British Standard

BRITISH STANDARD

BS 5649-7: 1985

Lighting columns —

Part 7: Method for verification of structural design by calculation

UDC [624.971:628.971]:624.04

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Road Engineering Standards Committee (RDB/-) to Technical Committee RDB/28 upon which the following bodies were represented:

Aluminium Federation
British Precast Concrete Federation Ltd.
British Steel Industry
Cement and Concrete Association
County Surveyor's Society
Department of Transport
Design Council
Electricity Supply Industry in England and Wales
Institution of Highways and Transportation
Institution of Mechanical Engineers
Institution of Municipal Engineers
Institution of Public Lighting Engineers
Lighting Column Manufacturers' Association
Lighting Industry Federation Ltd.

This British Standard, having been prepared under the direction of the Road Engineering Standards Committee, was published under the authority of the Board of BSI and comes into effect on
30 August 1985

The following BSI references relate to the work on this standard:
Committee reference RDB/28
Draft for comment 77/10155 DC

ISBN 0 580 14461 5

Amendments issued since publication

Amd. No.	Date of issue	Comments

Contents

Foreword

This Part of BS 5649 has been prepared under the direction of the Road Engineering Standards Committee. BS 5649 has been produced in Parts as the Parts of EN 40 have been produced by the European Committee for Standardization Technical Committee CEN/TC 50, Lighting columns and spigots.

BS 5649 consists of the following Parts:

— *Part 1: Definitions and terms*;

— *Part 2: Dimensions and tolerances*;

— *Part 3: Specification for materials and welding requirements*;

— *Part 4: Recommendations for surface protection of metal lighting columns*;

— *Part 5: Specification for base compartments and cableways*;

— *Part 6: Specification for design loads*;

— *Part 7: Method for verification of structural design by calculation*;

— *Part 8: Method for verification of structural design by testing;*

— *Part 9: Specification for special requirements for reinforced and prestressed concrete columns*.

CEN/TC 50, however, were unable to agree on a final version of Part 7 "Method for verification of structural design by calculation" and instead had to produce a Unification Report[1)], which give details of the sections of the draft Part 7 where agreement had been reached and highlighted the areas of difference. The British Standards Committee has therefore independently produced this Part of BS 5649. In doing so, the areas that obtained European agreement have been fully incorporated. The remainder of the document contains the information that the UK delegation of CEN/TC 50 supported, augmented with a limited amount of additional design criteria for door openings that has recently become available from research projects.

The method of calculation described in this standard is based on the principles contained in ISO 2394-1973 published by the International Organization for Standardization (ISO). ISO 2394 introduced the concept of limit state design where factored loading effects are compared with the relevant resistance of the structure.

BS 5649 has been issued in Parts as they were completed and approved, and until the nine Parts were published it was not possible to supersede the present British Standards for lighting columns. As the Parts were issued, recommendations were given for their implementation together with a list of clauses in the existing standards which they would eventually supersede. With the publication of this Part, the new standard is complete, and all Parts of the existing standards can be superseded after a suitable transition period.

[1)] Subsequently published as CEN Report CR 40-7 (May 1984) "Lighting columns, — verification of structural design by calculation".

The British Standards affected by BS 5649 are BS 1308, BS 1840 and BS 3989, specifications for concrete, steel and aluminium street lighting columns, respectively. It is anticipated that BS 1840 and BS 3989 will be withdrawn one year from the publication of this Part of this standard and that BS 1308 will be withdrawn three years from the publication of this Part of this standard.

In the interim period it is permissible for lighting columns to be specified to comply with either BS 1308, BS 1840, BS 3989 or BS 5649. Purchasers specifying lighting schemes during the interim period should, where possible, permit either alternative.

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.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 16, 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.

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1 Scope

This Part of BS 5649 describes the criteria to be used when verifying the structural design of a lighting column by calculation. It applies to steel and aluminium columns complying with BS 5649-3 and to concrete columns complying with BS 5649-9.

It applies to post top columns ≤ 20 m nominal height and to columns with brackets ≤ 18 m nominal height.

The calculations are applicable to circular cross sections and regular polygonal cross sections of not less than eight sides.

NOTE 1 Any changes to the calculations required because of the use of other cross sections are outside the scope of this standard and should be agreed between the purchaser and the supplier.

NOTE 2 Care should be taken when applying the formulae detailed in this standard as they include a factor, where appropriate, to produce an answer in the units specified. To assist reference, the major equations are numbered (1) to (14).

The structural design of a lighting column can be verified by calculation in accordance with this Part of BS 5649 or, if the manufacturer considers it necessary it can be verified by testing (see BS 5649-8).

NOTE 3 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 5649, the definitions given in BS 5649-1 apply.

3 Symbols

The following symbols are used in this Part of BS 5649. The definitions are abbreviated, the full definitions being given in the text.

a	Overall length of door opening.
a_s	Area of legs of closed hoops at a section.
A_e	Effective cross-sectional area of door reinforcement.
A_s	Cross-sectional area of door reinforcement.
b	Mean dimension of flat side of a polygonal section.
b_o	Mean dimension of flat side at edge of door opening.
B_x	Factor.
B_y	Factor.
C	Length of halves of straight edge of door opening.
d	Diameter of cross section.
d_l	Mean diameter of hoop reinforcement.
d_o	Diameter of central bore.
d_w	Width of door reinforcement.
E	Modulus of elasticity.
F	Factor.
g	Factor.
G	Modulus of rigidity.
h	Nominal height of lighting column.
L	Effective length of door opening.
m_{ox}	Distance from centroid of door reinforcement measured normal to the x-x axis.
m_{oy}	Distance from centroid of door reinforcement measured normal to the y-y axis.
m_x	Distance from centre of column wall at the door opening measured normal to the x-x axis.
m_y	Distance from centre of column wall at the door opening measured normal to the y-y axis.
M_p	Combined bending moment for closed regular cross section.
M_{up}	Bending strength for closed regular cross section.
M_{ux}	Bending strength about x-x axis.
M_{uy}	Bending strength about y-y axis.
M_x	Bending moment about x-x axis.
M_y	Bending moment about y-y axis.
N	Corner radius of door opening.
P	Factor.
R	Mean radius of cross section.
s	Longitudinal spacing of hoops.
S	Length of end connection of door reinforcement.
t	Wall thickness.
t_o	Lesser of t and t_w.
t_w	Thickness of reinforcement.
T_p	Torsional moment.
T_u	Torsional strength.
v	Radius of gyration of door reinforcement.
w	Bracket projection.
Z_p	Plastic modulus of closed regular cross section.
Z_{pn}	Plastic modulus of unreinforced door opening cross section about n-n axis.
Z_{py}	Plastic modulus of unreinforced door opening cross section about y-y axis.
Z_{pnr}	Plastic modulus of reinforced door opening cross section about n-n axis.
Z_{pyr}	Plastic modulus of reinforced door opening cross section about y-y axis.

γ_f Partial load factor.

γ_m Partial material factor.

θ Half angle of door opening.

π Constant = 3.1416.

ρ Factor.

σ_c Effective compressive strength of concrete at transfer of prestress.

σ_s Characteristic strength of material.

σ_t Characteristic shear strength.

σ_p Stress on cross section from prestressing force after taking account of prestressing losses.

ϕ_1 to ϕ_7 Factors as defined in text.

4 Basis of calculations

The approach to calculations used in this standard is based on limit state principles, where factored load effects are compared with the relevant resistance of the structure; two limit states shall be considered.

a) The ultimate limit state, which corresponds to the load-carrying capacity of the column.

b) The serviceability limit state, which relates to the deflection of the column in service.

