

Road lighting —

Part 7: Code of practice for the lighting of tunnels and underpasses

Committees responsible for this British Standard

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- British Lighting Association for the Preparation of Standards (Britlaps)
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- Chartered Institution of Building Services Engineers
- Council for the Protection of Rural England
- County Surveyors' Society
- Department of Transport
- Institution of Civil Engineering Surveyors
- Institution of Civil Engineers
- Institution of Electrical Engineers
- Institution of Lighting Engineers
- Institution of Mechanical Engineers
- Lighting Industry Federation Ltd.
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Foreword

This Part of BS 5489 has been prepared under the direction of the Electrical Illumination Standards Policy Committee and is a new edition of BS 5489-7:1990 which is withdrawn.

In recent years there has been an increase in the number of road tunnels in the United Kingdom and a marked growth in demand for underpasses.

In the 1990 edition emphasis was placed upon dealing with the longer tunnel which, because drivers have time to adapt to lower lighting levels, was divided into a number of lighting zones. Procedures for dealing with the different zones were detailed so that, overall, traffic can flow smoothly and safely with little discomfort to drivers.

The procedures can be adapted for shorter tunnels, underpasses and bridged roads and relate to all types of road, including motorways. Daytime recommendations for lighting were covered as well as those for night time and under adverse weather conditions.

This new edition introduces a revised definition of maintenance factor, and incorporates editorial improvements but it does not reflect a full review or revision of the standard, which will be undertaken in due course.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 36, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This Part of BS 5489 gives recommendations for the lighting of tunnels including underpasses and relates to all types of road including motorways.

Recommendations are given firstly for the lighting of longer tunnels and secondly, in clause 15, for the lighting of shorter tunnels and bridged roads, where variations from the basic recommendations become applicable. Tunnel lighting recommendations for daytime and after dark are given for all types of road together with the situations in which artificial lighting in daytime may be unnecessary. Attention is drawn to the importance of adhering to the maintenance schedule to ensure that the design lighting levels are always realized.

This Part of BS 5489 does not deal with subways reserved for pedestrians or cyclists, underground shopping areas, railway station taxi ranks, etc., or with traffic signs, signals and illuminated bollards.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 5489 the definitions given in BS 5225-1, BS 5489-1 and BS 6100-2.4.1 apply, together with the following.

NOTE See also Table 1.

2.1

access zone

the length of approach road before a tunnel entrance

NOTE Daylight screens, if present, are taken to be part of the tunnel.

2.2

access zone luminance (L_{20})

the average value of the luminance over a 20° diameter circular field of view seen by the driver from the access zone and centred on the tunnel entrance

NOTE The particular value of L_{20} at the stopping point SP is termed $L_{20}(\text{SP})$ and that at the adaptation point is termed $L_{20}(\text{A})$.

2.3

adaptation point (A)

that point on the road where as a result of the presence of the relatively dark tunnel entrance which forms a rapidly increasing part of the field of view, the adaptation level of the driver's eyes begins to decrease significantly

2.4

exit zone

a stretch at the end of a tunnel where the vision of a driver approaching the exit is influenced by the brightness outside the tunnel

2.5

interior zone

the main stretch of the tunnel, over which the lowest (basic) level of daytime lighting applies

2.6

interior zone luminance (L_{in})

the average¹⁾ luminance in the interior zone which constitutes the background field against which objects will be visible to drivers

NOTE This luminance is sometimes referred to as the basic daytime level when, at the appropriate stage, it extends throughout the tunnel.

2.7

stopping point (SP)

the position within the access zone on the approach road at a distance equal to the stopping sight distance from the tunnel entrance

2.8

stopping sight distance (SSD)

the theoretical forward sight distance required by a driver, at a given speed, in order to stop when faced with an unexpected hazard on the carriageway

NOTE This distance takes account of perception and reaction time and braking distance.

