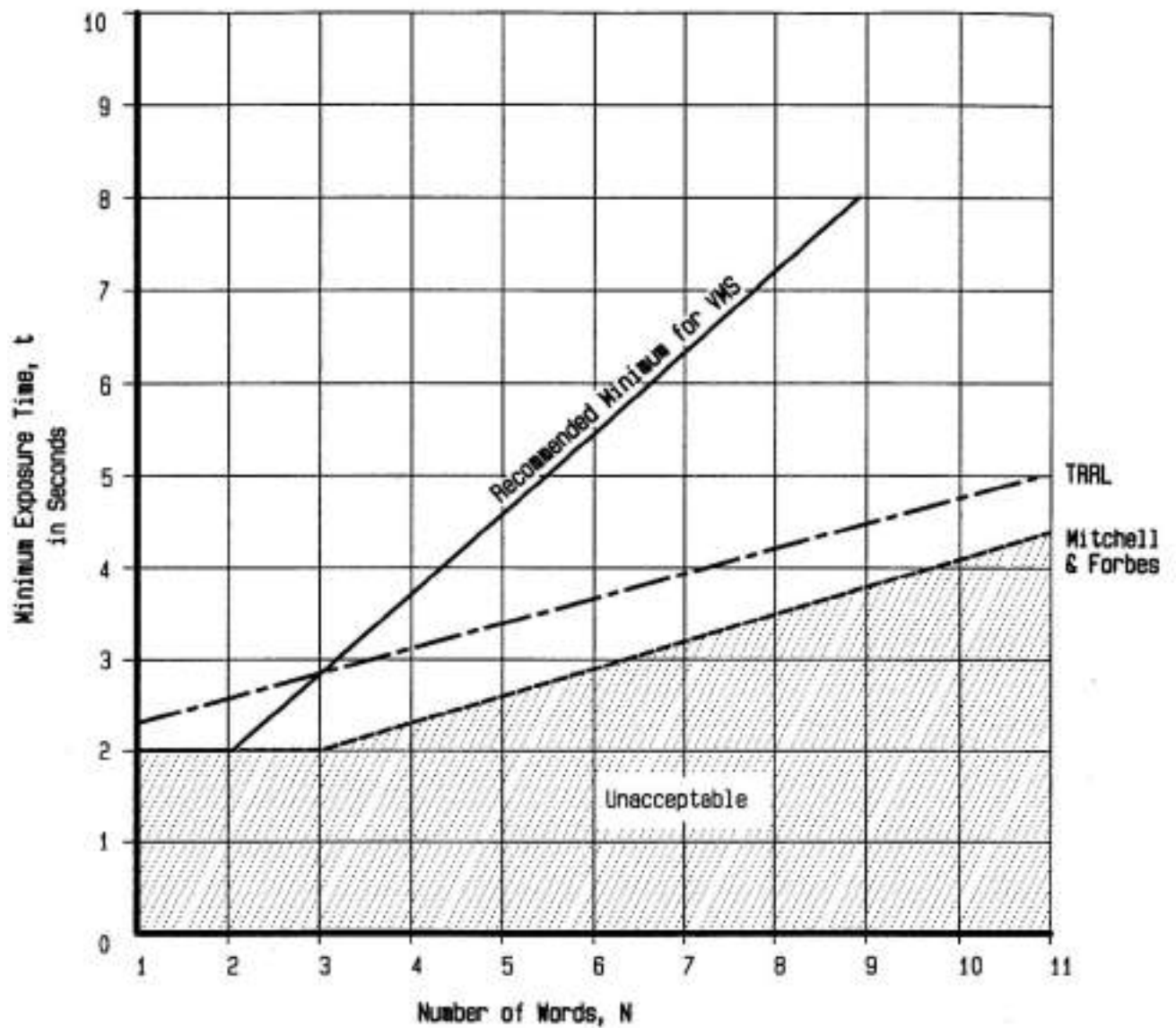


Fig 19.15

Minimum Reading Times for Short Word Messages

CAUSE	ACTION	LOCATION	DIST.	TIME
<ul style="list-style-type: none"> - Collision - Lane closed - Workmen - Roadworks - Fog - Smoke - Dust - Delay - Queue - Heavy rain - Flooding - Hail - Snow - Gusts - Crosswind - Bad visibility - Bad surface - Potholes - Construction - Shed load - Slippery road - Breakdown - Congestion - Animals - Debris on road 	<ul style="list-style-type: none"> - Drive slowly - Lane closed - Alternative route - Road closed - Road narrows - Slow down - Reduce speed - Minimum speed - Take - Turn left - Caution - Keep left - Keep right - No turn-off - Ramp closed - No entry - No heavy vehicles - No overtaking <p style="text-align: center;"><u>General</u></p> <ul style="list-style-type: none"> - Open up gaps - Keep following distance - Thank you - Road block - Switch headlamps on - No stopping - HOV lane - Speed checking - Keep left, pass right - VMS breakdown 	<ul style="list-style-type: none"> - Ahead - Before - At - After - From - Next - On-ramp - Off-ramp - Interchange - Bridge - Overpass - Underpass - M1 North - M1 South - M2 East - M2 West - N1 - N3 - N12 	<ul style="list-style-type: none"> - 1 km - 2 km - 3 km - 4 km - 5 km - 6 km - 7 km - 8 km - 9 km - 10 km 	<ul style="list-style-type: none"> - 5 min - 10 min - 15 min - 20 min - 25 min - 30 min - 35 min - 40 min - 60 min - 90 min - 2 hr - 3 hr - 4 hr - 5 hr - 6 hr - 7 hr - 8 hr - 9 hr - 10 hr - 11 hr - 12 hr - 24 hr

Fig 19.16

Typical Messages to be Displayed

19.7 TYPICAL EXAMPLES OF VMS

19.7.1 General

1 VMS applied in traffic related situations is still rare in South Africa with limited local examples available. However, examples of typical VMS and VMS-applications from Europe and the United States of America are given in Figure 19.17 to Figure 19.22, as follows:

- (a) Figure 19.17 Example of Fibre Optic VMS (limited message);
- (b) Figure 19.18 Example of Overhead-mounted LED VMS (multi-message);
- (c) Figure 19.19 Example of Overhead-mounted Fibre Optic Lane VMS (limited message);
- (d) Figure 19.20 Example of Horizontal Rotating Prism VMS (limited message);
- (e) Figure 19.21 Example of Vertical Rotating Prism VMS (limited message);
- (f) Figure 19.22 Example of Overhead-mounted Text/Graphics LED VMS (multi-message).



