

Code of practice for the design of road lighting —

Part 2: Lighting of tunnels

ICS 93.080.40

Committees responsible for this British Standard

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- Chartered Institution of Building Services
- Council for the Protection of Rural England
- County Surveyors' Society
- Department of Transport, Local Government and the Regions — Construction Directorate
- Department of Transport, Local Government and the Regions — Highways Agency
- General Aviation Awareness Council
- Institution of Electrical Engineers
- Institution of Lighting Engineers
- Institution of Mechanical Engineers
- Lighting Industry Federation Ltd
- Scottish Office — Construction and Building
- Co-opted members

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Contents

Committees responsible	Inside front cover
Foreword	ii
1 Scope	1
2 Normative references	1
3 Terms, definitions and symbols	1
4 Tunnel conditions	5
5 Tunnel lighting design	6
6 Calculation and measurement	13
Annex A (informative) Tunnel design, use and operational aspects that affect tunnel lighting design	16
Annex B (informative) Lighting systems	17
Annex C (normative) Daytime lighting of short tunnels	18
Annex D (normative) Determination of access zone luminance by direct measurement	22
Annex E (normative) Determination of access zone luminance by the grid method	23
Annex F (informative) Estimation of the access zone luminance	25
Annex G (informative) Uncertainty in measurement of illuminance	27
Bibliography	29
Figure 1 — Tunnel lighting class selection	7
Figure 2 — Luminance reduction curve	9
Figure 3 — Interior zone measurement positions	15
Figure B.1 — Symmetrical lighting system	17
Figure B.2 — Counterbeam lighting system	18
Figure C.1 — Look-through percentage	19
Figure C.2 — Visual angles	19
Figure C.3 — Visibility of a car	21
Figure C.4 — Visibility of a pedestrian/bicyclist	21
Figure E.1 — Perspective view of a tunnel entrance with superimposed 20° subtense circle	24
Figure E.2 — 20° field of view divided into assessment areas	24
Figure F.1 — Examples of tunnel approaches giving access zone luminances to be used	26
Table 1 — Stopping distances for various design speeds	6
Table 2 — Traffic flow	7
Table 3 — Values of k for different speed limits and tunnel lighting classes	8
Table 4 — Road surface luminance of the interior zone	10
Table 5 — Uniformity of the road surface luminance	10
Table C.1 — Transverse position of object and observer	20
Table E.1 — Typical luminance values	25
Table E.2 — Example of determination of access zone luminance, L_{20}	25
Table G.1 — Typical uncertainties in parameters and examples of their effect on illuminance values	28

Foreword

This part of BS 5489 has been prepared by Technical Committee CPL/34/8. BS 5489-2:2003+A1:2008 supersedes BS 5489-2:2003, which is withdrawn.

The start and finish of text introduced or altered by Amendment No. 1 is indicated in the text by tags **A1** **A1**.

The revision and consolidation of BS 5489 has been carried out following the publication of BS EN 13201, which has resulted in a need to withdraw many clauses of the formerly separate parts of BS 5489, and to adapt many remaining clauses to the technical requirements and terminology of the European Standard.

This new edition of BS 5489 contains guidance and recommendations that are intended to support BS EN 13201 and to enable designers of lighting systems to comply with that standard. The new edition of BS 5489 consists of two parts only:

- a) BS 5489-1, which gives guidance and recommendations for the lighting of roads and public amenity areas;
- b) BS 5489-2, which gives guidance and recommendations for the lighting of tunnels.

This new edition of this part of BS 5489 has been introduced following a full review, and is based on material from the CEN report CR 14380. In particular, it follows the principles of Annex A.2 of that report, which takes account of traffic flow and type of traffic in determining the lighting requirements. It also uses the method of determining the lighting requirements of short tunnels described in Annex A.5 of the CEN report.

In relation to carriageway luminance and the lighting on approach roads to tunnels, it takes account of the recommendations of BS EN 13201.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 29 and a back cover.

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1 Scope

This part of BS 5489 gives recommendations on the design of the lighting of tunnels for motorized and mixed traffic. It is applicable to all types of road including motorways.