2.9

threshold zone

the first stretch of the tunnel and that which constitutes the bright background against which objects are seen by drivers in the access zone between the SP and the tunnel entrance

2.10

threshold zone luminance (L_{th})

the average¹⁾ luminance in the threshold zone which constitutes the background field against which objects will be visible to drivers in the access zone between the SP and the tunnel entrance

NOTE The particular value of L_{th} at the inner end B of the threshold zone where the transition zone commences is termed $L_{\text{th}}(\text{B})$.

2.11

transition zone

succeeding stretch of the tunnel, after the threshold zone, with a luminance less than that in the threshold zone and designed to maintain an adequate visibility for drivers whilst they progress from the threshold zone to the interior zone

¹⁾ For the purposes of calculation the average is usually taken to be the average luminance over the road surface. See also clause 16.

2.12**transition zone luminance (L_{tr})**

the average²⁾ luminance in the transition zone which constitutes the background field against which objects will be visible to drivers

2.13**tunnel entrance, mouth or portal**

the point at which the covered section of the road commences. This includes any covering which admits daylight, i.e. daylight screens (see 2.1)

2.14**adaptation**

the process by which the properties of the visual system are modified according to the luminances or the colour stimuli presented to it

2.15**luminaire**

apparatus which distributes, filters or transforms the lighting given by a lamp or lamps and which includes all the items necessary for fixing and protecting these lamps and for connecting them to the supply circuit

2.16**flicker**

impression of fluctuating luminance or colour, occurring when the frequency of the variation of the light stimulus lies between a few hertz and the fusion frequency of the images

2.17**cut-off**

technique used for concealing lamps and surfaces of high luminance from direct view in order to reduce glare

2.18**reflectance**

ratio of the reflected radiant or luminous flux to the incident flux

2.19**interreflection**

general effect of the reflections of radiation between several reflecting surfaces

2.20**specular reflection**

reflection without diffusion in accordance with the laws of optical reflection as in a mirror

2.21**fluorescent lamp**

discharge lamp in which most of the light is emitted by a layer of fluorescent material excited by the ultraviolet radiation from the discharge

NOTE This term is most commonly applied to low pressure tubular fluorescent lamps.

2.22**high pressure sodium (vapour) lamp**

sodium vapour lamp in which the partial pressure of the vapour during operation is of the order of 100 mbar³⁾

2.23**low pressure sodium (vapour) lamp**

sodium vapour lamp in which the partial pressure of the vapour during operation does not exceed 0.05 mbar

2.24**louvre**

screen made of translucent or opaque components and geometrically disposed to prevent lamps from being directly visible over a given angle

2.25**utilization factor**

ratio of the utilized flux to the luminous flux emitted by the lamps

2.26**translucent plastics**

incompletely diffusing plastics through which objects are not seen distinctly

2.27**luminance**

at a point of a surface and in a given direction, the luminous intensity of an element of the surface, divided by the area of the orthogonal projection of this element on a plane perpendicular to the given direction

Table 1 — Stopping sight distances (SSD) for various design speeds

Design speed (in km/h)	120	100	85	70	60	50
SSD (in m)	215	160	120	90	70	50
NOTE These values are extracted from Department of Transport Standard TD 9/81 obtainable from DOE/DTP Publication Sales Unit, Building 1, Victoria Road, South Ruislip, Middlesex HA4 0NZ.						

²⁾ For the purposes of calculation the average is usually taken to be the average luminance over the road surface. See also clause 16.

³⁾ 1 mbar = 100 N/m² = 100 Pa.

3 General

The object of installing lighting in a road tunnel is to enable traffic to flow through it with the same speed, degree of safety and comfort as on the approach roads.

This aim can be achieved only when road users are sufficiently aware visually of the roadway ahead of them and, in particular, of the presence or absence of other vehicles and possible obstructions. The major difference between tunnel lighting and conventional road lighting is in the need for lighting by day. A driver should be able to see a certain distance ahead such that if an unexpected hazard appears, the driver can react and stop within that distance. When this distance extends into a tunnel there should be a sufficiently high lighting level inside to maintain visibility. If the lighting level is not high enough, the driver will be unable to see into the tunnel, the so-called “black hole effect”.