NOTE In following this approach, simplifications appropriate to lighting columns have been adopted. These are:

1) the number of separate partial safety factors have been reduced to a minimum;

2) serviceability partial safety factors have been eliminated as these all have a value equal to unity.

5 Strength requirements (ultimate limit state)

5.1 Application of calculations

The adequacy of the strength of the column shall be calculated for the following critical cross sections.

a) The point at which the column is fixed. (Normally at ground level.)

b) The lower edge of the door opening(s). If two or more door openings are provided, the strength of each opening shall be verified.

c) The point at which the bracket begins if the column and bracket consist of one piece, or the point at which the bracket is attached if the bracket is detachable.

d) Transition from one diameter to another when the column is stepped.

e) Any other critical position, e.g. change of material thickness.

5.2 Characteristic loads

The characteristic loads for strength requirements shall be the loads calculated in accordance with BS 5649-6.

5.3 Characteristic strength of materials

5.3.1 *General.* The characteristic strength with a statistical probability of 95 % shall be used in the calculation. Where statistical data is not available, the minimum values given in the relevant national or international standard shall be taken as the characteristic strength.

5.3.2 *Metal lighting columns.* The characteristic strength σ_s (in N/mm^2) of steel and aluminium alloys shall be either:

a) the lower yield stress; or

b) the 0.2 % proof stress.

The values used shall make allowance for any reduction in material strength that may result from the jointing process used in the structure.

5.3.3 ***Concrete lighting columns***

5.3.3.1 *Concrete.* The characteristic strength σ_s (in N/mm^2) of concrete shall be taken as 0.85 of the compressive strength as specified in **3.1** or **4.1** of BS 5649-9:1982, as appropriate.

NOTE In BS 5649-9, the compressive strength relates to values obtained from test cylinders.

5.3.3.2 *Reinforcing and prestressing steels.* The characteristic strength σ_s (in N/mm^2) of reinforcing and prestressing steel shall be taken as:

a) the elastic limit or 0.2 % proof stress in the case of reinforcing steel;

b) the ultimate tensile strength in the case of prestressing steel.

5.4 Loads to be used for calculations

The characteristic loads specified in **5.2** shall be multiplied by the appropriate partial load factors, γ_f, given in Table 1 to give the loads to be used for calculating bending and torsion moments.

Table 1 — Partial load factors, γ_f

Load	Partial load factor, γ_f
Dead loads	1.1
Wind loads	1.1

5.5 Calculation of moments

5.5.1 *Bending moments.* The bending moments, M_x and M_y (in N·m), about the orthogonal axes x-x and y-y, respectively, shall be calculated for each position specified in **5.1** using the loads specified in **5.4**. For sections with openings, the x-x and y-y axes shall be taken as shown in Figure 4, Figure 5 and Figure 8.

NOTE For polygonal sections, the axes may be positioned through the centre of a flat side or through a corner.

For closed regular cross sections, the bending moments M_x and M_y may be combined to give a single moment, M_p (in N·m) that gives the most adverse action on the column cross section being considered and shall be calculated from the equation:

$$M_p = \sqrt{M_x^2 + M_y^2} \qquad (1)$$

5.5.2 *Torsion moments.* On columns with an asymmetric bracket/lantern arrangement the torsion moment, T_p (in N·m) shall be calculated for each position specified in **5.1** using the loads specified in **5.4**.

5.6 Strength of section

5.6.1 *General.* The strength in bending and the strength in torsion of the particular cross section shall be calculated in accordance with **5.6.2** and **5.6.3**, as appropriate.

Either the strength in bending M_{ux} and M_{uy} (in N·m) shall be calculated for the particular cross section, where M_{ux} and M_{uy} are the bending strengths about orthogonal axes x-x and y-y, respectively, which coincide with the direction of the moments M_x and M_y in **5.5.1** or, where M_p has been calculated in accordance with **5.5.1**, the strength in bending M_{up} of the particular cross section in the direction of M_p shall be calculated.

The strength in torsion T_u (in N·m) of the particular cross section shall also be calculated.

5.6.2 *Metal columns*

5.6.2.1 *Closed regular cross sections.* For closed circular cross sections and closed regular polygonal cross sections, the strength of the sections shall be calculated from the following equations:

a) *Bending strength* (in N·m)

$$M_{ux} = M_{uy} = M_{up} = \frac{\sigma_s \phi_1 Z_p}{10^3 \gamma_m} \qquad (2)$$

b) *Torsion strength* (in N·m)

$$T_u = \frac{\sigma_s \phi_2 \pi R^2 t}{10^3 \gamma_m} \qquad (3)$$

where

ϕ_1 is a factor having the value obtained from the curve appropriate to the cross section in Figure 1 where the value of $\rho = (R/t)\sqrt{\sigma_s/E}$;

ϕ_2 is a factor with a value equal to $\dfrac{0.473E}{\sigma_s(R/t)^{1.5}}$ but not greater than 1.0;

E is the characteristic modulus of elasticity of the material as specified in **6.3** (in N/mm^2);

R is the mean radius of the cross section (see Figure 2) (in mm);

t is the wall thickness (see Figure 2) (in mm);

γ_m is a partial material factor having the appropriate value given in Table 2;

σ_s is the characteristic strength of the material as specified in **5.3.2** (in N/mm^2);

Z_p is the plastic modulus of the closed regular cross section (in mm^3).

NOTE For the purpose of this standard Z_p may be taken as having a value of:

$4R^2t$ for circular cross sections;

$4.32R^2t$ for octagonal cross sections.

5.6.2.2 *Unreinforced openings in regular cross sections.* For unreinforced openings in circular cross sections and regular polygonal cross sections, the strengths of the sections shall be calculated from the following equations:

a) *Bending strength* (in N·m)

$$M_{ux} = \frac{\sigma_s g \phi_3 Z_{pn}}{10^3 \gamma_m} \qquad (4)$$

$$M_{uy} = \frac{\sigma_s g \phi_3 Z_{py}}{10^3 \gamma_m} \qquad (5)$$

b) *Torsion strength* (in N·m)

$$T_u = \frac{\sigma_s g \phi_4 \phi_5 R^3 t}{10^3 \gamma_m L} \qquad (6)$$

where

ϕ_3 is a factor having a value equal to $\dfrac{t^2E}{t^2E + 0.08RL\sigma_s}$ but not greater than ϕ_1;

ϕ_4 is a factor having a value equal to $\dfrac{t^2E}{t^2E + 0.05RL\sigma_s}$ but not greater than ϕ_2;

ϕ_5 is a factor having the value obtained from Figure 3 using the appropriate values of R/L and θ;

ϕ_1, ϕ_2, E, σ_s and γ_m are as defined in **5.6.2.1**;

θ is the half angle of the door opening (see Figure 4) (in degrees);

g is a factor having the following values:

circular cross sections: 1.0;

polygonal cross sections: $(15t/b_o)^{0.6}$ but not greater than 1.0;

b_o is the mean dimension of the flat side at the edge of the opening (see Figure 4) (in mm). When b_o is less than $4t$ the value of b_o shall be taken as equal to b;

b is the mean dimension of the flat side of a polygonal section (see Figure 4) (in mm);

L is the effective length of the opening and has the value of $(a - 0.43N)$ (in mm);

a is the overall length of the opening (see Figure 4) (in mm);

N is the corner radius of the opening (see Figure 4) (in mm);

R is the mean radius of the cross section (see Figure 4) (in mm);

t is the wall thickness (see Figure 4) (in mm);

Z_{pn} is the plastic modulus of the section about the plastic neutral axis n-n (in mm^3);

Z_{py} is the plastic modulus of the section about the plastic neutral axis y-y (in mm^3).

