

Characteristics of retroreflective materials used in traffic control devices

S Mohan, N Dutta & S M Sarin

Central Road Research Institute, Mathura Road, New Delhi 110 020, India

Received 25 February 2000; accepted 18 September 2000

The present paper discusses the characteristics of various retro-reflective materials used in traffic road marking paint, road studs, and road signs. Glass beads of refractive index 1.50, 1.65 and 1.90 are commonly used for this purpose.

One of the major tasks involved in driving is identification of the object/road sign and to do the manoeuvring in different situations to avoid accidents. Whole of the task has to be performed within one or two seconds¹. For vehicle safety, Indian Roads Congress (IRC) has recommended the minimum safe stopping sight distance required for vehicles moving with 40 and 80 km/h as 30 and 120 m, respectively. In tackling complicated situations on road, it is necessary that the object should be visible from a longer distance. The visibility of the object depends upon the luminance level, conspicuity of the object, shape, size, contrast with background and colour. Efforts to improve visibility are continuing since 1921, when first white stripe was painted in Wayne county in USA². But, the painted stripes are worn off by traffic within one month.

Later on, good visibility was obtained by using glass beads of different sizes and refractive index in road markings. The glass beads of certain characteristics and under certain conditions catch the light from the source and reflect it back. This principle of retro-reflection improves the visibility of the ordinary paint film or studs². In the present paper, the characteristics of some of the control devices such as thermoplastic reflecting paint, reflecting sheets and studs is discussed which are presently in use for fabricating various traffic control devices and also the role of reflecting materials in avoiding the road traffic accidents.

Phenomenon of retroreflectivity

The phenomenon implies backward return of reflected light. The light beam enters the glass bead, and can bend or refract downward. This beam shines the back surface of bead having a paint containing TiO₂ acting as a white colouring matter. The white paint at the back helps the glass bead to act as a

mirror. This condition of refraction is only satisfied when the glass beads are transparent, spherical and properly imbedded in the paint film. The optimum imbedment of glass beads in the paint film of thickness 0.007-0.010 inch is between 50 to 60% for better retro-refraction². Thus, the glass bead of proper size can only be embedded in a particular thickness of paint film. The bending of light is controlled by refractive index (RI) of the glass beads. The higher the RI, the greater would be bending of light. More the RI, more would be the return of light and brighter would be the line². In general, glass beads act as a magnifying lens. It is the chemical composition of the glass beads which determines RI. The glass beads of RI 1.50 have high silicon content. The glass beads of RI 1.90, are more transparent and do not contain silica or calcium. The manufacturing process of glass bead of RI 1.90 is very complicated, so the cost is more. Moreover, their density is also higher than other glass beads. The use of glass beads of RI 1.90 increases the cost of traffic control devices. The most commonly used glass beads for traffic control devices are of RI 1.50 and 1.65 beads. The process of retroreflectivity through glass beads has considerable potential to improve visibility of the paint and road signs even under unlit conditions.

Type of traffic control devices used in improving night time visibility

The main purpose of all the traffic control devices like road signs, markings, delineators, studs, bollards, etc.³, is to guide the motorists on road. There were 4500 fatal accident in 1961 increasing to 60000 in 1991⁴. The reflective materials improve the conspicuity and legibility of the road signs and markings especially at crucial time of night. The early deduction of obstruction on road can avoid accident and can improve road safety. The safe stopping distance required for motorist at various speeds is

given⁵ in Table 1, as achievable through better traffic control devices.

Letters written on the sign are of 15" height. On the basis of principle of legibility formula (1" letter height for every 50 ft. distance), a sign of 15" letter could be legible from 750 ft.. Awareness of the sign at 1000 ft or more is the minimum requirement of a motorist. If a driver is travelling at 55 miles/h and begins or is able to read the sign, there are only 9.3 sec left to reach the road sign⁵. The driver should be aware of the sign or the danger at least 3 sec before reaching it because in order to avoid accident, at least 3 seconds are needed for maneuvering and decision taking. The reflective road materials or sheets have the potential of carrying the jobs of early recognition of sign at a distance of 1000 ft. The visibility of these control devices is improved considerably by using glass beads of different size, grading and RI.