Fig 19.17

Example of Fibre Optic VMS (Limited Message)



Fig 19.18 Example of Overhead-mounted LED VMS (Multi-Message)



Fig 19.19

Example of Overhead-mounted Fibre Optic
Lane VMS (Limited Message)



Fig 19.20 Example of Horizontal Rotating Prism VMS (Limited Message)



Fig 19.21 Example of Vertical Rotating Prism VMS (Limited Message)



Fig 19.22

Example of Overhead-mounted Text/Graphics
LED VMS (Limited Message)

19.8 SPECIFICATIONS

19.8.1 General

- 1 SANS Standard Specification 1519-1: 2006 Road Signs - Part 1: Retroreflective Sheeting Material is relevant for all light reflecting VMS. There is no specific Code of Practice for light emitting VMS in South Africa. For this purpose the standards set out in the CIE-report CIE 111 - 1994, will be applicable.

19.8.2 Photometric Performance of VMS

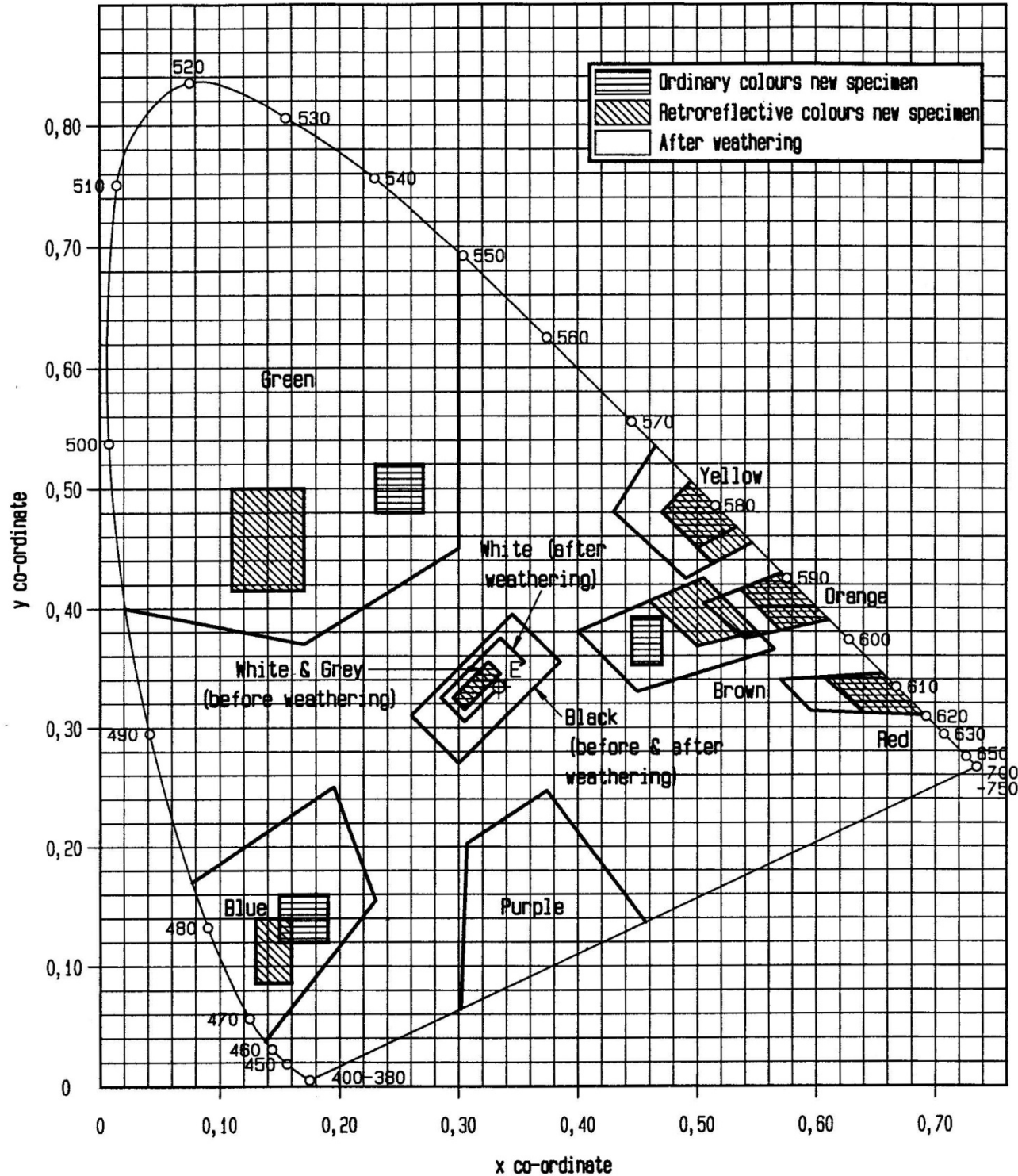
- 1 All VMS displays fall into one of two categories:
 - (a) light reflecting signs; or
 - (b) light emitting signs.
- 2 Light reflecting signs use an external light source to make the sign visible, whereas light emitting signs operate by using an internal light source to make the sign visible. With regard to the photometric characteristics, VMS shall comply with certain specifications which are discussed briefly below and in depth in Section 19.10.

19.8.3 Light Reflecting VMS

- 1 Retroreflective properties of these signs shall comply with SANS 1519 - 1: 2006 Part 1. The colour boundaries for normal and retroreflective colours when new, and after weathering, are shown in Figure 19.23. This is covered in more detail in Volume 1, Chapter 1, Subsection 1.5.7.
- 2 The luminous intensity during night time hours should be decreased by a factor of ten to prevent glare and irradiation.