NOTE For the purpose of this standard the following values of Z_{pn} and Z_{py} may be taken for circular sections and regular octagonal sections:

$$Z_{pn} = 2FR^2t\cos\frac{\theta}{2}\left(1 - \sin\frac{\theta}{2}\right)$$

$$Z_{py} = FR^2t(1 + \cos\theta)$$

where

F is a factor having the following values:

circular cross sections: 2.0;

octagonal cross sections:2.1.

Table 2 — Partial material factors, γ_m

Material	Partial material factor, γ_m
Steel	
Specified elongation ≥ 5 %	1.15
Specified elongation < 5 %	1.30
Aluminium	
Specified elongation ≥ 5 %	1.15
Specified elongation < 5 %	1.30
Concrete	
Centrifugally spun	1.3
Non-spun	1.5
Steel reinforcement (in concrete columns)	1.15
Prestressing wire (in concrete columns)	1.15

NOTE For values of specified elongation refer to the appropriate standard listed in BS 5649-3.

5.6.2.3 *Reinforced openings in regular cross sections.* For the purposes of this clause, for reinforced openings in circular cross sections and regular polygonal cross sections the classification of reinforcement type shall be in accordance with the appropriate type shown in Figure 5. In addition, the reinforcement shall be fixed to the column wall at the door and the clear distance between individual fasteners or intermittent fillet welds shall not be greater than 12 t_o. The strengths of the sections shall be calculated from the following equations:

a) *Bending strength* (in N m)

$$M_{ux} = \frac{\sigma_s\phi_6 Z_{pnr}}{10^3\gamma_m} \quad (7)$$

$$M_{uy} = \frac{\sigma_s\phi_6 Z_{pyr}}{10^3\gamma_m} \quad (8)$$

b) *Torsion strength* (in N m)

$$T_u = \frac{\sigma_s\phi_6(\phi_5 + P\phi_7)R^3t}{10^3\gamma_m L} \quad (9)$$

where

ϕ_5 is as defined in **5.6.2.2**;

ϕ_6 is a factor having the following values:

a) *reinforcement types 1, 2 and 3* (see Figure 5)

$$\frac{\pi^2E}{\pi^2E + \sigma_s(L/v)^2} \text{ but not greater than } \phi_1$$

b) *reinforcement type 4* (see Figure 5)

$$\frac{(2t + t_w)^2 E}{(2t + t_w)^2 E + 0.32RL\sigma_s} \text{ but not greater than } \phi_1$$

NOTE 1 Where a higher value for ϕ_6 would thereby be obtained, type 4 reinforcement may be considered as type 2.

ϕ_7 is a factor having a value obtained from Figure 7 using the appropriate values of R/L and θ;

v is the radius of gyration of the actual door reinforcement [i.e. area A_s (see Figure 5)] about its centroidal axis parallel to the wall of the column at point of attachment (in mm);

NOTE 2 A length of column wall, not greater than $10t$, as indicated in Figure 5, may be assumed to act with the reinforcement for the purpose of calculating v.

P is a factor having a value equal to A_e/Rt but not greater than the lesser of $L/4R$ or 1.6;

ϕ_1, E and γ_m are as defined in **5.6.2.1**;

θ and L are as defined in **5.6.2.2**;

σ_s is the characteristic strength of the material used for the column or the reinforcement, as specified in **5.3.2**, whichever is the least (in N/mm^2);

R is the mean radius of the cross section (see Figure 5) (in mm);

t is the wall thickness (see Figure 5) (in mm);

t_o is the lesser of the two values t and t_w (in mm^2);

t_w is the thickness of the reinforcement at the side of the door opening (see Figure 5) (in mm). For the purposes of the calculations t_w has a consistent value, which may be taken as being less than the actual thickness;

A_e is the effective cross-sectional area (in mm^2) of the door reinforcement and shall be taken as equal to the least value of the following.

a) A_s, the actual cross-sectional area of the door reinforcement as indicated on Figure 5. Where the value for A_s is not uniform over the length of the door opening the minimum area shall be taken.

b) St_o.

c) The total shear strength (in N) of all fasteners in each length S divided by σ_s.

d) The total shear strength (in N) of all fasteners in each length C divided by σ_s.

The shear strength of fasteners shall be taken as the shear strength of fillet weld per unit length times the appropriate length or the shear strength of the individual fasteners times the appropriate number of fasteners, as appropriate. The shear strength shall be calculated using a shear stress equal to $\sigma_s/\sqrt{3}$. The throat thickness of fillet welds shall be taken as being the lesser value of:

1) the actual throat thickness; or

2) the value of t_o;

S is the length of the end connection of the door reinforcement (see Figure 6) (in mm). Where the upper and lower end connections have different lengths the lesser value shall be taken;

C is the length of the upper or lower halves of the straight edge of the door opening (see Figure 6) (in mm);

Z_{pnr} is the plastic modulus of the section, including the effective door reinforcement, about the plastic neutral axis n-n (in mm^3);

Z_{pyr} is the plastic modulus of the section, including the effective door reinforcement, about the plastic neutral axis y-y (in mm^3).

NOTE For the purposes of this Part of BS 5649 the following values of Z_{pnr} and Z_{pyr} may be taken for circular sections and regular octagonal sections:

$$Z_{pnr} = 2R^2 t \left\{ 2\cos\left(\frac{\theta}{2} - \frac{90B_x}{\pi}\right) - \sin\theta + B_x\cos\theta \right\}$$

$$Z_{pyr} = 2R^2 t \left\{ 1 + \cos\theta + B_y \sin\theta \right\}$$

where

$$B_x = \frac{A_e}{Rt} \times \frac{m_{ox}}{m_x}$$

$$B_y = \frac{A_e}{Rt} \times \frac{m_{oy}}{m_y}$$

m_{ox} is the distance from the centroid of the actual door reinforcement (i.e. area A_s) to the x-x axis (see Figure 5) measured normal to the axis (in mm);

m_{oy} is the distance from the centroid of the actual door reinforcement (i.e. area A_s) to the y-y axis (see Figure 5) measured normal to the axis (in mm);

m_x is the distance from the centre of the column wall at the edge of the opening to the x-x axis (see Figure 5) measured normal to the axis (in mm);

m_y is the distance from the centre of the column wall at the edge of the opening to the y-y axis (see Figure 5) measured normal to the axis (in mm).

5.6.3 *Concrete columns*

5.6.3.1 *Closed regular cross sections.* The bending strength and torsion strength of closed regular cross sections shall be as follows.

a) *Bending strength* (in N m). For closed regular cross sections, the appropriate bending strengths M_{ux}, M_{uy} or M_{up} shall be calculated by inelastic analysis based on the short term stress-strain curves derived from the characteristic material strengths divided by the appropriate partial material factor, γ_m, given in Table 2 where M_{ux}, M_{uy} and M_{up} are defined in **5.6.1**.