It gives recommendations for those aspects of lighting that are concerned with traffic safety, such as arrangements, levels and other parameters including daylight. It does not give recommendations for aspects of lighting that concern visual comfort.

This part of BS 5489 excludes the lighting of underpasses or subways reserved for pedestrians or cyclists, which is covered in BS 5489-1.

NOTE This part of BS 5489 is based on photometric considerations, and all values of luminance and illuminance are maintained values.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 667, *Illuminance meters — Requirements and test methods*.

BS 7920, *Luminance meters — Requirements and test methods*. ^[A1]

BS EN 12665, *Light and lighting — Basic terms and criteria for specifying lighting requirements*.

BS EN 13201-2, *Road lighting — Part 2: Performance requirements*.

BS EN 13201-3:2003, *Road lighting — Part 3: Calculation of performance*.

BS EN 13201-4, *Road lighting — Part 4: Methods of measuring lighting performance*.

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this part of BS 5489, the terms and definitions given in BS EN 12665, BS EN 13201-2, BS EN 13201-3 and the following apply.

3.1.1

access zone

part of the open road immediately outside (in front of) an entrance portal, covering the distance over which an approaching driver should be able to see into a tunnel

3.1.2

access zone length

distance between the stopping distance point ahead of an entrance portal, and the entrance portal itself

3.1.3

access zone luminance

average luminance contained in a conical field of view, subtending an angle of 20° with the apex at the position of the eye of an approaching driver and aimed at the centre of the entrance portal

NOTE Access zone luminance is assessed from a point at a distance equal to the stopping distance from the entrance portal at the middle of the relevant carriageway or traffic lane.

3.1.4

carriageway

part of a road normally used by vehicular traffic

3.1.5

contrast revealing coefficient

ratio between road surface luminance and illuminance on a vertical plane facing oncoming traffic and at a height of 0.2 m above the road surface, at a given point in a tunnel

3.1.6

counterbeam lighting

lighting comprising luminaires the luminous intensity distribution of which is asymmetrical in a plane parallel to the tunnel axis and the main beam of which is directed towards oncoming traffic in a tunnel

3.1.7

daylight screen

device that transmits (part of) the ambient daylight

NOTE Daylight screens may be applied for the lighting of the threshold zone of a tunnel.

3.1.8

design speed

speed adopted for a particular stated purpose in designing a road

3.1.9

emergency lane

lane parallel to the traffic lane(s), not destined for normal traffic, but for emergency (police) vehicles and/or for broken-down vehicles

NOTE An emergency lane is commonly referred to as a “hard shoulder”.

3.1.10

entrance portal

part of the tunnel construction that corresponds to the beginning of the covered part of a tunnel or, when open daylight screens are used, to the beginning of the daylight screens

3.1.11

entrance zone

combination of threshold zone and transition zone(s)

3.1.12

exit portal

end of the covered part of a tunnel or, when open daylight screens are used, end of the daylight screens

3.1.13

exit zone

part of a tunnel where, during daytime, the vision of a driver approaching the exit is influenced predominantly by the brightness outside the tunnel

NOTE The exit zone stretches from the end of the interior zone to the exit portal of the tunnel.

3.1.14

interior zone

part of a tunnel following directly after the transition zone

NOTE The interior zone stretches from the end of the transition zone to the beginning of the exit zone.

3.1.15

interior zone luminance

average road surface luminance of a transverse strip at a given location in the interior zone of a tunnel

3.1.16

look-through percentage

area of the apparent exit portal of a tunnel, as a percentage of the area of the apparent entrance portal, when viewed in perspective from the stopping distance

3.1.17

mixed traffic

traffic that consists of motor vehicles, cyclists, pedestrians etc.

3.1.18

overall uniformity

ratio of the lowest to the average road surface luminance

3.1.19**parting zone**

first part of the open road directly after the exit portal of a tunnel

NOTE The parting zone is not a part of the tunnel, but it is closely related to the tunnel lighting. The parting zone begins at the exit portal.