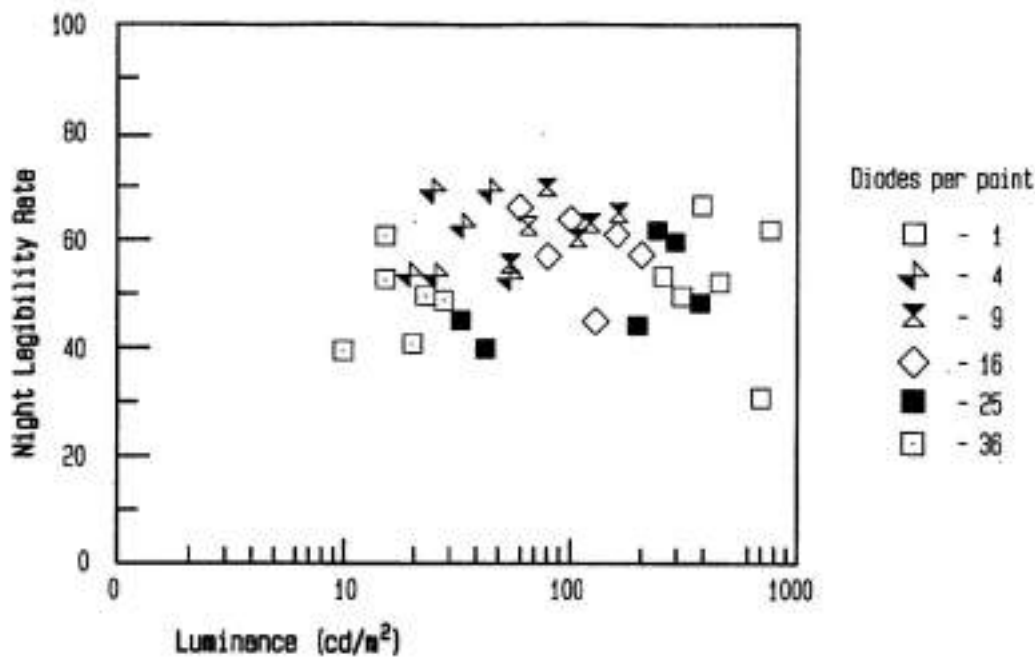
19.8.4 Light Emitting VMS

- 1 The specifications for light emitting signs as set out in Technical Report CIE 111 - 1994: Variable Message Signs, shall be applicable to all light emitting signs used in South Africa (Testing and Evaluation is covered in Section 19.10).
- 2 Luminance and irradiation compensation values are given in Figure 19.24 and the luminous intensity distribution in Figure 19.25. More detail on the contrast measurement is provided in Section 19.10.

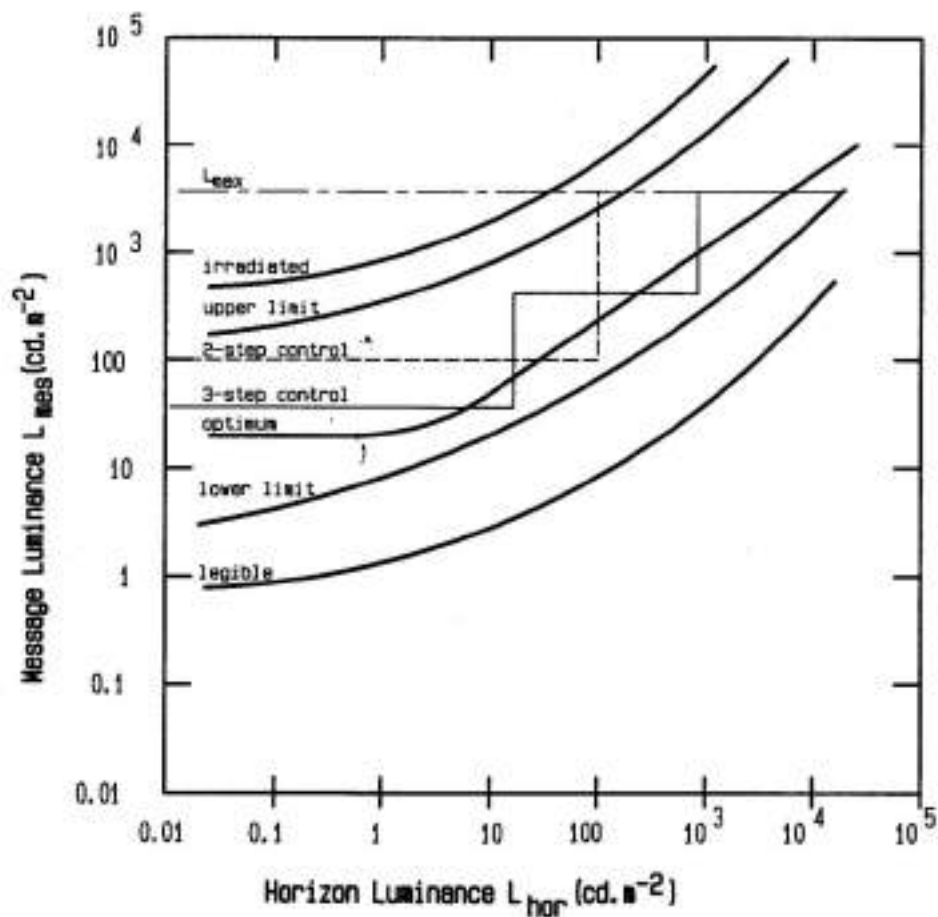


Refer to SANS 1519-1: 2006 and SANS 1519-2: 2004 for specifications and colour co-ordinates

