Steel, concrete and composite bridges —

Part 9: Bridge bearings —

Section 9.1 Code of practice for design of bridge bearings

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Amendments issued since publication

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Foreword

BS 5400 is a document combining codes of practice to cover the design and construction of steel, concrete and composite bridges and specifications for loads, materials, and workmanship. It comprises the following Parts and Sections:

— *Part 1: General statement;*

— *Part 2: Specification for loads;*

— *Part 3: Code of practice for design of steel bridges;*

— *Part 4: Code of practice for design of concrete bridges;*

— *Part 5: Code of practice for design of composite bridges;*

— *Part 6: Specification for materials and workmanship, steel;*

— *Part 7: Specification for materials and workmanship, concrete, reinforcement and prestressing tendons;*

— *Part 8: Recommendations for materials and workmanship, concrete, reinforcement and prestressing tendons;*

— *Part 9: Bridge bearings;*

— *Section 9.1: Code of practice for design of bridge bearings;*

— *Section 9.2: Specification for materials, manufacture and installation of bridge bearings;*

— *Part 10: Code of practice for fatigue.*

This Section of Part 9, together with Section 9.2, supersede appendix F of BS 5400-2:1978, which is to be withdrawn by an amendment.

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.

This code of practice represents a standard of good practice and takes the form of recommendations. Compliance with it does not confer immunity from relevant legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to vi, pages 1 to 18, 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 Section of Part 9 of BS 5400 gives recommendations for the design and performance of the most common types of bridge bearings. It should be read in conjunction with the other Parts of BS 5400 that cover loading, design, materials and workmanship of steel, concrete and composite bridges. The recommendations given in this Section of Part 9 are appropriate only when the materials and workmanship comply with Section 9.2.

This Section of Part 9 does not cover concrete hinges and special bearings for moving bridges, e.g. swing and lift bridges.

2 References

The titles of the publications referred to in this Section of Part 9 are listed on the inside back cover.

3 Definitions and symbols

3.1 Definitions. For the purposes of this Section of Part 9, the following definitions, together with those given for **design loads** and **design load effects** in Part 1, apply.

3.1.1
elastomer

a compound containing natural or chloroprene rubber with properties similar to those of rubber

3.1.2
roller bearing

a bearing consisting essentially of one or more steel rollers between parallel upper and lower steel plates (See Figure 1(a) and Figure 1(b).)

3.1.3
rocker bearing

a bearing consisting essentially of a curved surface in contact with a flat or curved surface and constrained to prevent relative horizontal movement. The curved surfaces may be cylindrical or spherical. (See Figure 1(c) and Figure 1(d).) Rocker bearings permit rotation by rolling of one part on another

3.1.4
knuckle bearing

a bearing consisting essentially of two or more members with mating curved surfaces. The curved surfaces may be cylindrical or spherical. [See Figure 1(e), Figure 1(g) and Figure 1(h).] Knuckle bearings permit rotation by sliding of one part on another

3.1.5
leaf bearing

a bearing consisting essentially of a pin passing through a number of interleaved plates fixed alternately to the upper and lower outer bearing plates [See Figure 1(f).]

3.1.6
sliding bearing

a bearing consisting essentially of two surfaces sliding one on the other [See Figure 1(i).]

3.1.7
elastomeric bearing

a bearing comprising a block of elastomer that may be reinforced internally with steel plates

3.1.8
laminated bearing

an elastomeric bearing reinforced with steel plates [See Figure 1(j).]

3.1.9
plain pad bearing

an unreinforced elastomeric bearing

3.1.10
strip bearing

a plain pad bearing for which the length is at least ten times the width

3.1.11
pot bearing

a bearing consisting essentially of a metal piston supported by a disc of unreinforced elastomer that is confined within a metal cylinder [See Figure 1(k).]