3.1.20**speed limit**

maximum legally allowed speed on any given road

3.1.21**stopping distance**

distance needed to bring a vehicle, driving at design speed, to a complete standstill

3.1.22**symmetrical lighting**

lighting comprising luminaires the luminous intensity distribution of which is symmetrical in a plane parallel to the tunnel axis

3.1.23**threshold zone**

first part of a tunnel, directly after the entrance portal

NOTE The threshold zone begins at the entrance portal.

3.1.24**threshold zone lighting**

lighting of the threshold zone of a tunnel, which allows drivers to see into the tunnel whilst in the access zone

3.1.25**threshold zone luminance**

average road surface luminance of a transverse strip at a given location in the threshold zone of a tunnel

3.1.26**threshold zone luminance ratio**

ratio between the threshold zone luminance and the access zone luminance at a given point in a tunnel

3.1.27**traffic flow**

number of vehicles passing a specific point in a stated time in a stated direction

3.1.28**traffic lane**

strip of carriageway intended to accommodate a single line of moving vehicles

3.1.29**transition zone**

part of a tunnel following directly after the threshold zone

NOTE The transition zone stretches from the end of the threshold zone to the beginning of the interior zone. In the transition zone, the lighting level is decreased from the level at the end of the threshold zone to the level of the interior zone.

3.1.30**transition zone luminance**

average road surface luminance of a transverse strip at a given location in the transition zone of a tunnel

3.1.31**visual guidance**

optical and geometrical means of providing drivers with information on the course of the road in a tunnel

3.2 Symbols

Ⓐ For the purposes of this part of BS 5489, the following symbols apply.

A	area of a segment on a perspective view of a tunnel entrance
E_w	maintained wall illuminance, in lux (lx)
f	focal length of camera lens, in millimetres (mm)
H	height of tunnel entrance portal, in metres (m)
H_L	mounting height of luminaire, in metres (m)
h	height of printed film negative, in millimetres (mm)
I_w	luminous intensity in direction of point on wall, in candelas per kilolumen (cd/klm)
k	ratio of threshold zone luminance to access zone luminance
L	luminance, in candelas per square metre (cd/m ²)
L_{in}	interior zone luminance, in candelas per square metre (cd/m ²)
L_{th}	threshold zone luminance, in candelas per square metre (cd/m ²)
L_{tr}	transition zone luminance, in candelas per square metre (cd/m ²)
L_v	equivalent veiling luminance, in candelas per square metre (cd/m ²)
L_w	maintained wall luminance, in candelas per square metre (cd/m ²)
L_{20}	access zone luminance, in candelas per square metre (cd/m ²)
LTP	look-through percentage
MF	maintenance factor
P	height of calculation point on wall above road surface, in metres (m)
q_c	contrast revealing coefficient
SD	stopping distance, in metres (m)
TI	threshold increment, as a percentage (%)
t	time, in seconds (s)
U_l	longitudinal uniformity
U_o	overall uniformity of road surface luminance
α	angle between vertical plane containing the incident light path and the vertical plane at right angles to the wall, in degrees (°)
α_i	visual angle for an apparent entrance portal in the vertical plane, in degrees (°)
α_u	visual angle for an apparent exit portal in the vertical plane, in degrees (°)
β_i	visual angle for an apparent entrance portal in the horizontal plane, in degrees (°)
β_u	visual angle for an apparent exit portal in the horizontal plane, in degrees (°)
ε	angle of incidence of light to the horizontal plane, in degrees (°)
θ_H	angle subtended by tunnel height, in degrees (°)
θ_P	angular height of print, in degrees (°)
ρ_{dif}	diffuse reflection factor of wall
Φ	initial luminous flux of the lamp or lamps in luminaire, in kilolumens (klm) Ⓐ

4 Tunnel conditions

4.1 General

NOTE 1 Information on tunnel design, use and operational aspects that affect tunnel design is given in Annex A.

Road and traffic conditions in tunnels can differ considerably from those that prevail on the open road. The design of tunnel lighting installations should take these different conditions into account, particularly with regard to traffic safety.