Fig 19.23 Chromaticity Chart for Light Reflecting Displays



Detail 19.24.1 Percentage of Letters Correctly Read at Night Versus Contrast



Detail 19.24.2 Step-Control Schemes to Compensate for Irradiation

Fig 19.24 Luminance and Irradiation Compensation for Light Emitting Displays

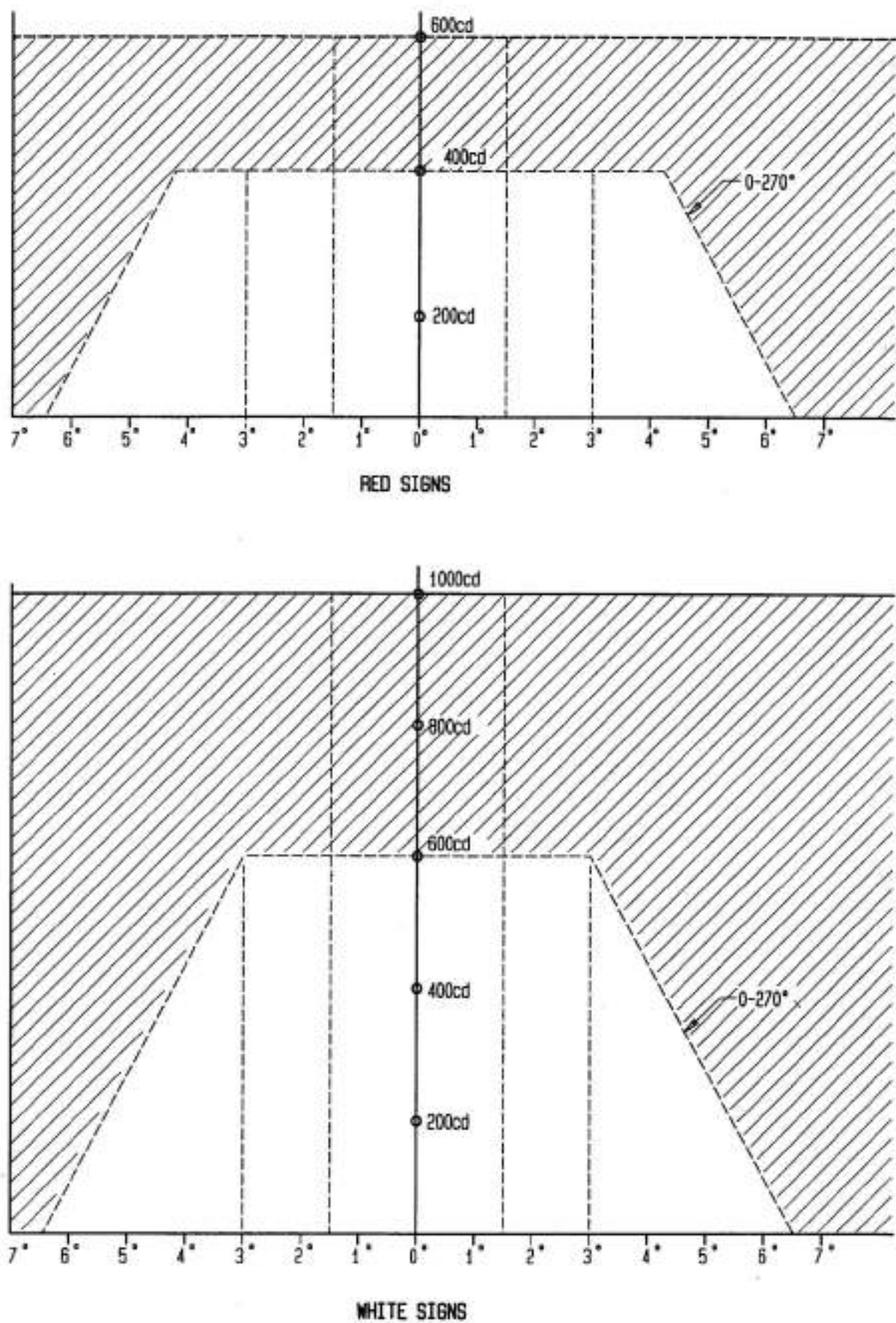


Fig 19.25 Luminous Intensity Distribution for VMS

19.9 MAINTENANCE OF VMS

19.9.1 General

- 1 Since VMS are usually mounted on overhead gantries, provision should be made in the design of the supporting framework to allow access to the signs for maintenance. The design of the VMS should be such that the average component failure rate will be less than once per year.

19.9.2 Typical Maintenance

- 1 For the proper operation of a VMS system, the following important maintenance features should be kept in mind:
 - (a) VMS housing should be moisture and dust free;
 - (b) provision should be made to prevent extreme temperatures in the housing and to maintain temperatures within the component limits;
 - (c) all doors should be tamper free and vandal resistant;
 - (d) the design of the housing should be such as to allow easy access to all components, assemblies and parts requiring routine maintenance;
 - (e) all moving parts (5% annual disk pivot "locking" on reflective disk displays) should be maintained on a regular basis;
 - (f) provision should be made in the design to prevent any panels, doors, or other objects falling onto the road during maintenance;
 - (g) light sources on VMS (incandescent displays, fibre optic displays and sign face illumination) have a limited life and require regular checking and replacement;

- (h) inoperative pixels (LEDs, bulbs, disks, etc.) should be kept to less than 2%;
- (i) sufficient spares should be carried by the maintenance authority for components with a high failure rate to speed up replacement.

19.9.3 Checklist

- 1 The questions listed below provide a checking process designed to assist maintenance units:
 - ☐ are the resources available for the maintenance of the VMS to be undertaken in-house?
 - ☐ has provision been made to carry adequate spares?
 - ☐ what has been done to safeguard installations from lightning and electrical surges?
 - ☐ are there any special protection precautions with regard to environmental conditions that need to be considered?
 - ☐ will the materials used for the signs and housing withstand the elements?
 - ☐ will it be safe to do maintenance on the signs once erected?
 - ☐ have the necessary precautions been taken to allow the safe and unobstructed flow of traffic while maintenance is in progress?
 - ☐ has a proper maintenance programme been prepared?

19.10 TESTING AND MEASUREMENT

19.10.1 General

- 1 A great deal can be done in the design of a variable message sign to ensure optimum performance. It is hoped the guidelines, contained in this report, will ease the design process and ensure that neither time nor money are invested in inappropriate sign designs. However comprehensive the guidelines, it is unlikely that they will be exhaustive and yet be sufficiently flexible to cope with changes in technology and approach. Since variable message signs are a relatively new means of passing information to vehicle drivers, some of the benefits remain uncertain. Hence there is a requirement for testing and evaluating the performance of variable message signs, both prior to and after installation. If the performance and effectiveness of a sign or signing system cannot be measured the value of the sign or system cannot be assessed.
- 2 Variable message signs may be evaluated both before and after installation employing both subjective and objective measures of performance. Before the sign is installed, a sign might be subjectively assessed by trained observers or by an experimental procedure using typical users or objectively by physical measures of performance. After the sign is in place it's performance might be assessed by evaluating the user's subjective opinion or by observing user behaviour. At least some aspects of manufacture, and of testing and measurement, in particular the physical aspects, are likely to be covered, in time, by SABS standards.

19.10.2 Subjective Measures of Performance

- 1 Subjective evaluations of sign performance prior to installation can be criticised for inducing bias and for being unscientific. However, such evaluations are convenient to conduct and can indicate some weaknesses in a signs design before further time and money is invested. Such a technique is particularly of value where observers are making relative, rather than absolute, judgements about performance. An appropriate approach might be to erect the sign (including any screens or covers) outside and allow observers to view the sign from a distance towards the limits of the sign's legibility distance. The observers are then asked to make subjective judgements as to the relative performance of the sign in terms of legibility, readability and conspicuity. This method has been used casually, and with some success, within the United Kingdom's Department of Transport for a number of years, and has been found to become more effective as observers gain experience. The approach can be criticised for being both subjective and qualitative. At least some aspects of manufacture, and of testing and measurement, in particular the physical aspects, are likely to be covered, in time, by SABS Standards.

19.10.3 Objective Measures of Performance

- 1 The use of human observers might be considered to be appropriate in determining sign performance and a suitable experimental method might eliminate the problems of subject bias and the qualitative nature of the data. While the earlier method of evaluation was quite a rapid procedure a carefully designed experiment would naturally require more time and energy. The principle factor of interest in sign design is often legibility distance and this has been measured using a variety

of methods. However an appropriate model for measuring the legibility distance of signs might be Forbes' (1939) experimental method for measuring pure legibility. Standardised methods of subject selection and analysis might be used to allow for a direct comparison of results between signs. Other experimental methods would be required to measure other parameters of sign performance such as readability and conspicuity. However, these experiments could also employ driver subjects as was suggested by Forbes (1939). Objective measures of sign performance could also be based on physical measures of various characteristics of the sign.

