

BS 5489-2:2016



BSI Standards Publication

Code of practice for the design of road lighting — Part 2: Lighting of tunnels

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Published by BSI Standards Limited 2016

ISBN 978 0 580 85616 7

ICS 93.080.40

The following BSI references relate to the work on this document:

Committee reference EL/1/3

Draft for comment 15/30296173 DC

Publication history

First published September 1974

Second edition March 1987

Third edition August 1992

Fourth edition December 2003

Fifth (present) edition April 2016

Amendments issued since publication

Date	Text affected
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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.

Foreword

Publishing information

This part of BS 5489 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30 April 2016. It was prepared by Subcommittee EL/1/3, *Tunnel lighting*, under the authority of Technical Committee EL/1, *Light and lighting*. A list of organizations represented on these committees can be obtained on request to their secretary.

Supersession

This part of BS 5489 supersedes BS 5489-2:2003+A1:2008, which is withdrawn.

Relationship with other publications

BS 5489 consists of two parts:

- Part 1: *Lighting of roads and public amenity areas*;
- Part 2: *Lighting of tunnels*.

Information about this document

This is a full revision of the standard to align the standard with current best practice.

The aim of this standard is to promote wider understanding of the lighting of tunnels for motorized and mixed traffic and to give guidance on the design decisions that need to be made. It contains recommendations that are essential to the design process and that will enable production of designs that are appropriate and justifiable.

Use of this document

As a code of practice, this part of BS 5489 takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this part of BS 5489 is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the preparation of this part of BS 5489 that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

The design of lighting for tunnels is a complex process with many different aspects and therefore it is important that this standard is read thoroughly to ensure that all relevant issues are taken into account.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

The word "should" is used to express recommendations of this standard. The word "may" is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the clause. The word "can" is used to express possibility, e.g. a consequence of an action or an event.

Notes and commentaries are provided throughout the text of this standard. Notes give references and additional information that are important but do not form part of the recommendations. Commentaries give background information.

Contractual and legal considerations

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.

1 Scope

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

This standard is applicable to those aspects of lighting that are concerned with traffic safety, such as arrangements, levels and other parameters including daylight.

This standard is not applicable to aspects of lighting that concern aesthetics.

This part of BS 5489 is not applicable to the lighting of underpasses or subways reserved for pedestrians or cyclists, which is covered in BS 5489-1.

NOTE 1 This part of BS 5489 is based on photometric considerations, and all values of luminance and illuminance are maintained levels.

NOTE 2 In this standard "lamp" and "lamps" also include LED light sources.

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*

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 13201-3:2015, *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 in front of an entrance portal, covering the distance over which an approaching driver can see into a tunnel

3.1.2 access zone length

distance between the stopping sight 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 sight distance from the entrance portal and 1.5 m above 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
- 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 intended 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 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 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 sight 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 sight 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 traffic flow**
number of vehicles passing a specific point in a stated time in a stated direction
- 3.1.27 traffic lane**
strip of carriageway intended to accommodate a single line of moving vehicles
- 3.1.28 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.
- 3.1.29 transition zone luminance**
average road surface luminance of a transverse strip at a given location in the transition zone of a tunnel
- 3.1.30 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
SSD	stopping sight 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(s) in luminaire, in kilolumens (klm)

4 Tunnel conditions

4.1 General

COMMENTARY ON 4.1

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. Lighting can prevent any feeling of anxiety and 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 external lighting conditions, the speed, volume (traffic flow) and composition of the traffic, the layout of the approach road and the tunnel, and the immediate surroundings.

Tunnels should be classified according to the traffic flow, and the type and mix of traffic, in accordance with 5.2.

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

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

4.2 Daytime conditions

COMMENTARY ON 4.2

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 needs to be a sufficiently high lighting level to maintain visibility. If the lighting level is not high enough, the driver might be unable to see into the tunnel, the so-called "black hole effect".

During approach and entry to a tunnel, drivers' eyes adapt 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.

The lighting of a tunnel should be sufficient to:

- a) avoid the "black hole effect" when a driver is unable to see into the tunnel;
- b) reduce the likelihood of a collision with another vehicle (or cyclist or pedestrian);
- c) enable a driver to react and stop within the stopping sight distance, SSD (see 5.1), if an unexpected hazard appears;
- d) provide visual guidance.

For tunnels longer than 200 m, the lighting design should be designed in accordance with Clause 5. For shorter tunnels, the recommendations in 4.4 should be followed.

A linear lighting system or illuminated road studs can reinforce visual guidance. However, lighting levels should not be reduced.

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 than during daytime should be used in the tunnel, with all zones treated in the same manner (see 5.7).

4.4 Daytime lighting of short tunnels

COMMENTARY ON 4.4

Lighting design for 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 sight 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 sight distance. 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, when the exit portal is in a relatively large dark frame, other road users and 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. For tunnels of length between 25 m and 200 m, the method described in Annex C should be used to determine what daytime lighting is needed, if any. If full daytime lighting is needed, it should be in accordance with Clause 5.