NOTE The short term stress strain curves (Figures 2.1, 2.2 and 2.3 of BS 8110-1:1985) may be used.

b) *Torsion strength* (in N m). The torsion strengths T_u of circular or octagonal closed sections, with longitudinal steel reinforcement and/or prestressing wires shall be the greater of the two values calculated from equations (10) and (11) below, where appropriate.

$$T_u = \frac{\pi (d^3 - d_o^3)}{12 \times 10^3} \times \sqrt{\sigma_t (\sigma_t + \sigma_p)} \qquad (10)$$

$$T_u = \frac{a_s \pi d_1^2}{4s \times 10^3} \times \frac{\left(\begin{array}{c}\text{Characteristic strength}\\ \text{of reinforcement}\end{array}\right)}{\gamma_m} \qquad (11)$$

where

d is the diameter of cross section of the column (see Figure 8) (in mm);

d_o is the diameter of the central bore of the column (see Figure 8) (in mm);

σ_t is the characteristic shear strength with a value equal to $0.1 \sqrt{(\sigma_s/\gamma_m)}$ (in N/mm^2), where σ_s is the characteristic strength of concrete as specified in **5.3.3**;

γ_m is as defined in **5.6.2.1**;

σ_p is the stress on the cross section from the prestressing force after taking account of the prestressing losses (in N/mm^2). Account has to be taken of the reduction of σ_p in the transmission length. For reinforced concrete $\sigma_p = 0$;

d_1 is the mean diameter of the hoop reinforcement (see Figure 8) (in mm);

a_s is the total area of the legs of closed hoops at a section (in mm^2);

s is the longitudinal spacing of hoops (in mm).

The value from equation (11) shall only be adopted where reinforcement hoops are provided around the longitudinal steel reinforcement and the total area of longitudinal steel (in mm^2) in the cross section exceeds:

$$\frac{a_s \pi d'_1}{2s} \times \frac{\left(\begin{array}{c}\text{Characteristic strength of}\\ \text{hoop reinforcement}\end{array}\right)}{\left(\begin{array}{c}\text{Characteristic strength of}\\ \text{longitudinal reinforcement}\end{array}\right)} \qquad (12)$$

5.6.3.2 *Other cross sections (including those with openings).* The bending strength and torsion strength of other cross sections (including those with openings) shall be as follows.

a) *Bending strength* (in N m). The bending strengths M_{ux} and M_{uy} (see **5.6.1**) of other cross sections, including those with openings, shall either be obtained by an inelastic analysis based on the short term stress-strain curves derived from the characteristic material strengths divided by the appropriate partial material factor, γ_m, given in Table 2, provided instability of the section does not occur before failure or by an empirical method based on tests.

NOTE Advice on instability of concrete sections is given in BS 8110-1.

b) *Torsion strength* (in N m). The torsion strength T_u of other cross sections, including those with openings, shall either be calculated using an appropriate analytical method, which has been proved suitable for the particular cross section, or by an empirical method based on tests.

5.6.3.3 *Additional requirements for prestressed concrete columns.* For prestressed concrete columns the following additional requirements shall apply.

a) *Concrete.* The maximum initial stress in the concrete in the lighting column at transfer shall not be greater than 0.6 σ_c, where σ_c (in N/mm^2) is the effective compressive strength of the concrete in the lighting column at the moment of transference of the prestressing force.

b) *Complete structure.* Prestressing losses shall be calculated in accordance with the method given in BS 8110-1.

5.7 Acceptance of design for strength

The strength of the column shall be considered acceptable if for all the positions specified in **5.1**, the following is satisfied:

$$\frac{M_x}{M_{ux}} + \frac{M_y}{M_{uy}} + \frac{T_p}{T_u} \leqslant 1; \qquad (13)$$

or alternatively for closed regular cross sections:

$$\frac{M_p}{M_{up}} + \frac{T_p}{T_u} \leqslant 1 \qquad (14)$$

where

M_x, M_y and M_p are as defined in **5.5.1**;

T_p is as defined in **5.5.2**;

M_{ux}, M_{uy}, M_{up} and T_u are as defined in **5.6.1**.

6 Deflection requirements (serviceability limit state)

6.1 Application of calculations

The horizontal and vertical deflections of the lantern connection under the action of the characteristic loads shall be calculated.

6.2 Characteristic loads

The characteristic loads for deflection requirements shall be the loads calculated in accordance with BS 5649-6 with the factor k taken as equal to 1.0 for wind loads.

6.3 Characteristic material properties

The characteristic moduli of elasticity, E, and rigidity, G, shall be taken as follows:

steel:

modulus of elasticity = 210×10^3 N/mm^2;

modulus of rigidity = 80×10^3 N/mm^2;

aluminium:

modulus of elasticity = 70×10^3 N/mm^2;

modulus of rigidity = 27×10^3 N/mm^2;

concrete:

appropriate values given in BS 8110-1 shall be taken.

6.4 Calculations of deflections

6.4.1 *Horizontal deflection of the lantern connection(s).*

The total horizontal deflection (in m) calculated from the effects of the loads specified in **6.2** shall be taken as the sum of the following.

a) The horizontal deflection caused by flexure of the column shaft and the bracket due to the simultaneous effect of the wind on the column shaft, bracket and lantern(s).

b) The horizontal deflection caused by torsion of the column shaft and any vertical section of the bracket due to the simultaneous effect of the wind on the section of the bracket deviating from the vertical and the lantern(s).

6.4.2 *Vertical deflection of the lantern connection(s).*

The vertical deflection (in m) calculated from the effects of the loads specified in **6.2** shall be taken as that caused by the flexure of the column shaft and bracket due to the simultaneous effect of the masses of the section of the bracket deviating from the vertical and the lantern.

6.4.3 *Additional requirements for concrete columns.*

The reduced stiffness of the portions of the columns that will be cracked under the action of tensile stresses shall be taken into account in calculating the deflections.

For reinforced concrete columns, the extent of cracking shall be that obtained under the full unfactored loading used in the strength calculations.

For prestressed concrete columns, account shall be taken of prestressing losses.

6.5 Acceptance of design for deflection

6.5.1 *Horizontal deflection.* The total horizontal deflection of each lantern connection, calculated in accordance with **6.4.2**, shall not exceed 0.04 ($h + w$):

where

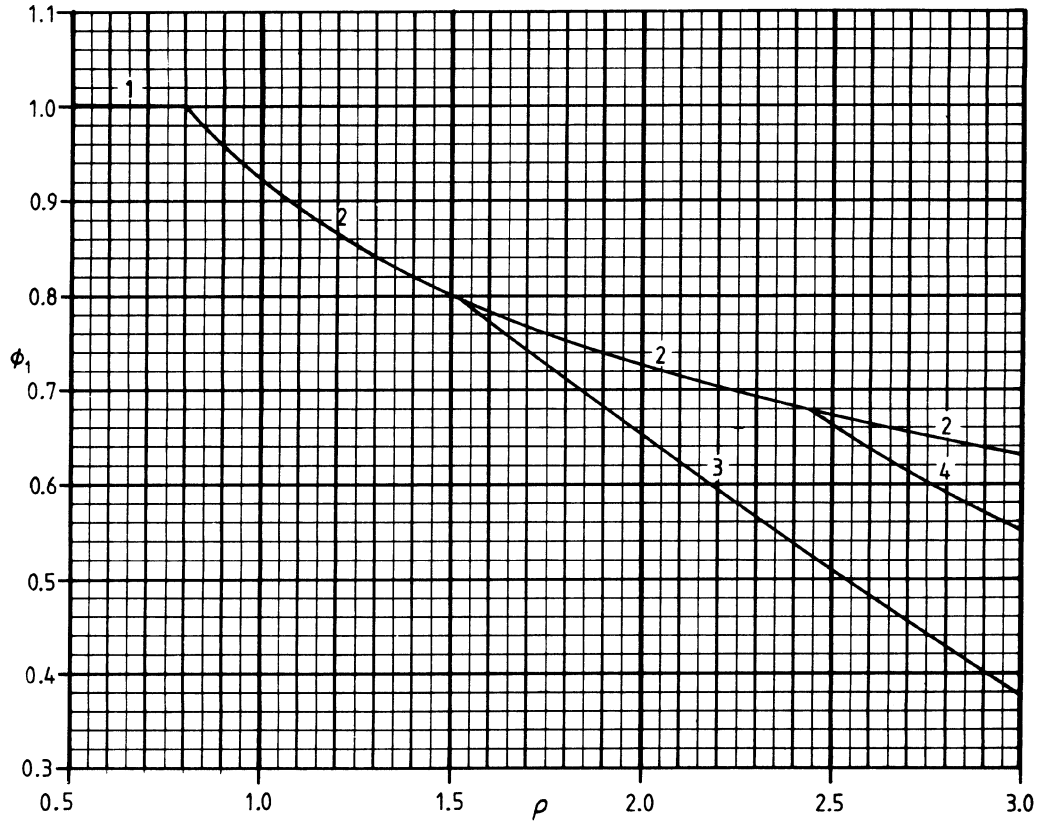
h is the nominal height of the lighting column (in m) as defined in BS 5649-2;