- 2 Such measures might have the advantage of being more easily and rapidly made than a measure of actual sign performance. Objective physical measures might then be related to tables of sign performance to estimate how a sign might perform in a real driving situation.
- 3 The luminance, and thence the contrast of reflecting variable messages signs, can be measured directly. The measurement of luminance for emitting variable message signs, however, is complicated by the need to average the luminous intensity of individual elements over the area of the characters or message. Padmos *et al* (1988) determine the luminance of the message by means of the formula below:

$$L_{mes} = \frac{l_{mes}}{A} = \frac{l_{pix}}{d^2} \quad \text{Formula - 1}$$

where:

L_{mes} is the luminance of the message, in cd m^{-2} ;

l_{mes} is the light intensity of the message, in cd;

A is the area of the message, in m^2 ;

l_{pix} is the light intensity of pixel, in cd;

d is the square root of the product of the vertical and horizontal separation between the elements.

- 4 Implicit in the equation is an allowance for irradiance around the message of $d/2$. Padmos *et al* use message luminance as their basic physical measure. Colomb and Hubert (1991) point out that contrast perhaps approximates the human visual response more effectively and provide a formula for sign contrast which is given below:

$$C = \frac{U_L F}{L_F} = \frac{(L_i + L_F)}{L_F} \quad \text{Formula - 2}$$

where:

C is the contrast ratio;

L is the luminance of the character, in cd m^{-2} ;

L_F is the background luminance, in cd m^{-2} ;

L_i is $(l_p \times 35)/S$ which is the internal luminance of the sign, in cd m^{-2} ;

l_p is the intensity per element and S is the area of the 35 element matrix.

The calculation makes no allowance for irradiance in the calculation of area S .

- Some technologies, such as liquid crystal displays, when “off” still emit some light which will apparently reduce contrast. Therefore caution is required when using physical measures so that it should be ensured that the human performance is still adequate.

19.10.4 Actual Performance

- Determining actual performance once a sign has been installed might seem to be too late but it would allow for remedial action to be taken and to gain further insight into the placement and use of variable message signs. If the objective of a variable message sign is to divert a certain proportion of the traffic the number of vehicles diverted by the use of particular messages could be logged via, for example, a traffic control system.

19.10.5 Evaluation and Testing of Optical Characteristics

- Variable message signs designed for use on public roads can be subjected to a number of tests to establish their suitability for the environment in which they are being used. It is anticipated that most countries will be able to determine the environmental testing but may not have sufficient knowledge of the variable message sign technologies, or the way they are used, to make a meaningful assessment of how to test the optical characteristics of the sign.
- The following subsections are included to give some guidance on the testing issues. The contents will enable a purchaser to define some basic testing which is relevant to the application of the technology being used. It is anticipated that as the technologies become more refined and we gather more experience in the method of testing variable message signs, the guidance given will be improved. It is, therefore, very important that anyone using the information contained in this document ensure that it is reviewed periodically and, if necessary, updated to reflect the level of testing appropriate for the day. Feedback on specific experience is therefore welcomed.

19.10.6 Test Modules

- Variable message signs can in many instances be extremely large. It is therefore, not generally possible to perform laboratory tests on such signs. It is suggested that the manufacturers should submit for evaluation a suitable test module(s) which is fully representative of the production unit. For optical testing control equipment may be external in order to make the modules less bulky. It may be necessary to test more than one module.

19.10.7 General Optical Test Requirements

- The optical tests shall be conducted by a skilled photometrist at an optical test house having been accredited under an agreed accreditation scheme, or alternatively undertaken by a test house which can demonstrate the traceability of its optical standards to National Calibration Standards. Measurement equipment shall be within the calibrated period stated for that equipment and adequate precautions shall be taken to eliminate the effects of stray light from all other sources when conducting light and colour measurements. The module under test shall be complete in respect of the fitment of all optical components, which include all screens, louvers and hoods

where these are employed. All components of the optical system shall be in their correct physical position and orientation. Material surfaces shall be finished to the standards that will be achieved within the production equipment. It should be emphasized to the suppliers that measurements can only achieve a meaningful result if all optical components are fitted and assembled in the correct position.

- It is suggested that each type of sign submitted for testing should contain a minimum of one hundred elements or three complete matrixes. Tests can then be carried out on each sign type and colour. Test modules may be provided which cause problems in fitting to the optical equipment in the normal vertical position. Signs may therefore, be inverted or be operated on their side, subject to the recommendations of the supplier. In these cases consideration should be given to the correct optical orientation of components and services with that of the test and measurement equipment to ensure a representative assessment. Some optical assemblies must be suitably aged so that their electrical and optical characteristics are stable at the time of testing. This is considered satisfactory when two measurements of luminous intensity being made at an interval of fifteen minutes in a given direction do not differ by more than plus or minus 3%. The measurement of any retroreflective components must not be undertaken until the luminous source has been in operation for a sufficient period of time so as to be stabilised.

19.10.8 Luminance Ratio Measurement - General

- The measurement configuration of the sign, solar simulator source and the photometer shall be arranged in accordance with that shown in Figure 19.26.
- The solar simulator shall have a spectral content close to that of natural daylight and a colour temperature of at least 5 000 K. The solar simulator source, in conjunction with optical attenuation device, shall be capable of achieving a level of illuminance up to 40 000 lux, which shall be uniform (10%) over the area of measurement. Or if a solar simulator is not capable of 40 000 lux its effect may be calculated. The test module must be fitted with a control mechanism which will simulate the dimming control. It is recommended that full instructions shall be provided by the supplier to enable the module to be tested at the correct level for the luminance ratio tests.

19.10. Luminance Ratio Measurement – Test Area

- It is recommended that the test area shall meet criteria given below:
 - consist at minimum of a 5 by 5 matrix of elements (see Figure 19.27 - Detail 19.27.1);
 - if a square which has just enclosed a 5 by 5 matrix of elements would have a side of less than 100 millimetres then the test matrix shall include further elements, of the same type and pitch, to fill a square of side equal to, or greater than 100 millimetres (see Figure 19.27 - Detail 19.27.2);
 - matrix elements may consist of more than one light emitter;