3.2 Symbols. The symbols used in this Section of Part 9 are as follows.

A	overall plan area of elastomeric bearing
A_e	effective plan area of elastomeric bearing
A_1	reduced effective plan area of elastomeric bearing
b	overall width of bearing (the shorter dimension of a rectangular bearing)
b_e	effective width of elastomeric bearing
E	modulus of elasticity
E_b	bulk modulus of elastomer
G	shear modulus of the elastomer
H	horizontal force
k	a factor
l	overall length of bearing (the longer dimension of a rectangular bearing
l_e	effective length of elastomeric bearing
l_p	force-free perimeter of elastomeric bearing

Q^*	design loads
R	radius of cylinder or sphere or convex surface
R_l	radius of concave surface
S	shape factor
S'	shape factor of thickest elastomer layer
S^*	design load effects
T	minimum shade air temperature
t	thickness of a plain pad or strip bearing
t_1, t_2	thickness of adjacent elastomer layers
t_e	effective thickness of elastomer in compression
t_1	thickness of an individual elastomer layer in a laminated bearing
t_q	total thickness of elastomer in shear
V	vertical design load effect
α_b	angular rotation across width b of bearing
α_l	angular rotation across length l of bearing
γ_{f3}	partial safety factor
γ_{fL}	partial load factor
γ_m	partial material factor
l	total vertical deflection
δ	vertical deflection of individual elastomer layer
δ_b	maximum horizontal relative displacement of parts of bearing in the direction of dimension b of the bearing
δ_l	maximum horizontal relative displacement of parts of bearing in the direction of dimension l of the bearing
δ_r	maximum resultant horizontal relative displacement of parts of bearing obtained by vectorial addition of δ_b and δ_l
ϵ_e	nominal strain in elastomer slab due to compressive loads
ϵ_q	shear strain in elastomer slab due to translational movement
ϵ_t	total nominal strain in elastomer slab
ϵ_α	nominal strain in elastomer due to angular rotation
σ_u	nominal ultimate tensile strength of material
σ_s	stress in steel

NOTE   It is essential that the units used for these symbols in the formulae are compatible with each other.

4 Function of bearings

The function of bearings is to provide a connection to control the interaction of loadings and movements between parts of a structure, usually between superstructure and substructure.

A guide to the suitability of various types of bearing for different functions is given in Table 1. To achieve the required degree of freedom it may be necessary to combine the characteristics of different types of bearing, the resultant bearing as a whole providing the required movements and load resistance, e.g. a plane sliding bearing to allow translation with a pot bearing to provide for rotation. The basic features of the various types of bearings are illustrated in Figure 1.

5 Design considerations

5.1 General. The load and movement capacities of the bearings for any particular structure should be compatible with the assumptions made in the overall design of that structure. Except where otherwise stated in this Section of Part 9, the design of structural steel elements forming parts of bearings should satisfy the recommendations of Part 3. Where yield stress is referred to, it is to be taken as the nominal yield stress. Where materials other than those dealt with in Section 9.2 are used, the recommendations of the appropriate British Standard should be adopted.

5.2 Limit state requirements

NOTE   *Compliance with limit states.* Bearings designed in accordance with this Section of Part 9 may be considered to satisfy the recommendations of **5.2.1** and **5.2.2**.

5.2.1 *Serviceability limit state.* The design should be such that bearings will not suffer damage that would affect their correct functioning, or incur excessive maintenance costs during their intended life.

5.2.2 *Ultimate limit state.* The strength and stability of bearings should be adequate to withstand the ultimate design loads and movements of the structure.

5.3 Design life. Bearings and their installations should be designed to be compatible with the design life of the bridge (see Part 1) taking into account the consequences of maintenance and/or replacement.

5.4 Provision for resetting and replacement. Where practicable, and whenever the expected design life of the bearings is significantly less than that of the structure, provision should be made for the removal and replacement of the whole or parts of the bearings.

Facilities for correcting the effects of any differential settlement and tilt should be provided unless the structure has been designed to accommodate such effects.

5.5 Provision for handling. Where necessary, suitable handling attachments should be provided on bearings.

5.6 Access. Adequate space should be provided around bearings to facilitate their inspection and maintenance. Consideration should be given in the design of the structure to the means of access to the bearings.

5.7 Durability. Bearings should be detailed to exclude crevices and the like, which allow moisture and dirt to be trapped. The materials used in their manufacture and the protective and maintenance measures adopted against corrosion and deterioration due to environmental effects should be such as to ensure that bearings continue to function correctly throughout their design life. The recommendations in this Section of Part 9 are intended to meet the durability requirements of most structures in the UK. Where exceptional environmental conditions are encountered, additional precautions may be necessary.