Characteristics of reflective road marking paints

The process of road marking in India is mainly carried out by solvent borne traffic paint which has very poor visibility and has useful service life of only 45 days. Generally, a ray of light from head light strikes the pavement 46 m in advance of the vehicle and this light is either absorbed or reflected forward by the pavement surface and very little fraction of light is being reflected back to the driver's eye⁶. Thus,

Table 1—Sight distance for various speeds

Speed km/h	Stopping distance (m)	Intermediate distance (m)	Overtaking distance (m)
20	20	40	—
25	25	50	—
30	30	60	—
35	40	80	—
40	45	90	165
50	60	120	235
60	80	160	300
65	90	180	340
80	120	240	470
100	180	360	640

Table 2 — Physical characteristics and their recommended values for thermoplastic materials

Physical property	Recommended value as per BS:3261 Part I
Specific gravity	Not more than 2.15
Drying time	Not more than 10 min
Bond strength	Bond Strength with portland cement not to exceed 180 psi
Softening point	Above 65°C
Flow resistance	Not more than 25%
Luminance	Not less than 65%
Skid resistance	Not less than 45%
Retro-reflectivity	Not less than 25 cd/lux/m ²

there is a need of a retroreflective based material, which does not allow any diffusion of light and reflects back most of the light received by it to the driver's eye. This process is performed by glass beads of proper size embedded properly in the traffic paint.

Thermoplastic road marking material with a life more than 3 years was developed and made reflective by adding glass beads. The use of this reflective paint has started in India. The visibility of the control lines is improved considerably by adding glass beads. Thermoplastic material is a mixture of resins, glass beads, pigments and fillers in different proportions. The various properties of thermoplastic materials are given⁷ in Table 2. There are two methods of improving reflectivity of a paint: (i) by premix method, and (ii) drop on method. The grading of the glass beads by premix method and the drop on method are given⁸ in Tables 3 and 4.

Characteristics of reflective sheets

The reflective sheets are bright, durable, flexible and retro-reflective, which are designed for the production of various control devices. The sheets consist of tiny spherical lens (glass beads of size 80 µm.) adhered to a synthetic resin and encapsulated by flexible transparent plastic that has a smooth outer surface, and sold in the market in the form of rolls. These sheets are having either heat-activated or pressure-sensitive adhesives protected by removable thin layer of paper. The various properties of reflective sheets are given⁹ in Table 5 and retro-reflective characteristics are given¹⁰ in Table 6. The production of such sheets has not yet started in India.

Characteristics of retro-reflective raised pavement markers

The most commonly used raised pavement markers are cat's eye and reflective studs which improve the road safety by making reflectorised road markings as

Table 3—Glass beads particle size distribution for premix type thermoplastic paint

Sieve	Retained (%)
1.18 mm	0–3
850 µm	0–10
425 µm	90–100

Table 4 — Glass beads for drop on type thermoplastic paint

Sieve (µm)	Retained (%)
850	0–5
600	5–70
300	30–75
180	10–30
< 180	0–15

Table 5—Physical characteristics and recommended values for reflecting sheets

Material property	Requirement
Thickness	Less than 300 μm
Spectacular Gloss at 85°	More than 40 %
Tensile Strength	Above 2.25 kg
Adhesion	It should increase with increase in pressure and heat
Resistance to heat	No cracking at $71 \pm 3^\circ\text{C}$ for 24 h
Resistance to cold	No cracking at -57°C for 72 h
Resistance to humidity	No cracking for 100% RH at 27°C
Impact resistance	No cracking for 11.5 kg cm impact
Flexibility	19 mm 180°
Skrinkage	Under 0.8 mm in 10 min when adhesive surface is peeled off