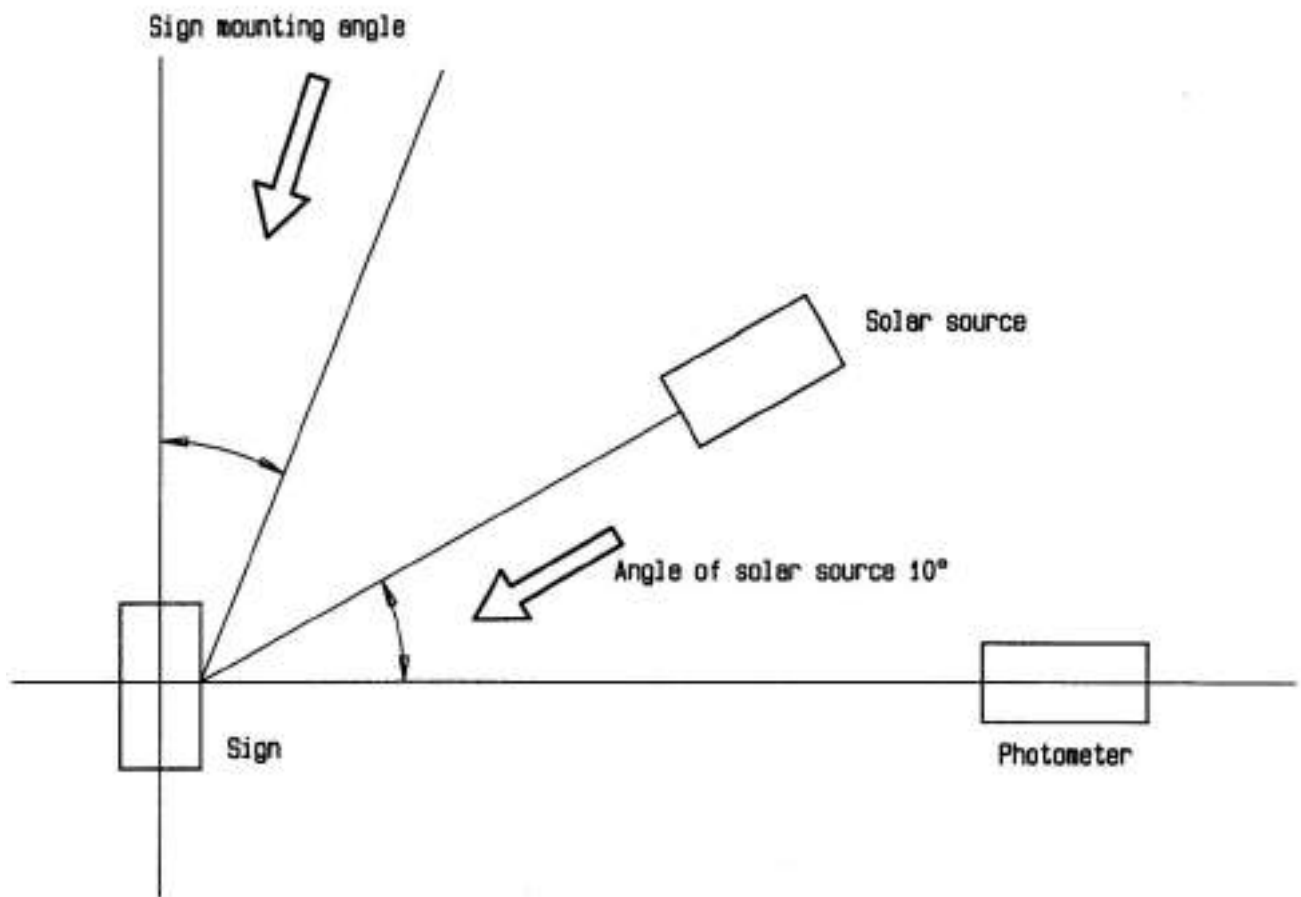
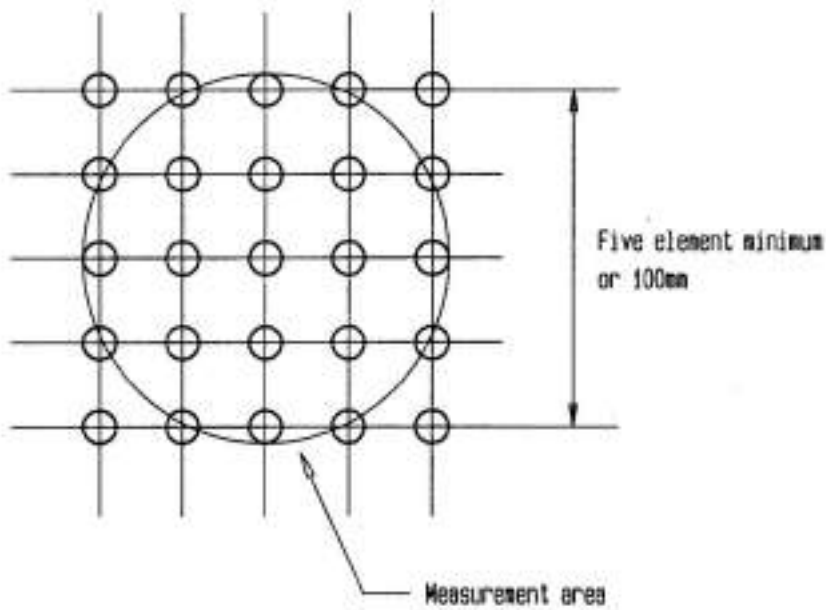
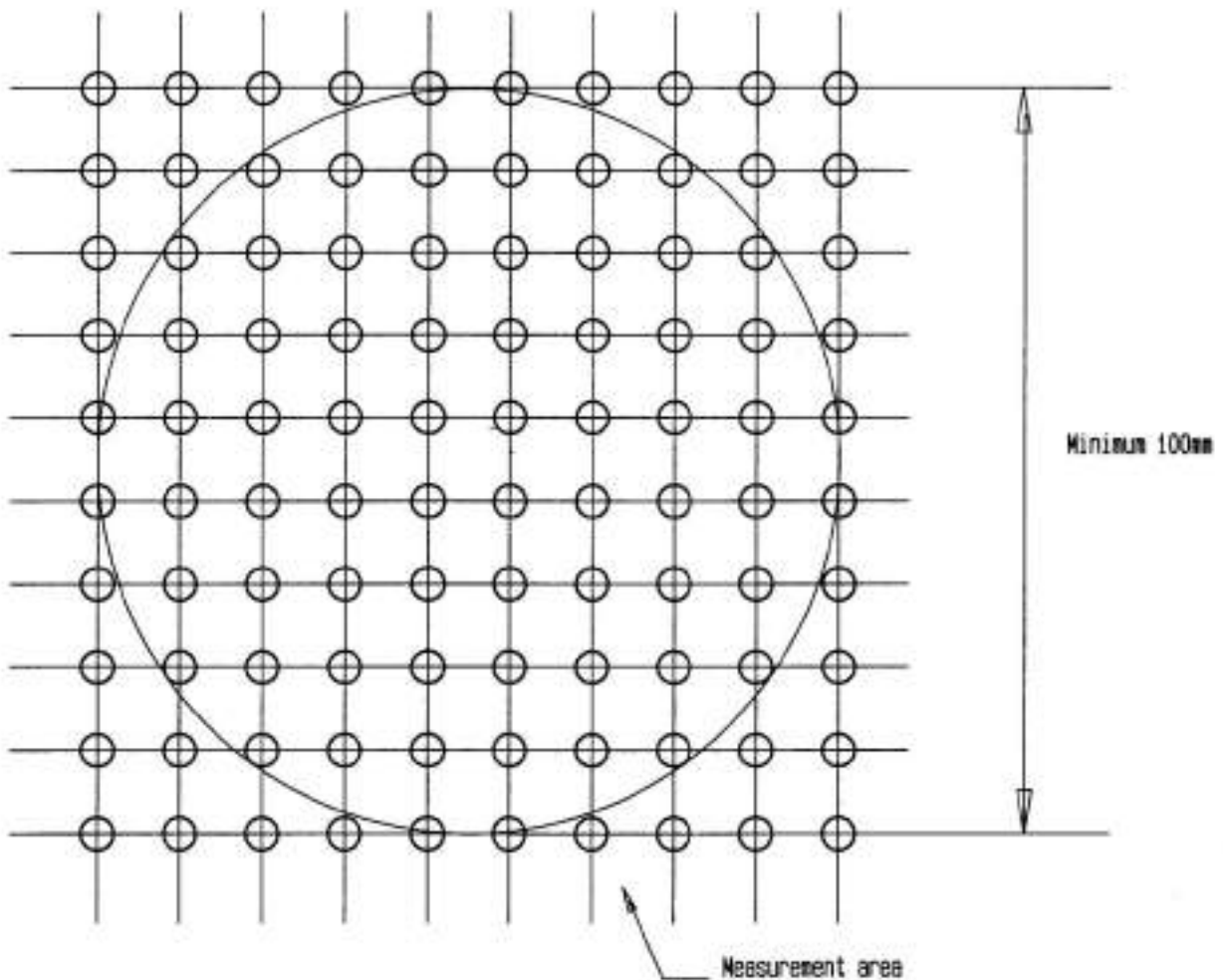