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.

Driving comfort is an important aspect of the quality of the lighting installations of road traffic tunnels. As a result of feelings of anxiety, drivers are likely to slow down near a tunnel entrance. Sudden drops in speed reduce traffic capacity and might lead to traffic jams and possibly to accidents. A lighting system that helps to overcome any feeling of anxiety can improve traffic safety, increase road capacity and improve driving comfort.

The difficulty of the driving task when approaching and passing through a tunnel is influenced by the speed, the volume (flow) and the composition of the traffic and by the layout of the road and the tunnel and their immediate surroundings.

The tunnel lighting class and lighting levels are affected by the traffic flow, and the type and mix of traffic, and should be determined in accordance with Clause 5.

NOTE 2 Information on different lighting systems is given in Annex B.

4.2 Daytime conditions

The major difference between tunnel lighting and conventional road lighting is in the need for lighting by day. A driver needs to 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 a tunnel, drivers’ 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 steadily reduced until it reaches the constant level in the tunnel interior zone. On emerging from a tunnel into daylight the eye adapts far more quickly to the higher luminance level.

Similarly, rearward visibility should be maintained when leaving a tunnel, to facilitate safe manoeuvres within the parting zone.

The lighting of a tunnel should be sufficient to:

- avoid the “black hole effect” when a driver is unable to see into the tunnel;
- reduce the likelihood of a collision with another vehicle (or bicycle or pedestrian);
- enable a driver to react and stop within the stopping distance *SD* (see 5.1) if an unexpected hazard appears;
- provide visual guidance.

4.3 Night-time conditions

During night-time the “black hole effect” does not exist, as the external luminance values are low. Lower lighting levels are needed in the tunnel than during daytime, with all zones treated in the same manner. (See 5.7.)

4.4 Lighting for different tunnel lengths

Lighting design for long and short tunnels differs according to the degree to which an approaching driver can see through the tunnel to the exit portal from a point at a distance equal to the stopping distance in front of the entrance portal.

The ability of a driver to see through a tunnel depends primarily on the length of the tunnel, although other design parameters also have an effect (width, height, horizontal and/or vertical curvatures, etc.).

The critical factor is whether approaching drivers can see vehicles, other road users or obstacles when their distance from the entrance portal is less than or equal to the stopping distance *SD* (see 5.1). When the exit portal is a large part of the scene visible through the entrance, other road users and objects can easily be seen silhouetted against the lighter scene behind the exit portal. On the other hand, artificial lighting is needed when the exit portal is in a relatively large dark frame, in which objects can be hidden. This can happen when a tunnel is relatively long in relation to width, or when a tunnel is curved in such a way that only a part of the exit can be seen or the exit cannot be seen at all.

Tunnels shorter than 25 m do not normally need daytime lighting. Tunnels longer than 200 m should always have artificial daytime lighting, to avoid adaptation problems for road users. For tunnels of length between 25 m and 200 m, the method described in Annex C should be used to determine if daytime lighting is needed. If full daytime lighting is needed, it should conform to the recommendations given in Clause 5.

If full daytime lighting is not needed for tunnels of length between 25 m and 200 m, some limited daytime lighting can be provided for tunnels where the traffic flow is classified as “high” (see 5.2), when luminance levels within the tunnel are low, and during the periods immediately before dusk and after dawn, particularly on overcast days. The decision to provide such limited daytime lighting is a matter for the highway authority.

NOTE The night-time lighting as described in 5.7 may be used for this purpose. It can be controlled by a photocell so that it is switched on when illuminance on the road surface at the centre of the tunnel falls to the value at which the external illuminance is used to switch on the access road lighting, and switched off when the illuminance at the centre of the tunnel increases to this level. Alternatively, a luminance meter can be used as described in 5.10, Note 2.

5 Tunnel lighting design

5.1 Determination of stopping distance

The stopping distance *SD* should be taken from Table 1, relative to the speed of the tunnel.