Table 6—Acceptable minimum coefficient of retroreflection (candles/lux/ m^2) for reflecting sheets

Observation angle (deg)	Entrance angle (deg)	White	Yellow	Green/Red	Blue
0.2	-4	250	170	45	20
0.2	+30	150	100	25	11
0.5	-4	95	62	15	7.5
0.5	+30	65	45	10	5.0

Table 7—Physical characteristics at its recommended values of pavement markers (studs)

Physical property	Recommended value
Slope of reflecting surface	30°
Area of reflecting surface	21.0 cm^2
Strength	It can support the load of 159.9 kg. at $23 \pm 2^\circ\text{C}$.
Bond strength	35.1 kg/cm^2

Table 8—Coefficient of luminous intensity (specific intensity) requirements

Observational angle (deg)	Horizontal entrance angle (deg)	Coefficient of Luminous Intensity mcd/lux					Specific Intensity (cd/ft c)				
		White	Yellow	Red	Green	Blue	White	Yellow	Red	Green	Blue
0.2	0	279	167	70	93	26	3.0	1.8	0.75	1.0	0.2
0.2	20	112	67	28	37	10	1.2	0.7	0.3	0.4	0.1

a permanent marking on the road. These studs are commonly used on centerline, road edges, speed breakers, narrow bridges, etc. Studs/Cat's eye are made up of aluminium or plastic body having single or double reflecting face with a slope of 30° from the base and a hole in the centre. The studs are fixed on the surface of the pavement by a nail. The recommended distance between two studs is 3 m¹¹.

In order to maximise the brightness level, two reflective faces of prismatic acrylic shell or polystyrene shell with an angle $10-30^\circ$ are used. The angular surface does not allow any dirt collection over it. The plastic face also does not allow any damage of braking/scratching of the markers due to overloaded trucks. The various properties and coefficient of retro-reflectivity and compressive strength are given¹¹ in Tables 7-8.

Conclusions

The use of retro-reflecting materials⁴ in the area of traffic control devices in India is not as popular as in the other countries and the manufacturing of glass beads of proper grading, refractive index and quality has not yet started in India. As a number of corridors of road systems in India are being designed for high speed traffic, the need of reflecting traffic control devices would increase day by day and it is right time

to start their production. So, the development of these materials would save our foreign exchange resources. Reflective materials have positive benefits in the area of traffic safety under poor visibility conditions.

References

- 1 Dale J M, Pavement marking materials and application for extended service life, *NCHRP, Synthesis of Highway Practice*, No. 138 (TRB Publication).
- 2 Dray F L, *J Traffic Eng*, 47 (3) (1977) 36.
- 3 Recommended Practice for Road Signs, *Indian Road Congress (IRC)*, No. 67, 1977.
- 4 *Road Safety Digest* (Loss Prevention Association of India Ltd), No. 4, 1992.
- 5 Recommended Practice for Sight Distance on Rural Highways, *Indian Road Congress (IRC)*, No. 66, 1976.
- 6 Schreiber G & Richey G, *Visual aspects of road markings* (CIE, Vienna, Australia), 73, 1988.
- 7 Sarin S M, Surinder Mohan, Sharfuddin, Shukla A & Singh A, Development of thermoplastic material as a substitute to road marking paint, *International Seminar on Highway Safety Management and Devices*, New Delhi, II-69, 1998.
- 8 Specification for Solid glass beads for use with road marking compounds and for other industrial uses, *BSI 6088* (1981).
- 9 Standard Test Method for Coefficient of Retro-reflection of Retroreflective Sheeting, *ASTM Designation*, E810-81, 1981.
- 10 Standard Specification for Retroreflective sheets, *ASTM Designation*, D4958, 1990.
- 11 Standard Specification for Extended Life type, Nonplowable, Prismatic, Raised, Retroreflective Pavement Markers, *ASTM Designation*, D4280, 1992.