Fig 19.26

Measurement of Luminance Ratio



Detail 19.27.1 Measurement of 5x5 Matrix



Detail 19.27.2 Measurement using 100mm Diameter Area

Fig 19.27

Measurement Test Area - 1

- (d) where fixed characters or symbols are formed by the physical arrangements of equally spaced single light elements, the test area shall meet the overall matrix size and dimensions of (a) and (b) above; the test matrix shall be made up of elements forming a matrix where the separation of elements is equal to the pitch of the single elements forming the character of symbol (see Figure 19.28 - Detail 19.28.1);
- (e) where fixed characters or symbols are formed by the physical arrangements of equally spaced groups of light emitters, the test area shall meet the overall matrix size and dimensions of (a) and (b); the test matrix shall be made up of similar groups of elements forming a matrix, where the separation of emitter groups in the test area shall be the same as that of the emitter groups forming the character (see Figure 19.28 - Detail 19.28.2).
- 2 Signs shall be measured over a circular area bounded by the square test area of emitters as detailed in Figures 19.27 and 19.28 as appropriate. The sign's luminance over the test area shall be measured, for the following level of illumination from the external solar source, 40 000, 4 000, 400, 40 and 4 lux. An additional measurement shall be taken with a random illuminance 40 000 lux and 400 lux. The measurements shall be taken with the sign in the following states:
- (a) all elements of the sign test area shall be active;
- (b) all elements of the sign test area shall be inactive.

- 3 Luminance contrast shall be calculated as follows:

$$\text{Contrast} = \frac{L_a - L_i}{L_i} \quad \text{Formula - 3}$$

where:

L_a is luminance resulting from the active sign under external illumination, in cd m^{-2} ;

L_i is luminance resulting from the inactive sign under external illumination, in cd m^{-2} .

19.10.10 Luminance Ratio Measurement – Multiple Light Sources

- 1 Signs incorporating multiple light sources for illuminating elements shall be tested in accordance with the above, under normal operating conditions as specified by the supplier. This may involve the illumination by more than one light source in order to comply with the performance requirements for higher levels of external illumination (40 000 lux).

19.10.11 Luminous Intensity (or Luminance) Half Angle

- 1 It is recommended that the minimum half angle for an optical category A sign shall be 5° and the minimum half angle for a category B or C sign shall be 10° .

TABLE 19.1

LIMITS OF CONTRAST

TABLE 19.1

External Illumination	Sign Group A	Sign Group B	Sign Group C
40 000 lux	7 to 50	7 to 50	3 to 50
4 000 lux	7 to 50	7 to 50	3 to 50
400 lux	3 to 25	3 to 25	3 to 50
40 lux	3 to 25	3 to 25	0,5 to 25
4 lux	3 to 25	0,5 to 25	0,5 to 25
Fog setting	3 to 25	0,5 to 25	0,5 to 25

where:

- (1) Group A comprises regulatory signs and warning signs, including signs conveying an enforceable speed limit or other prohibition, and signs warning of an impending hazard.
- Group B comprises motorway operational control signs such as advisory speeds.
- Group C comprises directional signs, other information signs, information complementing Group A or Group B signs, and signs for car parks.
- (2) Several formulae exist for the calculation of contrast and contrast ratio, it is therefore important that to achieve the results detailed in the above table, only the above formulae be used for the assessment of equipment to this specification.

- 2 The nominal half angle for a sign shall be determined by the measurement of a sign luminance or luminous intensity (without external illuminance from solar source), with sign rotation in the horizontal and vertical plane. Measurements shall be carried out with the sign at full brightness and then repeated with the sign fully dimmed.
- 3 The luminance or luminous intensity shall reduce evenly to 50% within a specified angle as the sign is rotated. Measurement shall continue to 16° on each axis. The measurements shall be carried out in steps of 1°. The horizontal half angle shall be determined as the mean of the rotations in both directions from the normal. Vertical rotation shall only be carried out below the central axis.