During approach and entry to the tunnel, the driver's eyes become adapted to the darker surroundings. This adaptation is a continuous process with the result that further into the tunnel, providing it is of sufficient length, the lighting level may be reduced in stages to a constant level in the tunnel interior. On emerging from a tunnel into daylight, however, the eye adapts far more quickly to the higher luminance level.

Similarly, rearward visibility should be maintained when leaving the tunnel, to facilitate safe manoeuvres immediately beyond the exit zone.

The environmental import of the lighting on its surroundings should not be forgotten. The context can range from open countryside to high density communal areas, or in the case of short tunnels may be related to a building or structure of architectural and historic importance. The effects of the type of lamp chosen, light spillage, fixtures and luminaires should all be considered.

4 Basis of design and summary of design procedure

First consideration in a tunnel lighting design is usually given to the determination of the highest access zone luminance occurring at the stopping point, i.e. $L_{20}(\text{SP})$. Methods of doing this are described in clause 5. From this value, the luminance to be provided in the threshold zone (L_{th}) can be derived as explained in clause 6.

The level of luminance so determined for the threshold zone of a tunnel is based upon the perception of an object 20 cm square, having a certain contrast. The theoretical background is summarized in Appendix A.

The basis for determining the luminances and lengths of each zone can be understood from Figure 2. The left hand side of this graph shows how the access zone luminance might vary with distance from the tunnel entrance for a driver approaching the tunnel from the stopping point (SP). The determination of the position of the adaptation point (A) and the way in which its distance from the tunnel entrance affects the length of the threshold zone are explained in 7.1 and 7.2.

The right hand side of Figure 2 represents the luminance necessary in the tunnel where the luminance axis of this plot is the vertical line through the position of the tunnel entrance. The luminance throughout the threshold zone is shown by the full line as being constant, i.e. $L_{\text{th}}(\text{B}) = L_{\text{th}}$. There may be a justification for reducing the threshold zone luminance over the length of the threshold zone. An example of such a reduction is shown in Figure 2. See also 7.3.

Beyond the end of the threshold zone, i.e. past point B, the luminance in the tunnel should be reduced through one or more transition zones to the luminance L_{in} chosen for the interior zone of the tunnel (see clause 9). The maximum rate at which the luminance can be reduced from $L_{\text{th}}(\text{B})$ to L_{in} is given by the appropriate luminance reduction curve in Figure 3. The method of fitting the curve to give the transition zone(s) is explained in clause 8. The experimental derivation of the lighting reduction curves is summarized in Appendix A. Lighting for the exit zone is covered in clause 10 and the recommendations for night-time lighting throughout the tunnel are given in clause 12.

The levels of luminance (in cd/m^2) specified in this standard are maintained values. The surface to which a recommended luminance applies is that of the background against which vehicles and objects will be seen (see 2.6). Although this background may comprise the road surface, the walls and even the roof, it is the average luminance of the road surface in a zone which should first be determined in ascertaining whether a lighting design meets the recommended luminance value. Subsequently consideration can be given to the lighting of the walls and possibly the roof (see clause 16).

Uniformity of luminance is considered in clauses 11 and 12.

The use of illuminance values to specify the lighting in tunnels is not recommended, but an additional computation of illuminance levels and uniformity may be produced for contractual purposes because it is simpler to check illuminance in the completed installation.

5 Determination of the access zone luminance (L_{20})

5.1 It has been found that the value of L_{20} provides adequate quantitative representation of the visual effect of the whole luminance pattern in the driver's field of view. In particular, the highest luminance level L_{th} to be provided in the threshold zone of the tunnel is dependent on the luminance pattern, and hence the maximum value of L_{20} , experienced by the driver at the stopping point (SP) in the access zone, i.e. the maximum value of $L_{20}(SP)$. The position of SP in the access zone is determined by the stopping sight distance (SSD).