5.8 Movement restraint. Where restraints are required to restrict the translational movement of a structure, either totally, partially or in a selected direction, they may be provided as part of or separate from the bearings and normally take the form of dowels, keys or side restraints.

In each case the restraints should allow freedom of movement in the desired direction(s). The forces generated by the restraints should be considered in the design of the bearings and their connections and in the design of the structure. Where reliance is placed on friction to resist these forces, the lower bound value of friction coefficients obtained from available test data appropriate to the surface condition in service should be assumed.

Where bearing replacement may be required during the life of a structure, the provision of a restraint (e.g. dowels) through the bearings may cause difficulties, and alternative location of the restraints should be considered.

5.9 Uplift. If uplift can occur, bearings and their fixings should be designed to limit separation of the parts to a value agreed with the Engineer and to resist the consequent forces.

Figure 1 — Types of bearing

(c) Linear rocker bearing

(d) Point rocker bearing

(e) Knuckle pin bearing

(f) Knuckle leaf bearing

(g) Cylindrical knuckle bearing

(h) Spherical knuckle bearing

(i) Plane sliding bearing

(j) Elastomeric laminated bearing

(k) Pot bearing
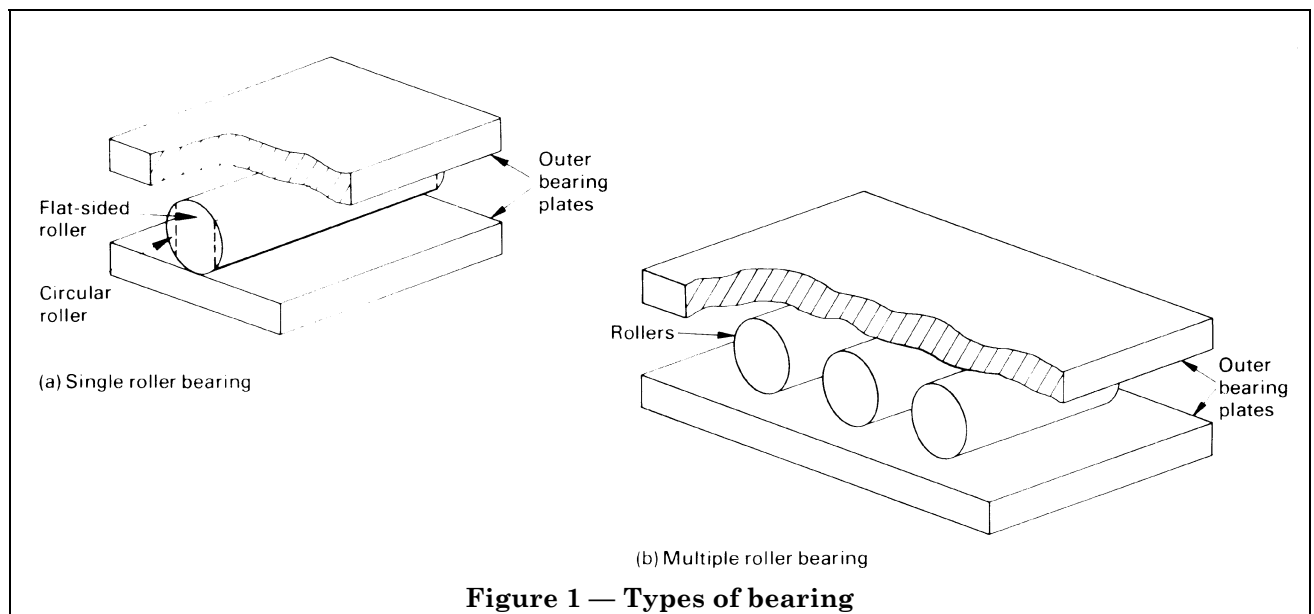
Figure 1 — Types of bearing *(concluded)*
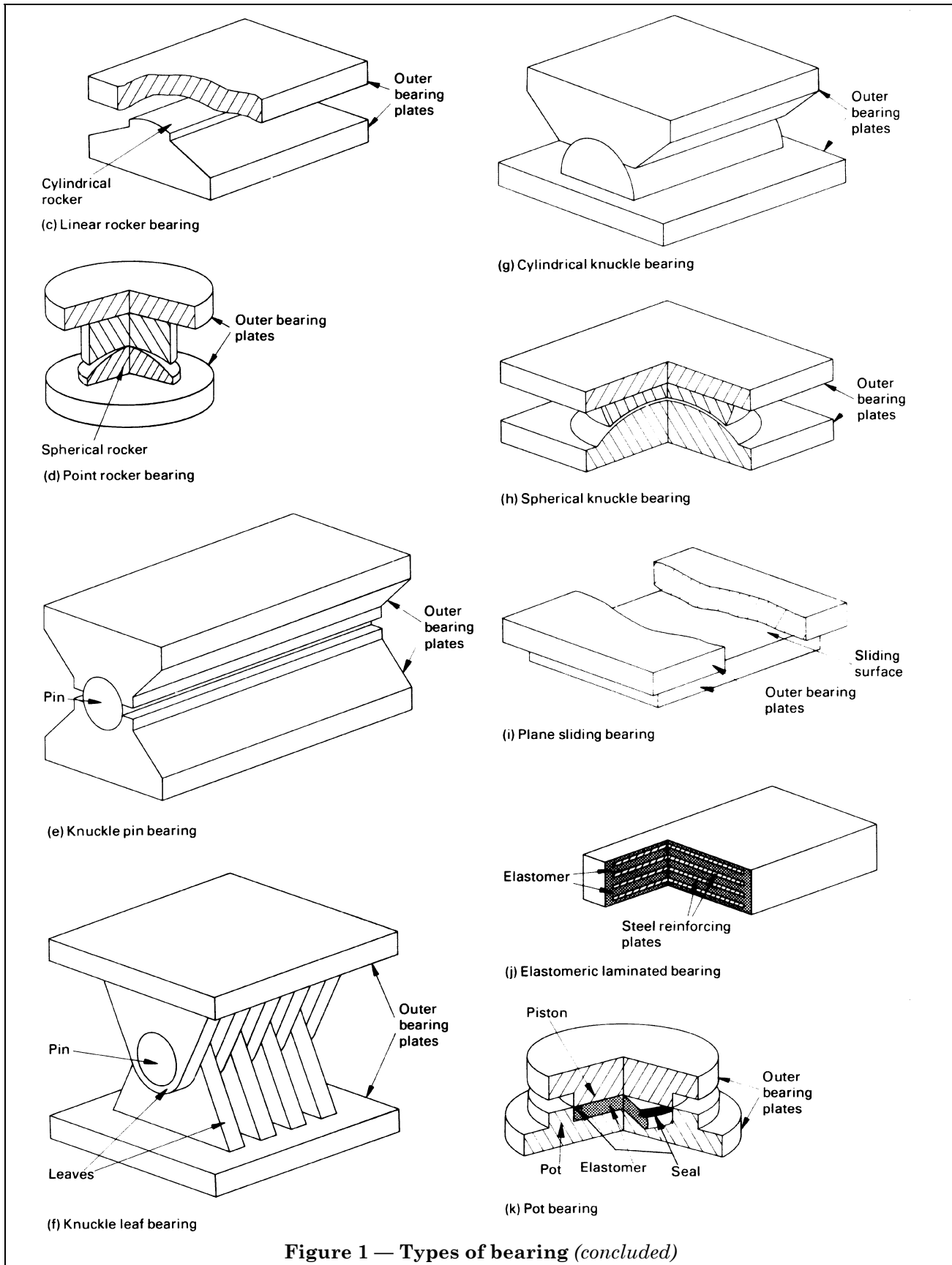
Table 1 — Bearing function

Type of bearing	Translation permitted		Rotation permitted			Loading resisted		
	Longitudinal	Transverse	Longitudinal (see note 1)	Transverse (see note 2)	Plan	Vertical	Longitudinal	Transverse
Roller								
Single cylindrical	✓	X	✓	X	X	✓	X	S
Multiple cylindrical	✓	X	X	X	X	✓	X	S
Non-cylindrical	✓	X	✓	X	X	✓	X	S
Rocker								
Linear	X	X	✓	X	X	✓	✓	S
Point	X	X	✓	✓	✓	✓	✓	✓
Knuckle								
Pin	X	X	✓	X	X	✓	✓	S
Leaf	X	X	✓	X	X	✓	✓	✓
Cylindrical	X	S	✓	X	X	✓	✓	S
Spherical	X	X	✓	✓	✓	✓	✓	✓
Plane sliding	✓	✓	X	X	✓	✓	S	S
Elastomeric								
Unreinforced	✓	✓	✓	✓	✓	✓	✓	✓
Laminated	✓	✓	✓	✓	✓	✓	✓	✓
Pot	X	X	✓	✓	S	✓	✓	✓
Guide								
Longitudinal	✓	X	✓	S	X	X	X	✓
Transverse	X	✓	S	✓	X	X	✓	X