Table 1 — Stopping distances for various design speeds

Design speed ^a km/h	Stopping distance (<i>SD</i>) m
120	215
100	160
85	120
70	90
60	70
50	50
NOTE These values are extracted from Volume 6, Section 1, Part 1 of the Highways Agency publication DMRB TD9/93 [1].	
^a The design speed is that which is applicable to normal usage of the tunnel. In abnormal usage, such as contraflow operation, the design speed does not apply.	

5.2 Tunnel lighting classification

The tunnel lighting classification should be based on the characteristics of the tunnel’s known usage (for existing tunnels) or projected usage (for new tunnels). The main influencing factors are:

- traffic flow;
- traffic type and mix;
- visual guidance.

Traffic flow should be classified as high, medium or low using Table 2.

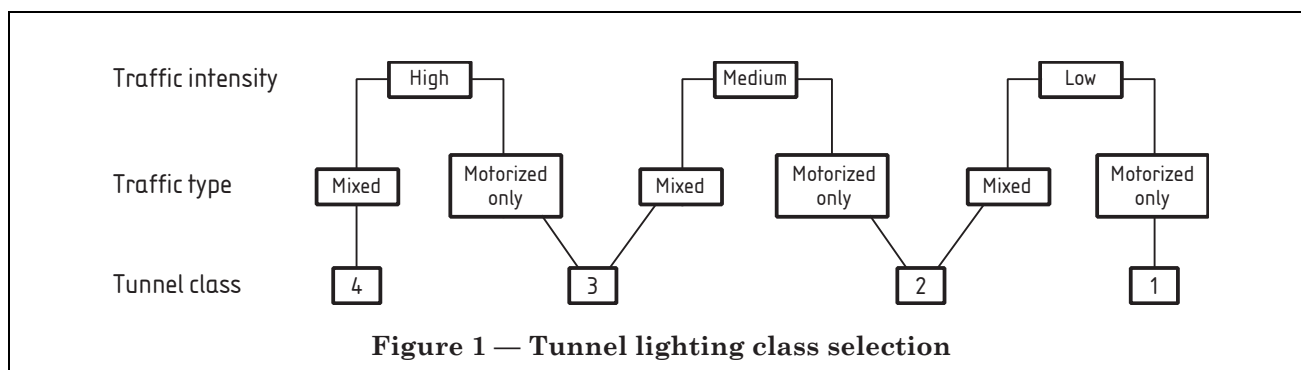
Table 2 — Traffic flow

Traffic flow category	Volume/rate of flow ^a	
	One-way traffic	Two-way traffic
High	>1 500	>400
Medium	500 to 1 500	100 to 400
Low	<500	<100

NOTE If the actual value is not known, peak hour traffic can be derived as follows. Average daily traffic (ADT, vehicles per day) is the most used concept in traffic planning and it is always known. Peak hour traffic (vehicles per hour) is in rural areas 10 % and in urban areas 12 % of ADT. On undivided roads, the number of vehicles per hour per lane can be calculated by dividing peak hour value by the total number of lanes. If the actual directional distribution is not known on dual carriageway roads, it can be assumed that the worst case direction carries two thirds of the traffic flow. The higher flow is then divided by the number of lanes of this carriageway.

^a Vehicles per hour per lane during peak hour.

The appropriate class of tunnel lighting should be determined from Figure 1, which takes into account the traffic flow category and whether traffic is mixed or motorized only.



5.3 Determination of access zone luminance

In order to determine the necessary daytime lighting levels within a tunnel, the access zone luminance should first be determined, in order to determine the threshold zone luminance and the luminance in the other zones.

There are two methods of determining access zone luminance L_{20} . Whenever possible direct measurement at the site should be used, as described in Annex D.

Where direct measurement is not possible, the grid method should be used, as described in Annex E.

A method of estimating L_{20} may be used to provide an interim value for provisional design purposes, but should not be used for the final design.

NOTE 1 The method given in Annex D is preferable, particularly when the orientation of the tunnel is likely to produce different results for each approach.

NOTE 2 A method of estimating L_{20} is given in Annex F.