The values of SSD to be used in conjunction with this Part of BS 5489 are shown in Table 1 as a function of the design speed, i.e. the traffic speed for which the road has been geometrically designed. These values of SSD should be used unless there are circumstances which will result in particularly onerous demands being placed upon drivers' perception as they approach the tunnel. In such cases the SSD relating to the next higher design speed in Table 1 should be used. Examples of these circumstances are:

- a) road junctions near or partly within the access or threshold zones of tunnels, giving increased likelihood of lane merging and speed changing;
- b) a mixture of slow and fast vehicles;
- c) limited cross section for emergency situations, e.g. narrow lane width or restricted verge provision.

NOTE Where such circumstances apply and the design speed is 120 km/h then the SSD should be increased to 295 m. For SSD values corresponding to design speeds not given in Table 1, a graph of the relationship between SSD and design speed should be plotted and the appropriate values read off.

It is assumed that the design speed and the operational traffic speed limit of the road system are the same. If they are not, then the tunnel lighting design may be based on the (lower) operational speed limit. However, if this limit were to be subsequently raised, then the lighting in the tunnel would probably be inadequate. It is not recommended that a speed limit be applied specifically to the tunnel section to compensate for lighting which is not up to the necessary standard. Such a procedure will only restrict freely flowing traffic and lead to the very situations which the lighting should be designed to avoid.

Speed of approach affects the value of $L_{20}(SP)$ in that the position of the SP in the access zone will vary; the slower the speed of approach, the nearer the tunnel entrance will the point be and generally the lower the value of $L_{20}(SP)$.

The following methods are recommended for the determination of L_{20} at any point in the access zone, including $L_{20}(SP)$.

1) **Direct measurement on site.** This can be carried out at existing tunnels or at the site of a proposed project. Details of the method are given in Appendix B. It is generally a rather expensive operation because of the equipment and time involved and should only be used where the tunnel has features difficult to assess by other methods. It is important to obtain the highest value of L_{20} , which is very dependent on sky conditions.

2) **Grid method.** This method can be used where 1) is impracticable but photographs or scale drawings of the tunnel approach are available. L_{20} is calculated as an average, weighted according to area, of the individual luminances of each part of the field of view. Typical component luminance values recommended for use are listed in Appendix C, together with a worked example. On-site measurements of component luminances (see Appendix B) can be used in the calculation to give more representative results.

3) **Comparison with existing tunnels.**

Considerable experience has been gained in providing satisfactory threshold zone lighting, both in this country and abroad, and it has been found that for a given type of tunnel approach (e.g. in mountains, built-up) a certain range of access zone luminances apply.

Diagrams of a number of access zone situations are given in Figure 4, together with the range of access zone luminances likely to apply under an illuminance of 100 klx (i.e. maximum summer value). The drawings are made from the distance shown and the 20° field of view is marked.

Comparison of the actual tunnel situation with the drawings will yield the range of values of L_{20} which is applicable.

5.2 Methods 1) and 2) of 5.1 give values of L_{20} that are as accurate as can reasonably be obtained as a basis for the lighting design in the tunnel. In the absence of the more precise data that would be provided by these methods, method 3) will give a first approximation of $L_{20}(SP)$ for initial design purposes. It is recommended that method 1) or method 2) of 5.1 is used for determining the final lighting design.

6 Threshold zone lighting during daylight

In order that drivers have adequate visibility into the tunnel, the threshold zone luminance L_{th} should be related to $L_{20}(SP)$ by a factor k as follows:

$$L_{th} = k L_{20}(SP).$$

The value of this factor varies with the nature of the road and the traffic: the road lighting categories defined in Table 1 of BS 5489-2 are used as a classification (see Table 5 of this standard).

Table 2 gives the recommended values of the threshold zone luminance L_{th} in terms of the factor k by which $L_{20}(SP)$ has to be multiplied.