w is the bracket projection (in m) as defined in BS 5649-2.

6.5.2 *Vertical deflection.* The vertical deflection of each lantern connection calculated in accordance with **6.4.3** shall not exceed $0.025w$, where w is as defined in **6.5.1**.

7 Permissible modifications to verified column

The design calculations for a given column with a particular bracket arrangement and projection, lantern(s) and k value shall be considered acceptable for the same column with the same style of bracket(s) but with reduced bracket projection and/or smaller effective lantern area(s) and/or smaller effective lantern weight(s) and/or a reduced k value.



NOTE 1 For circular cross sections and polygonal cross sections with 12 m or more sides. use curves 1 and 2.
NOTE 2 For regular octagonal cross sections use curves 1 and 2 when $\rho \leq 1.53$ and curve 3 when $\rho > 1.53$.
NOTE 3 For 10 sided regular polygons, use curves 1 and 2 when $\rho \leq 2.41$ and curve 4 when $\rho > 2.41$.
NOTE 4 The value of ϕ_1 for each curve may be obtained from the following.

Curve 1 $\phi_1 = 1.0$ For $0 < \rho \leq 0.8$.

Curve 2 $\phi_1 = (0.8/\rho)^{0.35}$ For $0.8 < \rho \leq 3.0$.

Curve 3 $\phi_1 = 0.81 - 0.3(\rho - 1.5)^{0.9}$ For $1.53 < \rho \leq 3.0$.

Curve 4 $\phi_1 = 0.81 - 0.24(\rho - 1.9)^{0.9}$ For $2.41 < \rho \leq 3.0$.

Figure 1 — Values of factor ϕ_1

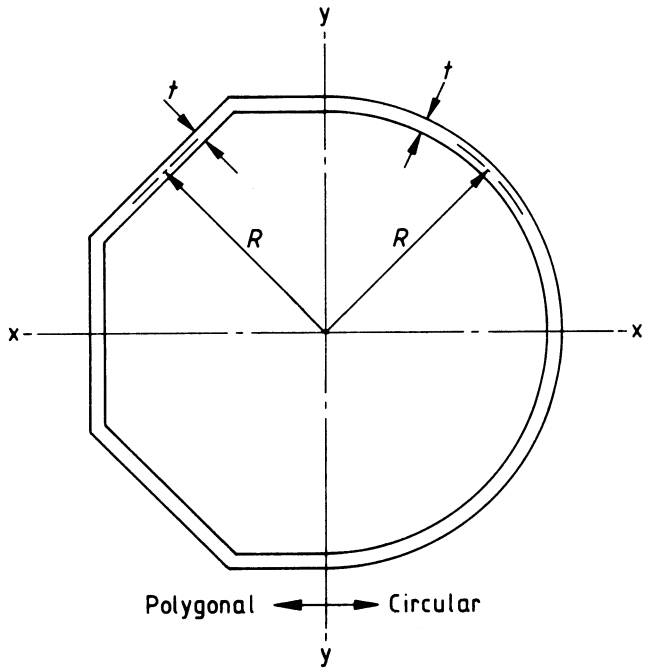
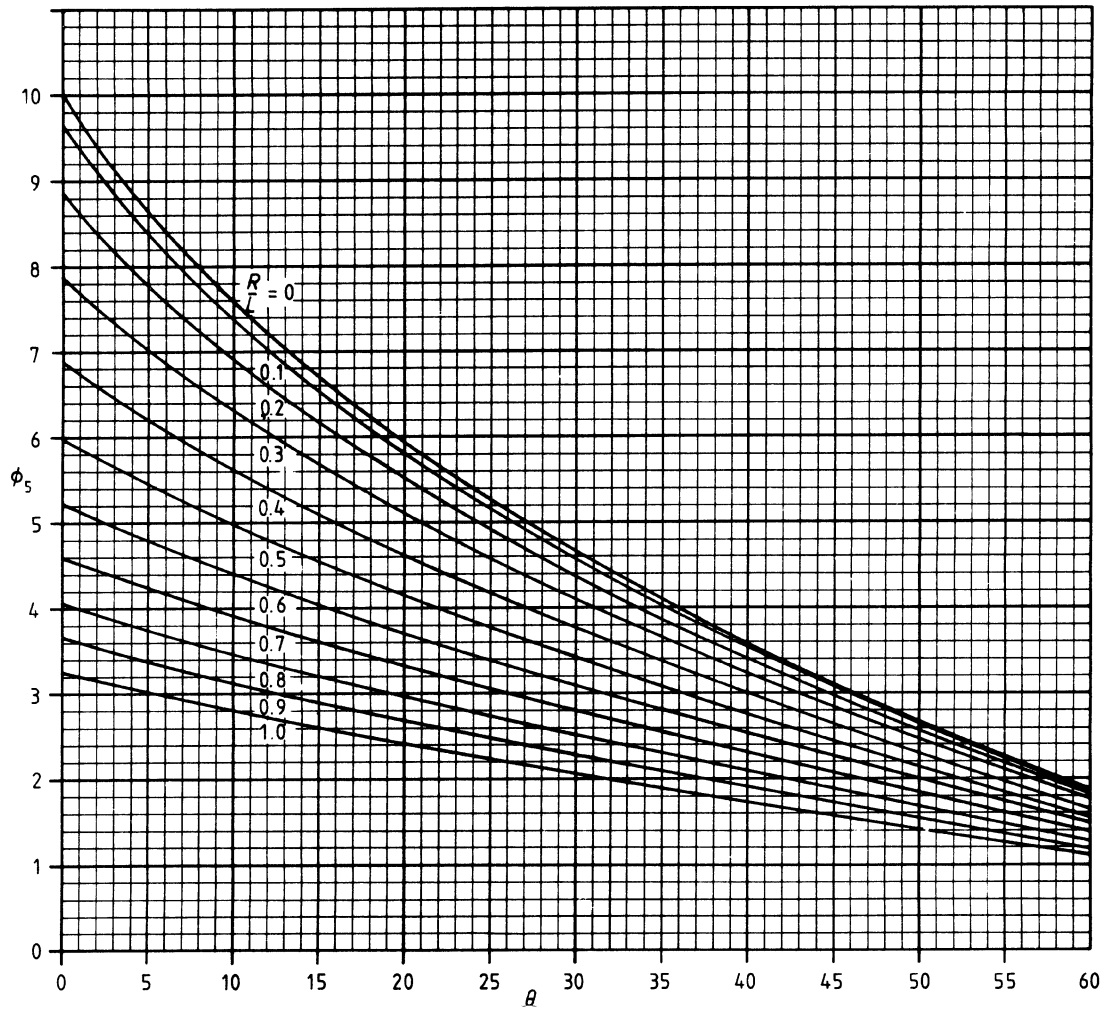


