# CHAPTER 18:
## ROAD MARKING MATERIALS

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

18.1.2 Introduction

(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 material 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 standpoints:

(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

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, 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.

4

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 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.

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.
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 retroreflectors 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 an 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 retroreflectors, the assumption 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 offsetting 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.

Fig 18.4 Retroreflective Beads for Road Markings
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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 discoulour on bituminous surfaces;
   (ii) the paint should resist chemical action of alkalinnes 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;
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 that 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 nor 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
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 spray paint 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.

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...
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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 experience. 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 placement 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...
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) pigments and fillers; and
   (c) glass spheres.

2. The exact chemical composition varies considerably. Formulæ 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 \((\text{TiO}_2)\) 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.
18.5.13 Service Life

Although thermoplastic markings have been in use for a number of years, there is little agreement on their service life. 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-dependent 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 tampered by simple 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.
18.5.4 THERMOPLASTICS AND OTHER DURABLE MARKINGS

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 a 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 fulfill 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 Dot® 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 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;
   (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 strength of the epoxy resins used today far surpass the internal physical strength of either concrete or asphalt pavements. Since road films, latex 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 area 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.

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 tend 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 in 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 located 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-reflective 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 in 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 coming 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-reflective 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

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# CHAPTER 19: VARIABLE MESSAGE SIGNS

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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).

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.

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.

19.1.3 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;
19.1.2 INTRODUCTION

The following are examples of applications of variable message signs:

(a) traffic management:
   (i) following distance control;
   (ii) lane control/management;
   (iii) safety management;
   (iv) construction/maintenance management;
   (v) ramp metering;
   (vi) demand management;
   (vii) priority access control;
   (viii) ride sharing control;
   (ix) high occupancy vehicle (HOV) control;
   (x) ramp metering;
   (xi) demand management;
   (xii) priority access control;
   (xiii) ride sharing control;

(b) control at crossings:
   (i) bridge management;
   (ii) toll gate management;
   (iii) mountain pass management;
   (iv) 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.

6 Department of Transport. Road Sign Note No. 10 - Variable Message Signs (VMS) - Draft. South Africa.
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 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 its 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 sign's design before future time and money is invested. Such a technique is particularly valuable 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 inappropriate 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 hence 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:

\[
L_{\text{mes}} = \frac{L_{\text{mes}}}{A} = \frac{\text{pix}}{c^2}
\]

where:
- \(L_{\text{mes}}\) is the luminance of the message, in cd m\(^2\);
- \(I_{\text{mes}}\) is the light intensity of the message, in cd;
- \(A\) is the area of the message, in m\(^2\);
- \(I_{\text{pix}}\) 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:

\[
C = \frac{U \cdot L_{\text{F}}}{(L_{\text{i}} + L_{\text{F}}) \cdot L_{\text{F}}}
\]

where:
- \(C\) is the contrast ratio;
- \(L\) is the luminance of the character, in cd m\(^2\);
- \(L_{\text{F}}\) is the background luminance, , in cd m\(^2\);
- \(L_{\text{i}}\) is \((I_{p} \times 35)/S\) which is the internal luminance of the sign, in cd m\(^2\);
- \(I_{p}\) 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

1 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

1 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.

2 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

1 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 module less bulky. It may be necessary to test more than one module.

19.10.7 General Optical Test Requirements

1 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, louvres 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.

2 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

1 The measurement configuration of the sign, solar simulator source and the photometer shall be arranged in accordance with that shown in Figure 19.26.

2 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

1 It is recommended that the test area shall meet criteria given below:

(a) consist at minimum of a 5 by 5 matrix of elements (see Figure 19.27 - Detail 19.27.1);

(b) 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);

(c) matrix elements may consist of more than one light emitter;
Fig 19.26 Measurement of Luminance Ratio
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:

\[
\text{Contrast} = \frac{L_a}{L_i}
\]

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\(^{-2} \).

### TABLE 19.1

<table>
<thead>
<tr>
<th>External Illumination</th>
<th>Sign Group A</th>
<th>Sign Group B</th>
<th>Sign Group C</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 000 lux</td>
<td>7 to 50</td>
<td>7 to 50</td>
<td>3 to 50</td>
</tr>
<tr>
<td>4 000 lux</td>
<td>7 to 50</td>
<td>7 to 50</td>
<td>3 to 50</td>
</tr>
<tr>
<td>400 lux</td>
<td>3 to 25</td>
<td>3 to 25</td>
<td>3 to 50</td>
</tr>
<tr>
<td>40 lux</td>
<td>3 to 25</td>
<td>3 to 25</td>
<td>0.5 to 25</td>
</tr>
<tr>
<td>4 lux</td>
<td>3 to 25</td>
<td>0.5 to 25</td>
<td>0.5 to 25</td>
</tr>
<tr>
<td>Fog setting</td>
<td>3 to 25</td>
<td>0.5 to 25</td>
<td>0.5 to 25</td>
</tr>
</tbody>
</table>

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.
2. Group B comprises motorway operational control signs such as advisory speeds.
3. Group C comprises directional signs, other information signs, information complementing Group A or Group B signs, and signs for car parks.

(1) 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:

\[
\text{Uniformity ratio} = \frac{L_{mn}}{L_n}
\]

where:

- \( L_{mn} \) is the mean luminance or luminous intensity of all elements, in cd m\(^{-2}\);
- \( L_n \) 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 of luminous intensity half angles.
Fig 19.28 Measurement Test Area (Text Matrix) - 1