Table 2 — Values of the factor k

Speed limit		Road lighting category	Factor k
mile/h	km/h		
70 and above	110 and above	Motorways	0.07
50 to 60	80 to 100	Category 2/1 roads and category 2/2 roads when these speed limits are applicable	0.06
30 to 40	50 to 70	Category 2/2 roads when these speed limits apply and category 3/3 roads	0.05

7 Extent of threshold zone

7.1 Determination of length of threshold zone

The length of the threshold zone is related to the position of the adaptation point A and the stopping sight distance (in metres) relevant to the speed of the traffic as follows:

threshold zone length is either 40 m or $(S_{SD} + 20 - d)$ whichever is the greater.

where

S_{SD} is the value of the SSD (in m);

d is the distance (in m) from the adaptation point A to the tunnel entrance.

The derivation of the zone length is shown in Figure 2. The additional 20 m on the SSD is to provide the necessary background to reveal an obstacle at the SSD for a driver at the adaptation point. Where the approach speed of the traffic is less than the design speed for the road, e.g. a toll plaza or any road layout which reduces the speed of the traffic on the immediate approach, the length of the threshold zone may be reduced to 40 m.

The contribution to the illumination of the threshold zone by daylight penetrating the entrance is dependent on the structural design and architectural treatment but generally no artificial lighting is necessary in the first 5 m of the tunnel.

7.2 Location of adaptation point (A)

The point A at which the adaptation level of a driver's eyes begins to decrease significantly as the tunnel entrance is approached is an imprecise one. It is, however, important to be able to make an estimation of its position because the greater the distance of point A from the tunnel entrance, the shorter the length of the threshold zone need be, with a consequent saving in cost.

The minimum distance between point A and the tunnel portal can be derived geometrically by considering the point where the top of the tunnel mouth just appears within the 10° angle of elevation of the driver's view (see Figure 5). This distance will be about 23 m for a tunnel entrance height of 5.5 m (see Table 3).

Table 3 — Location of the adaptation point (A)

Height of the top of the tunnel mouth m	Distance (d) from the adaptation point (A) to the tunnel entrance (mouth) m
5	20
5.5	23
6	26
6.5	28
7	31
7.5	34
8	37
8.5 and greater	40

The values in Table 3 should be used unless a direct determination of the location of A as detailed below shows that its distance from the tunnel mouth differs from the Table 3 distance by more than 3 m.

It is possible to assess the distance from A to a particular tunnel entrance directly, by plotting the values of L_{20} as a function of distance between the stopping point (SP) and the tunnel entrance. The values of L_{20} (i.e. average luminance over a 20° field of view centred on the tunnel entrance) may be determined in the manner described in 5.1 1) or 2) and Appendix B and Appendix C. The point $L_{20}(A)$ on the resulting curve nearest the tunnel entrance, where L_{20} drops to 90 % of $L_{20}(SP)$, will determine the distance from the tunnel entrance (see Figure 2). Where the position of such a drop in L_{20} is uncertain, the formula given on Figure 5 should be applied.

7.3 Visibility in threshold zone

The threshold zone is usually designed to have a constant luminance level throughout its length, i.e. $L_{th}(B) = L_{th}$. However, adequate visibility will be maintained if, after the first 20 m, the threshold zone luminance follows a similar pattern of reduction to that of the adaptation luminance as the driver approaches the tunnel. The access zone luminance values between the stopping point SP and the adaptation point A should be determined directly as described in 5.1 1) or (2). Then a two or three stepped reduction of the lighting in the threshold zone may be used to realize this graded luminance. At no point, though, should the steps go below the value of k times the corresponding value of L_{20} . At the end of the threshold zone, i.e. at B , $L_{th}(B) = k L_{20}(A)$.