NOTE A tunnel of length 200 m or less is a short tunnel.

5 Tunnel lighting design

5.1 Determination of stopping sight distance

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

Table 1 **Stopping sight distances for various design speeds**

Design speed ^{A)}	Stopping sight distance (<i>SSD</i>)
km/h	m
120	215
100	160
85	120
70	90
60	70
50	50

^{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.

NOTE 1 These values are extracted from Volume 6, Section 1, Part 1 of the Highways Agency publication DMRB TD9/93 [1]. At the time of publication of this standard, TD9/93 is undergoing revision.

NOTE 2 Where a speed limit of 20 mph applies, *SSD* can be taken as 35 m.

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 design should take account of the following influencing factors:

- a) traffic flow;
- b) traffic type and mix;
- c) visual guidance.

Traffic flow should be classified as high, medium or low in accordance with the values in Table 2.

Table 2 Traffic flow

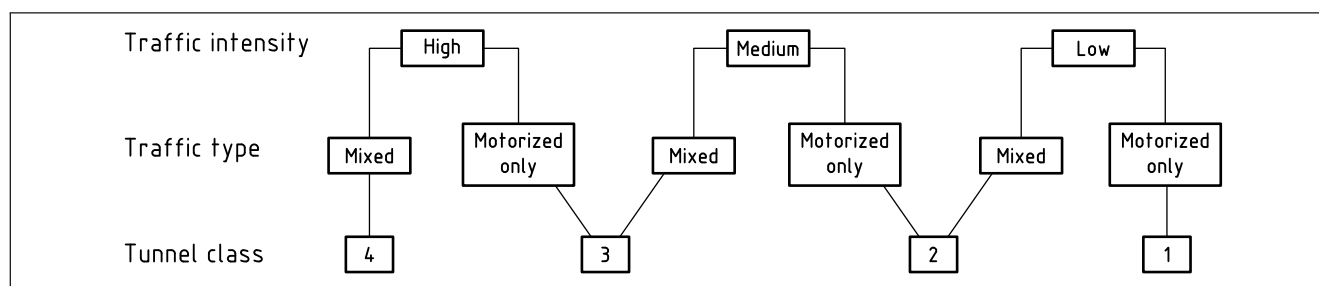
Traffic flow category	Volume/rate of flow ^{A)}	
	One-way traffic	Two-way traffic
High	>1 500	>400
Medium	500 to 1 500	100 to 400
Low	<500	<100

^{A)} Vehicles per hour per traffic lane during peak hour.

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 traffic lane can be calculated by dividing peak hour value by the total number of traffic 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 traffic lanes of this carriageway.

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.

Figure 1 Tunnel lighting class selection



5.3 Determination of access zone luminance

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

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 E.

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

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 F 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 G.

5.4 Determination of tunnel zone daytime lighting levels

5.4.1 Threshold zone

The road surface luminance of the threshold zone should be derived from the luminance of the access zone during daytime. The length of the threshold zone is equal to the stopping sight distance, SSD .

The threshold zone luminance L_{th} should be provided during daytime from the beginning of the threshold zone for a length of $0.5 SSD$ (see Figure 2). The appropriate value of k should be selected from Table 3, and the threshold zone luminance L_{th} should be calculated using equation (1).

$$L_{th} = k \times L_{20} \quad (1)$$

NOTE As the relative size of the entrance portal in the field of view is dependent on the access zone length, which in turn is dependent on the design speed, the value of k is dependent on the design speed. Furthermore, in order to reflect different tunnel traffic conditions, k is also dependent on traffic flow and type, which affect the tunnel lighting class, as shown in 5.2.

Table 3 Values of k for different speed limits and tunnel lighting classes

Tunnel lighting class	k value		
	Speed limit up to 40 mph	Speed limit 50 mph to 60 mph	Speed limit 70 mph
4	0.05	0.06	0.10
3	0.04	0.05	0.07
2	0.03	0.04	0.05
1	—	—	—

From half the stopping sight distance, SSD , onwards, the lighting level should gradually and linearly decrease to a value, at the end of the threshold zone, equal to $0.4L_{th}$. The gradual reduction over the last half of the threshold zone may also be in steps. However, the luminance level should not fall below the values corresponding to a gradual linear decrease.

5.4.2 Transition zone

In the transition zone, the average road surface luminance should be gradually reduced from the threshold zone towards the interior zone. At any position in the transition zone, the transition zone luminance L_{tr} should be not less than the luminance derived from Figure 2.

NOTE The transition zone starts at the end of the threshold zone ($t = 0$).

5.4.3 Interior zone

The average value of interior zone road surface luminance L_{in} should be not less than the value shown in Table 4 for the appropriate tunnel lighting class.