19.10.12 Luminance or Luminous Intensity Uniformity

- 1 The luminance or luminous intensity of elements shall be measured on axis and without external illuminance from the solar source. Ten areas each containing ten adjacent elements shall be measured. Each area may be overlapping. Each element within these areas shall be measured and the output of any two individual adjacent elements shall not vary by more than a ratio of 5:1.
- 2 To take into account the overall effect of the optical performance the information obtained from the one hundred measurements shall be used to calculate the uniformity ratio, this is as follows:

$$\text{Uniformity ratio} = \frac{L_m}{L_h} \quad \text{Formula - ①}$$

where:

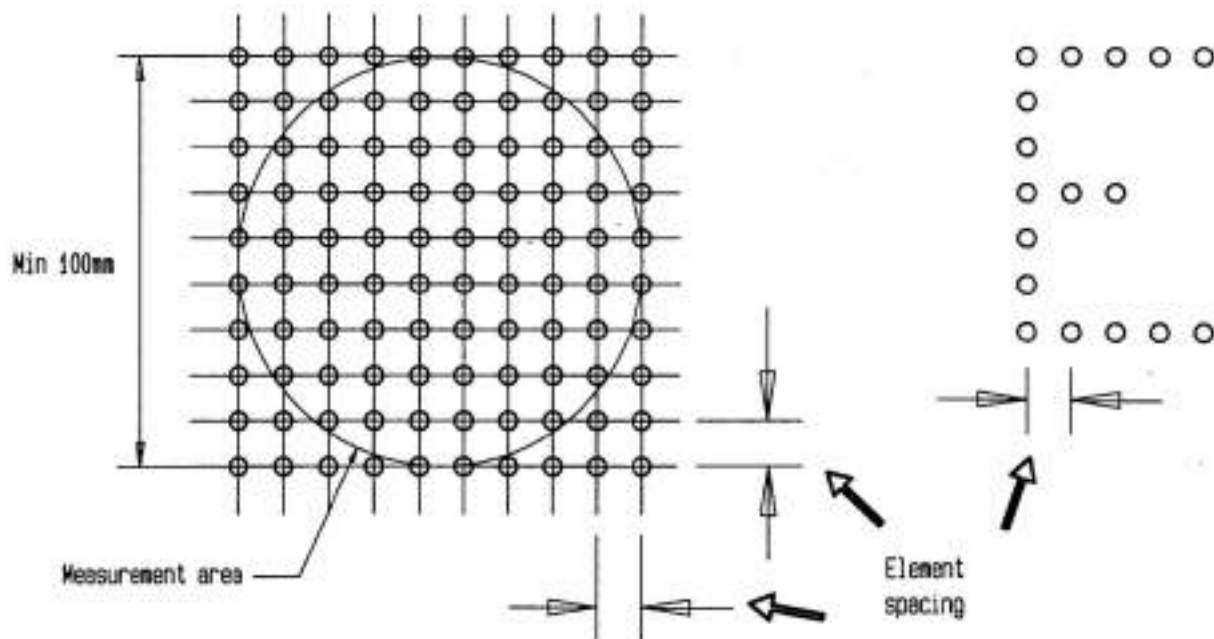
L_m is the mean luminance or luminous intensity of all elements, in cd m^{-2} ;

L_h is the luminance or luminous intensity of an individual element, in cd m^{-2} .

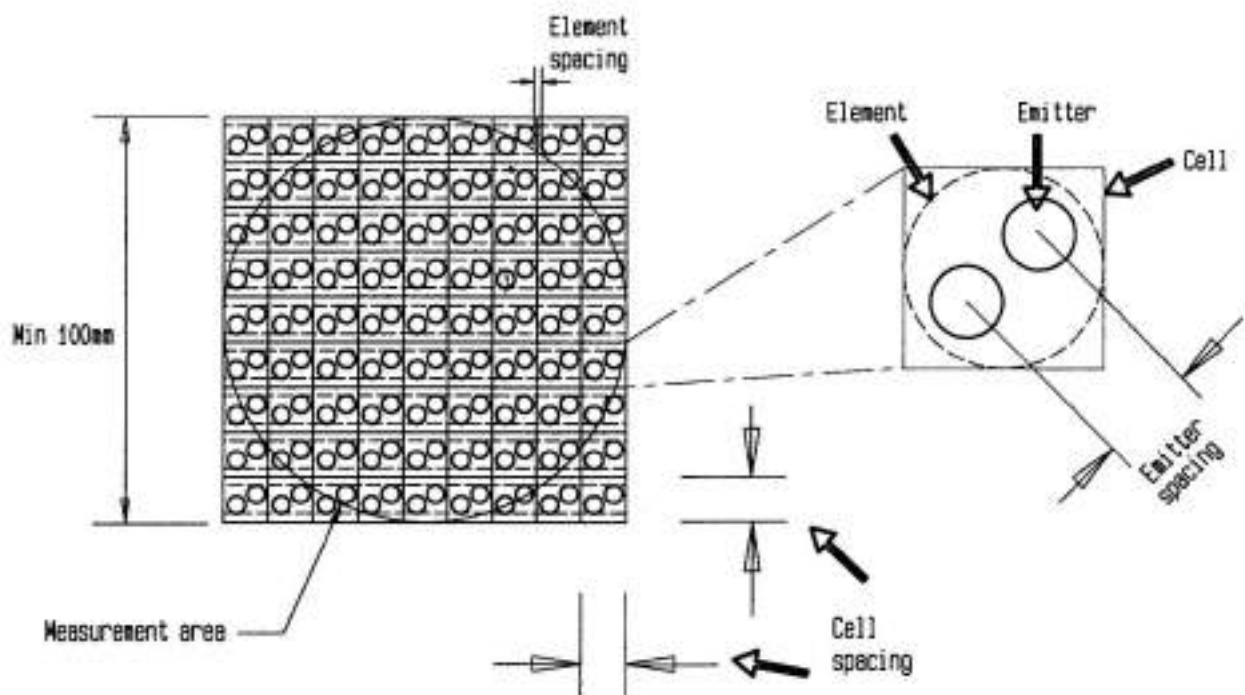
This ratio should be maintained in the range of 0,74 to 1,53.

19.10.13 Colour

- 1 The measurement of colour required by this document may be made by any method which gives results of required accuracy. Colour measurement shall be in terms of CIE x, y chromaticity co-ordinates.
- 2 Care should always be taken to ensure that only the chromaticity of the emitted coloured light is measured and that adequate precautions are taken to eliminate stray light from other sources. The sign equipment shall operate under the conditions specified by the supplier.
- 3 To determine the chromaticity of the sign, light may be received directed by the measuring instrument or reflected via a white diffusing screen, care being taken to ensure that the light is received in a suitable direction from the sign and that the part of the beam of light which enters the instrument is representative of the light being used for the test purposes. For measurements in a particular direction from the sign, a white diffusion screen is placed to receive the light normally at a sufficient distance to ensure that the apparent colour of the screen is uniform and that it is receiving substantially equal light from all parts of the light emitting aperture of the equipment. The screen may be coated with any recognised standard reflecting material, preferably barium sulphate, recommended by the CIE (1986). The measuring instrument is set to receive light from the screen at an angle of 45°. It is possible to illuminate the white screen at 45° to view it normally (45/0 degree method).
- 4 The chromaticity co-ordinates shall also be achieved at the luminance or luminous intensity half angles.



Detail 19.28.1 Measurement of Text Matrix



Detail 19.28.2 Measurement of Text Matrix Made of Emitter Groups

Fig 19.28

Measurement Test Area (Text Matrix) - 1