8 Transition zone lighting during daylight

This zone provides one or more lighting levels L_{tr} intermediate between the luminance at the inner end of the threshold zone $L_{th}(B)$ and the interior zone level L_{in} . To design this reduction in luminance, use is made of the reduction curves in Figure 3 which represent the acceptable rates of decrease in luminance at various traffic speeds. The curves are applied as follows.

- Select the reduction curve corresponding to the highest traffic speed in the tunnel. It will be necessary to interpolate for curves related to traffic speeds other than those shown.
- The vertical axis of luminance should be determined by setting the 100 % level equal to the value of $L_{20}(SP)$.
- Mark the points where luminances equal to $L_{th}(B)$ and L_{in} occur on the relevant reduction curve.
- To fix the zero position of the curve on the horizontal axis relative to the entrance to the tunnel, the distance shown on Figure 3 corresponding to the position of the luminance $L_{th}(B)$ should be subtracted from the length of the threshold zone (see 7.1). The answer represents the distance into the tunnel at which the reduction curve commences and is the correction that has to be added to the horizontal scale for the particular tunnel under consideration, such that the new zero is at the tunnel entrance. If the correction is negative, then the reduction curve is taken as beginning outside the tunnel. The fitting of the curve at the end of the threshold zone is shown in Figure 2.

e) The portion of the reduction curve between the luminances $L_{th}(B)$ and L_{in} shows the rate at which the luminance can be reduced through the transition zone(s) (see Figure 2). The total length of the transition zone(s) can be determined from the horizontal axis.

f) The luminance decrease is effected in a series of steps. It is recommended that the decrease between successive steps is not greater than the ratio 3 : 1, although in practice a slightly greater ratio (about 10 % greater) is allowable to facilitate the design of a simple switching arrangement. The steps should be drawn such that they form an approximation of the reduction curve with about equal portions above and below the curve. The fitting of the steps is shown in Figure 12 of the worked example in Appendix D.

NOTE For reasons of economy the first step is often made 2 : 1.

g) The steps should be arranged to follow the appropriate luminance reduction curve at all switching stages of the lighting (see clause 13).

9 Interior zone lighting during daylight

The maintained average luminance values L_{in} are given in Table 4.

Table 4 — Luminance in the interior zone

Speed limit		Road lighting category	Average maintained luminance L_{in} cd/m ²
mile/h	km/h		
70 and above	110 and above	Motorways	10
50 to 60	80 to 100	Category 2/1 roads and category 2/2 roads when these speed limits are applicable	5
30 to 40	50 to 70	Category 2/2 roads when these speed limits apply and category 2/3 roads	3

10 Exit zone lighting during daylight

At the exit the adaptation of the eye to the higher luminance is very rapid and extra lighting is not required to assist this adaptation. The purpose of lighting in the exit zone is:

- a) to give direct illumination of smaller vehicles which can otherwise be inconspicuous behind larger vehicles because of the glare effect of the exit;
- b) to enable drivers who are leaving the tunnel to have sufficient rear vision via their mirrors, particularly where overtaking vehicles are concerned.

A value of about five times L_{in} is sufficient and the length of this lighting zone in metres should roughly be equal to the traffic speed in kilometres per hour. In a two-way tunnel the threshold zone lighting for the opposing traffic will provide the recommended luminance.

When a one-way tunnel is likely to be used in two directions (for example during maintenance) provision may be required for additional lighting but this will usually be related to traffic travelling at reduced speed through a traffic management area.

11 Daytime uniformity ratio of luminance

Overall and longitudinal uniformities of road surface luminance are defined in BS 5489-1. The overall uniformity over the traffic lanes in all zones of a tunnel and under every stage of lighting except that at night should be not less than 0.4. The longitudinal uniformity along each traffic lane should be not less than 0.6. If these values of uniformity are met, then the uniformity of the lighting on the walls is likely also to be satisfactory.

12 Lighting during the night

12.1 Lighting in the tunnel

The maintained average road surface luminance at night should be reduced to between 2 cd/m² and 5 cd/m².