Key
✓ suitable
X not suitable
S special consideration required

NOTE 1   Rotation about transverse axis.
NOTE 2   Rotation about longitudinal axis.

5.10 Outer bearing plates or spreader plates.
The outer plates of bearings should be so proportioned that concentrated loads are sufficiently distributed to ensure that the permissible pressures on the adjacent bridge structure are not exceeded. The effective area for distributing a load may be taken as the contact area of the bearing member communicating the load to the plate plus the area within the uninterrupted dispersal lines drawn at a maximum of 60° to the line of application of the bearing reaction from the bearing contact area (see Figure 2). Where the adjacent structure is liable to deform significantly under load, the interaction of the structure and the bearing should be considered in the design of both.

5.11 Use of different types of bearing. When bearings with differing characteristics are used on the same line of support, the resulting interactive effects should be considered both in the design of the bearings and the structure.
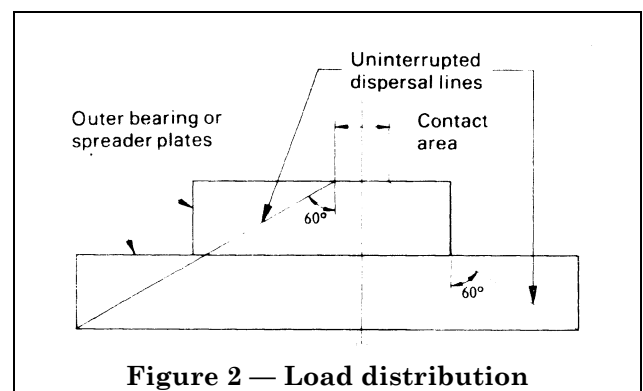
Figure 2 — Load distribution

5.12 Positioning of bearings. The position of bearings should be such that they are able to operate as assumed in the design of the structure. Any secondary effects resulting from either eccentric loading or movement not truly along a major axis of the bearing should be taken into account in the design of the bearing and surrounding structural elements. Bearings should be so located as to avoid the accumulation of dirt and debris likely to interfere with their performance and the structure so detailed that water is prevented from reaching the bearings.

5.13 Effects of variation within tolerances. The effects of variation in dimensions within the permitted tolerances of the bearing should be considered in the design of bearings, their connections and associated structure.

5.14 Loads and load effects

5.14.1 *General.* Bearings should be designed to resist the loads and load effects specified in Part 2 and, where applicable, the effects of creep, shrinkage and prestress, based on the recommendations given in Parts 4 and 5. Due allowance should be made for any eccentricities and specified dimensional tolerances in the application or distribution of loading. The design loads Q^* on the bearings should be the nominal loads multiplied by the appropriate values of γ_{fL}, all as specified in Part 2. Design load effects S^* at the serviceability limit state and ultimate limit state should be obtained by multiplying the effects of the design load Q^* by γ_{f3}. Values of γ_{f3} should be taken as 1.0 for the serviceability limit state and 1.1 for the ultimate limit state unless otherwise stated.

5.14.2 *Loading resulting from resistance to movement*

5.14.2.1 *General.* The bearings, their connections and associated structures should be designed to transmit forces arising from resistance to movement due to friction of mechanical bearings or shear resistance of elastomeric bearings.

5.14.2.2 *Limitation on friction coefficient values.* The friction coefficients in **5.14.2.3**, **5.14.2.4** and **5.14.2.5** are applicable when determining the load effects caused by friction; they are not applicable when calculating stabilizing forces against externally applied loads.

5.14.2.3 *Coefficient of friction for roller bearings.* For design purposes, the coefficient of friction for roller bearings should be as given in Table 2.