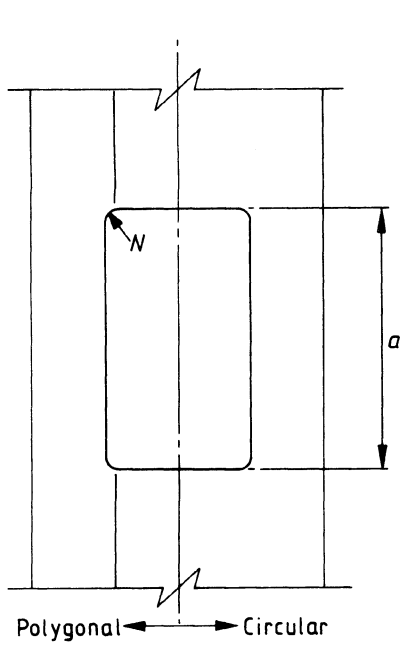
Figure 2 — Closed regular cross sections of metal lighting columns



NOTE ϕ_5 may be obtained from the following expression:

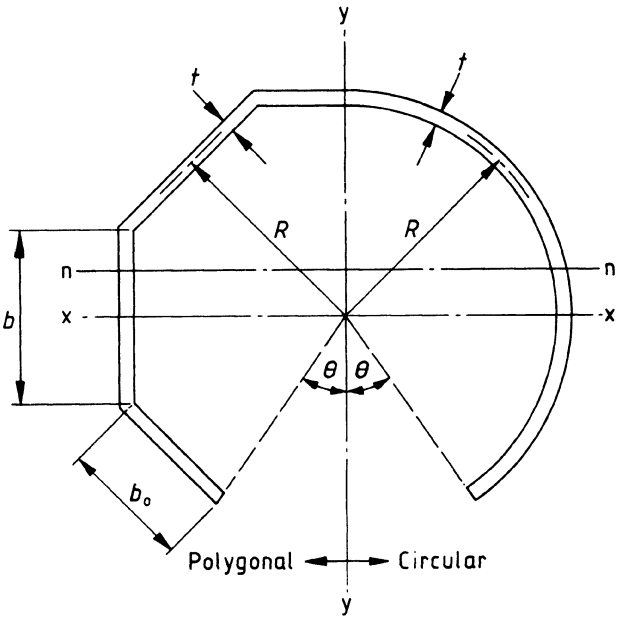
$$\phi_s = \frac{10 \cos^2 (\theta/2)}{1 + 1.73 \tan \theta} \left(\frac{1 + 2.15 \tan \theta + 0.85\ R/L}{1 + 2.15 \tan \theta + 0.85\ R/L + 3.8(R/L)^2} \right)$$

Figure 3 — Values of factor ϕ_5



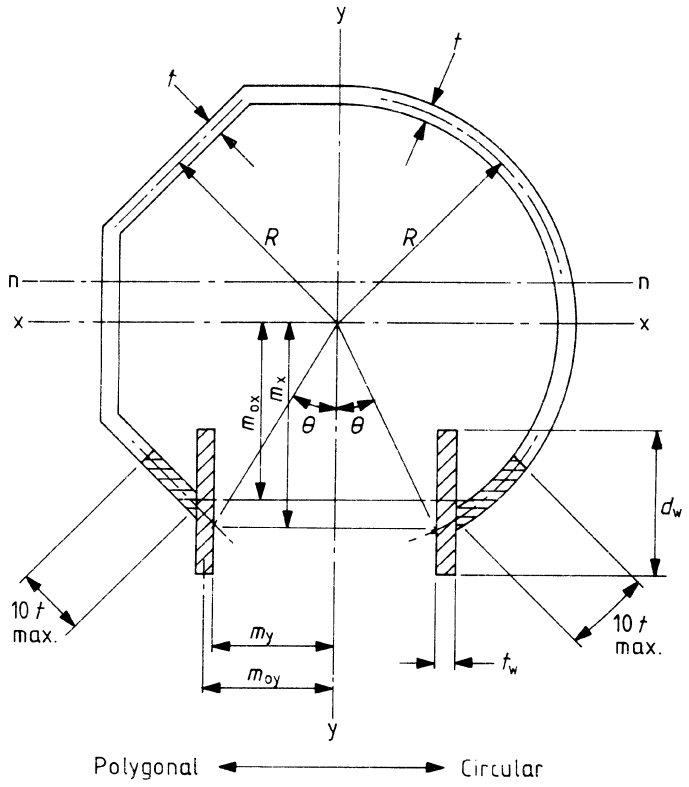
NOTE *N* is the corner radius of the door opening.

(a) Elevation



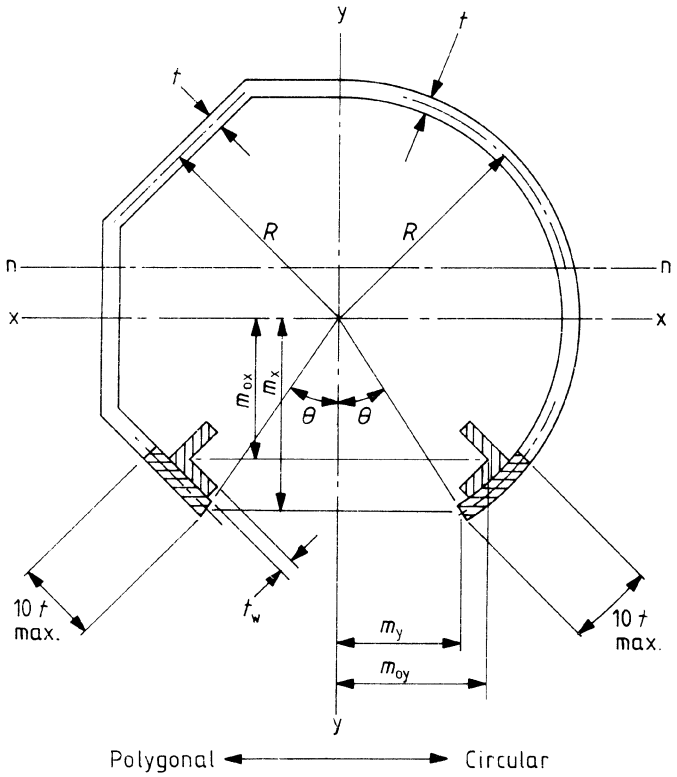
(b) Cross section

Figure 4 — Unreinforced door openings in metal lighting columns



NOTE $A_s = t_w\ d_w$.