In some cases, though, it may not be possible to achieve a value as low as 5 cd/m² because of the practical considerations involved in complying with other recommendations in this standard; for example, to avoid flicker effects it may be necessary to reduce luminaire spacing to a value which gives an average luminance greater than 5 cd/m². A higher luminance than 5 cd/m² is permissible, but 12.2 should be noted. If a tunnel is unfit for traffic then consideration should be given to safety lighting at night for pedestrian use and for breakdowns.

These recommendations assume that the approach roads to the tunnel are lit. If, for a particular reason, they are not, e.g. from environmental considerations, then the road surface luminance in the tunnel at night should be 1 cd/m². This is to avoid a "black hole effect" on leaving the tunnel. Drivers should be advised to keep their headlights on.

12.2 Lighting on the approach roads

If the tunnel is lit at night, the approach roads on either side should, unless there is a special reason, be lit for a distance of at least 200 m to an average road surface luminance which meets the recommendations of BS 5489-2 (see Table 5 where the values are reproduced from BS 5489-2).

Table 5 — Lighting requirements for traffic routes

Category	Maintained average luminance $\bar{L}_{cd}/m^2$	Overall uniformity ratio U_O	Longitudinal uniformity ratio U_L	Examples
2/1	1.5	0.4	0.7	High speed roads Dual carriageway roads
2/2	1.0	0.4	0.5	Important rural and urban traffic routes Radial roads District distributor roads (see BS 6100)
2/3	0.5	0.4	0.5	Connecting, less important roads Local distributor roads Residential area major access roads

The approach road luminance should, however, be greater than one-third of that in the tunnel. If the luminance is less than one-third, then the photometric requirements of a higher lighting category should be used to determine the luminance of the approach roads over a distance of 200 m from either portal. If the luminance for category 2/1 (i.e. 1.5 cd/m^2) is still too low, then the average road luminance should be increased until it is equal to one-third of the average luminance in the tunnel. The necessary luminaire spacing can be calculated using the method described in BS 5489-2. In such cases, the higher level of lighting over the 200 m of either approach road will act as a transition between the normal road lighting and the tunnel lighting.

12.3 Uniformity ratio of night-time tunnel lighting

Overall and longitudinal uniformities should not be less than those values recommended for the lighting of the approach roads. For longitudinal uniformity the observer's distance towards the centre of the road should be $W_k/4$ m from the nearside kerb (where W_k is the road width). If these values of uniformity on the road are met, then the uniformity of the lighting on the walls is also likely to be satisfactory.

If the approach roads are not lit, then the uniformities of the road surface luminance in the tunnel should be not less than those recommended for category 2/2 (see Table 5 where the values are reproduced from BS 5489-2).

13 Transition between day and night lighting

The highest level of lighting provided in the threshold and transition zones will be necessary only when the highest ambient luminances occur at the tunnel portal and its surroundings. At lower ambient luminances, and in particular at dusk, the tunnel entrance lighting needs to be reduced towards the level recommended in clause 12 for operation at night.

Conversely, the lighting should be increased at dawn.

The change should be effected in stages, the number of stages depending on the luminance in the threshold zone; the higher this luminance is, the greater the number of stages needed. It is recommended that a close, rather than a coarse, following of the change in ambient lighting be adopted. Although an instantaneous reduction of luminance level in the threshold and transition zones by a factor of five is acceptable visually, present-day practice favours smaller reductions in several stages for economic reasons as well as for reasons of greater visual comfort.

The switching stages should therefore be arranged to give the optimum arrangement so that the energy costs are reduced and the wiring costs are not excessive. Ideally, the more the steps, the greater the energy saving. In particular, it should be noted that more than half the electrical load will be attributable to the two maximum stages if the switching ratio is 3 : 1. Running costs should be weighed against the cost of extra switching equipment to provide a greater number of smaller reductions. Typical stages of lighting in the threshold and transition zones are, therefore:

- full daytime 100 %
- 50 % to 65 %
- 25 % to 35 %