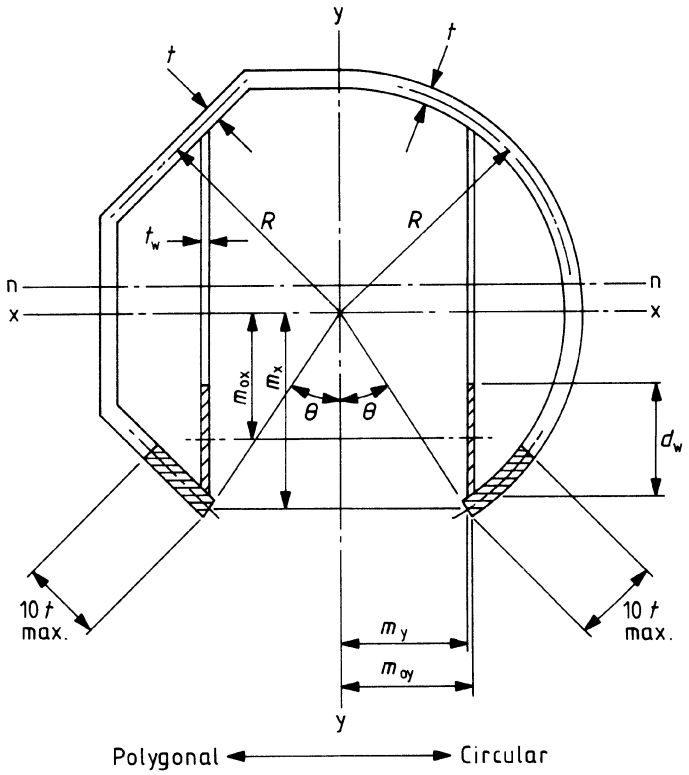
(a) Type 1



NOTE A_s is the area of the reinforcement, which may take the form of an angle, as shown, or any other cross section.

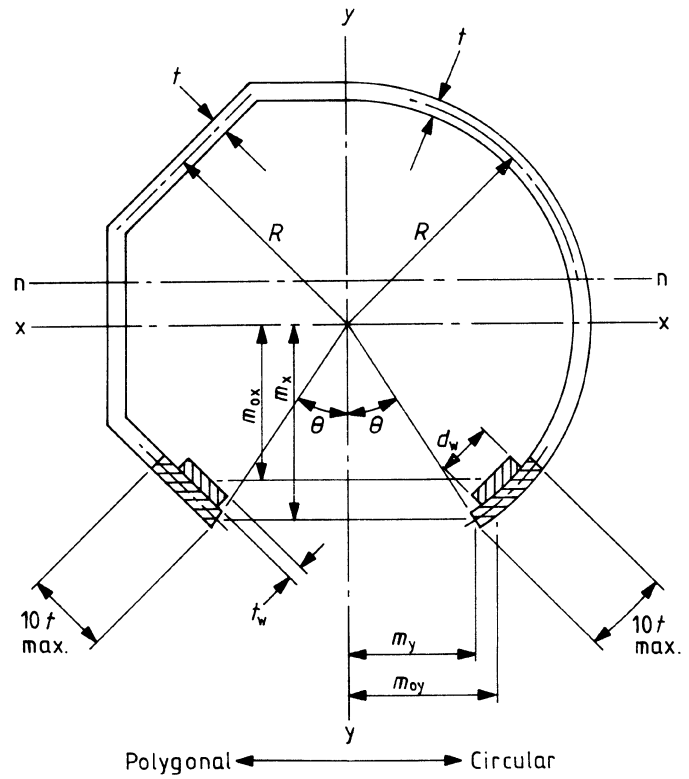
(b) Type 2

Figure 5 — Cross sections of reinforced door openings in metal lighting columns



NOTE $A_s = t_w\, d_w$.
For type 3 reinforcement, take d_w as the lesser of m_x or $20t_w$.

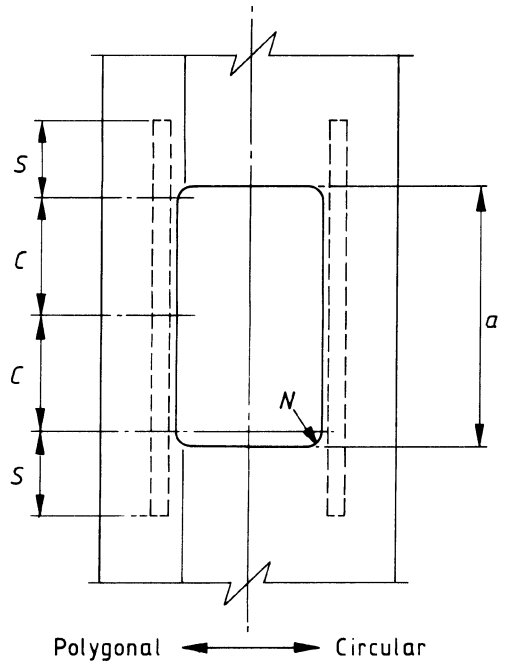
(c) Type 3



NOTE $A_s = t_w\, d_w$.
For type 4 reinforcement, take d_w has to be greater than $4t_w$, and t_w has to be greater than t.

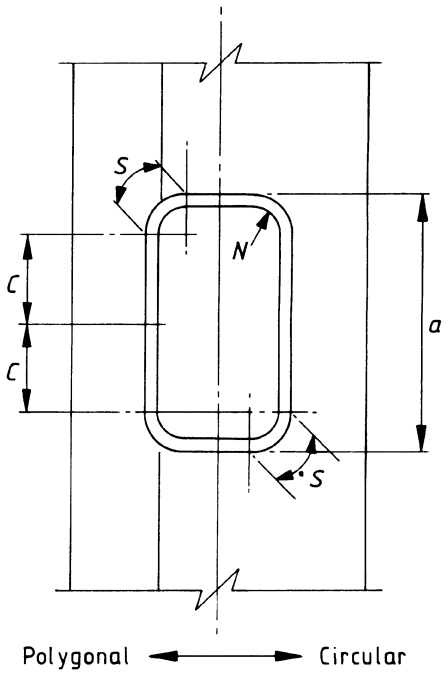
(d) Type 4

Figure 5 — Cross sections of reinforced door openings in metal lighting columns *(concluded)*



NOTE *N* is the corner radius of the door opening.

(a) Reinforcement projecting beyond the door opening



NOTE 1 *N* is the corner radius of the door opening.
NOTE 2 In this form of reinforcement S is the length of connection of the curved portion of the reinforcement.

(b) Reinforcement continuous around the door opening

Figure 6 — Elevation of reinforced door openings in metal lighting columns

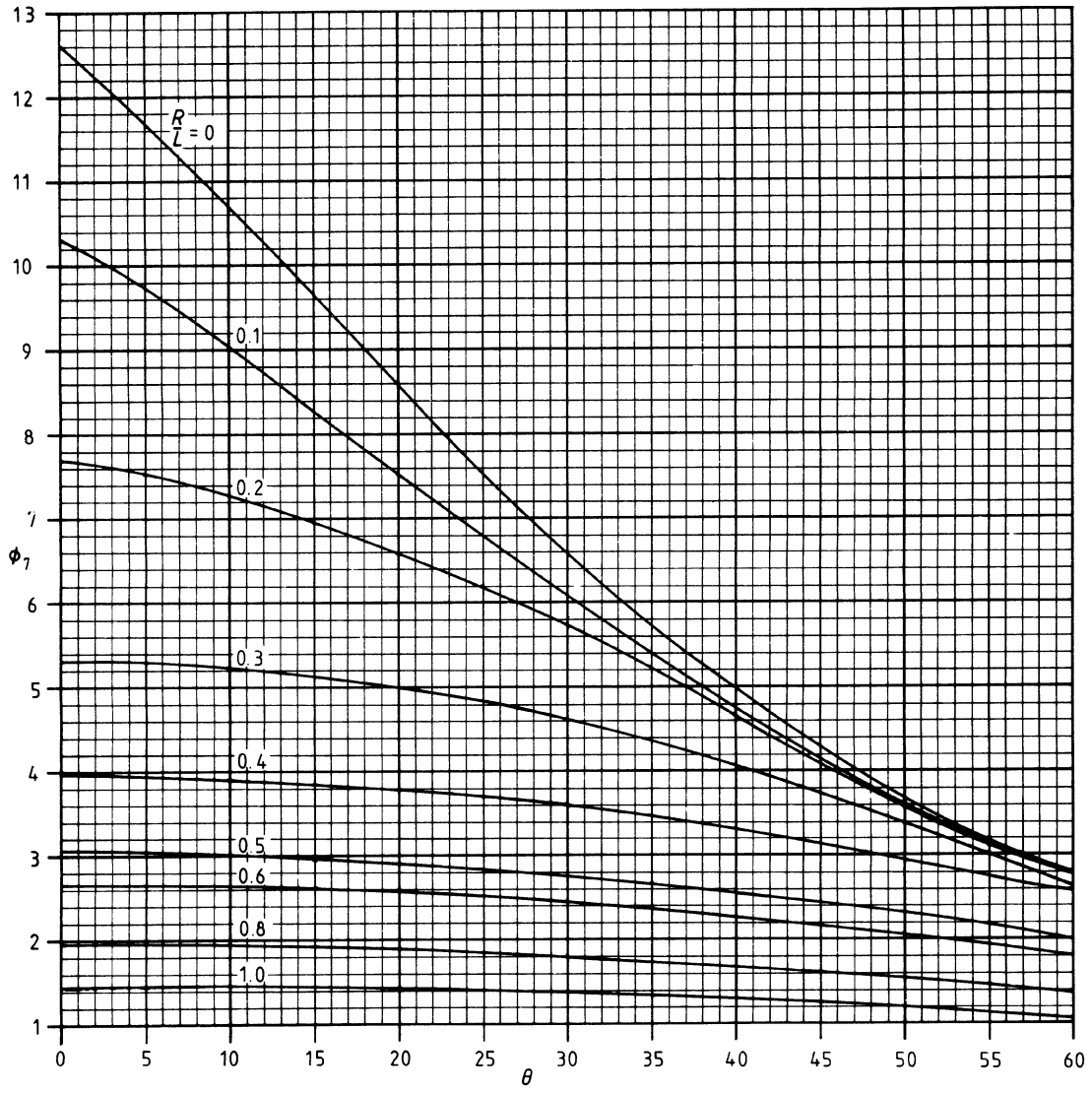
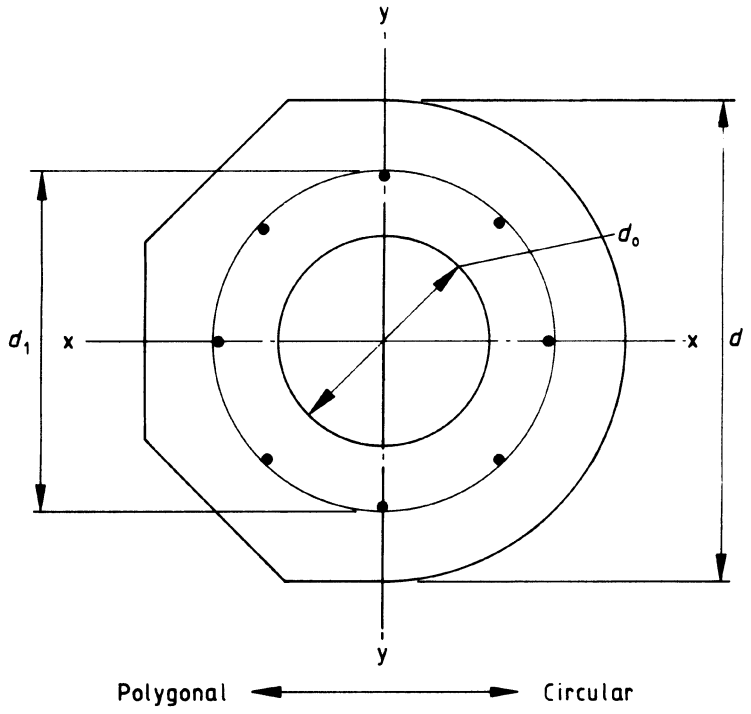
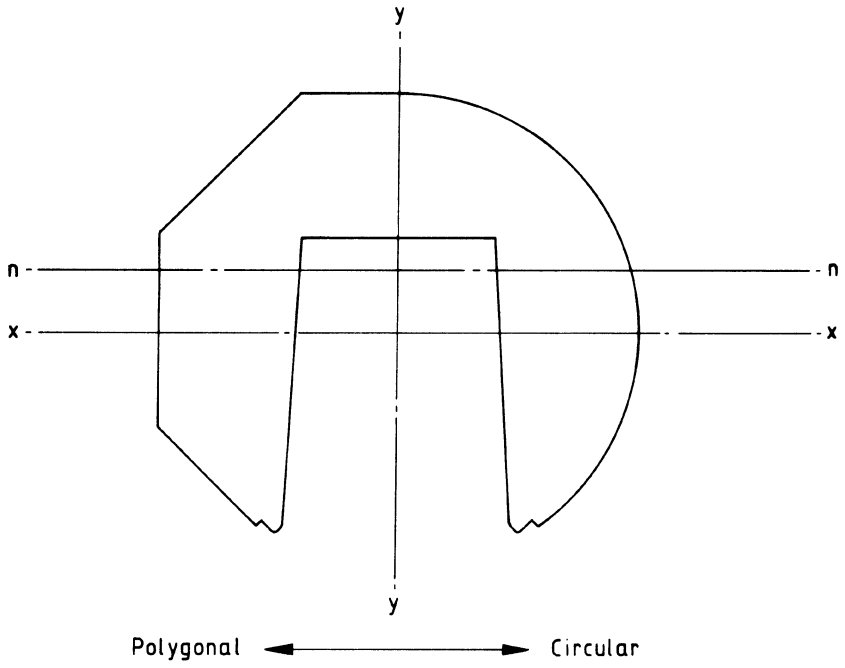


Figure 7 — Values of factor ϕ_7



(a) Closed regular cross section



(b) Cross section with opening

Figure 8 — Cross sections of concrete lighting columns

Publications referred to

BS 1308, *Concrete street lighting columns*[2)].
BS 1840, *Steel columns for street lighting*[2)].
BS 3989, *Aluminium street lighting columns*[2)].
BS 5649 (EN 40), *Lighting columns.*
BS 5649-1 (EN 40), *Definitions and terms.*
BS 5649-2 (EN 40), *Dimensions and tolerances.*
BS 5649-3 (EN 40), *Specification for materials and welding requirements*[3)].
BS 5649-4 (EN 40), *Recommendations for surface protection of metal lighting columns*[2)].
BS 5649-5 (EN 40), *Specification for base compartments and cableways*[2)].
BS 5649-6 (EN 40), *Specification for design loads.*
BS 5649-7 (EN 40), *Method for verification of structural design by calculation*[3)].
BS 5649-8 (EN 40), *Method for verification of structural design by testing.*
BS 5649-9 (EN 40), *Specification of special requirements for reinforced and prestressed concrete lighting columns.*
BS 8110, *Structural use of concrete*[4)].
BS 8110-1, *Code of practice for design and construction.*
ISO 2394, *General principles for the verification of the safety of structures*[2)].
CEN Report CR 40-7, *Lighting columns — verification of structural design by calculation*[2)].

[2)] Referred to in the foreword only.
[3)] Parts 3 and 7 are Part of BS 5649 only and do not form Part of EN 40.
[4)] Revision of CP 110.

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