Table 2 — Coefficient of friction for roller bearings

	Type of roller bearing	Coefficient of friction
a)	Roller bearings with one or two rollers in steel complying with BS 4360, or cast iron complying with BS 2789 with a hardness of 110 HB to 240 HB	0.03
b)	Roller bearings as a) but with more than two rollers	0.05
c)	Single roller bearings with hardened steel contact surfaces with a hardness not less than 500 HB	0.02
d)	Multiple roller bearings as c)	0.03
e)	Single roller bearings and bearing plates in special high tensile corrosion resistant steel hardened throughout with finely ground finish with a hardness not less than 350 HB	0.01
f)	Multiple roller bearings as e)	0.015

NOTE   Values of hardness given in the above table are in accordance with BS 240-1.

5.14.2.4 *Coefficient of friction for sliding bearings.* Recommended design coefficients of friction for bearings with stainless steel sliding on pure PTFE continuously lubricated are given in Table 3.

NOTE   PTFE with lubricant contained in lubrication cavities complying with Section 9.2 can be considered as continuously lubricated for the purposes of Table 3.

Table 3 — Coefficient of friction for stainless steel sliding on pure PTFE continuously lubricated

Bearing stress	Coefficient of friction
N/mm^2	
5	0.08
10	0.06
20	0.04
30 and over	0.03

NOTE   Linear interpolation may be used for intermediate values.

The load used for calculating the bearing stress should be that with which the coefficient of friction is being used.

In the absence of test data, for design purposes, the coefficient of friction of pure unlubricated PTFE on stainless steel should be taken as twice the values given in Table 3. For PTFE sliding on any surface other than stainless steel, the coefficient of friction should be based on test data.

The values given in Table 3 may be used for air temperatures down to – 24 °C.

5.14.2.5 *Coefficient of friction for guides.* For guides with filled PTFE sliding on stainless steel, the coefficient of friction should be taken as four times the values given in Table 3 for pure continuously lubricated PTFE on stainless steel.

For guides with bronze sliding on steel or cast iron, the coefficient of friction should be taken as 0.35.

5.14.2.6 *Shear resistance of elastomeric bearings.* For elastomeric bearings where horizontal movement is accommodated by shear in the elastomer, the nominal horizontal force H due to expansion or contraction is given by the expression

$$H = AG\delta_r/t_q$$

where

  A is the actual plan area of the individual elastomer slabs;

  G is the shear modulus of the elastomer;

  δ_r is the maximum resultant horizontal relative displacement of parts of the bearing;

  t_q is the total thickness of elastomer in shear.

Typical values of G are given in **10.4**. An allowance of ± 20 % should be made in the calculated value of H to give the most adverse effect.

For movements due to live load effects on railway bridges, the value of G should be doubled. Due allowance should be made in the value of G for temperature variation.

5.14.3 *Restraints against translation.* Where restraints are provided on bearings to resist translational movements, they should be designed to resist either the design load effects or 5 % of the permanent vertical design load on the bearing, whichever is the greater.

If restraint against translation is to be provided by several bearings, consideration should be given to the effects of any clearance between working parts of the bearings and their guides during their service life and the effects of the stiffness of the structure on the distribution of the resulting loads between the bearings.

5.15 Movements

5.15.1 *General.* Bearings should have sufficient capacity to accommodate the worst combination of all the nominal movements calculated in accordance with the other Parts of BS 5400 multiplied by a factor comprising γ_{fL} and γ_{f3}. This factor will vary according to the cause of movement and the limit state.

For movement resulting from

  temperature effects,

  shrinkage and creep of concrete, and

  deformations, rotations and differential settlements of the supports,

the factor should be taken as 1.0 for the serviceability limit state and 1.3 for the ultimate limit state, when applicable.

For movement resulting from

  permanent and transient loading, and

  erection procedures (including prestressing and shrinkage of welds),

γ_{fL} should be obtained from Part 2 and γ_{f3} is as given in **5.14.1**.

Movements should be considered at the serviceability limit state for elastomeric bearings and at the ultimate limit state for all other types of bearing.

NOTE   Bridge movements are either reversible, e.g. due to temperature, transient loads, erection procedure, or irreversible, e.g. due to permanent load, prestress, creep, shrinkage and settlement of supports.

5.15.2 *Effects on other parts of the structure.* The design of other elements of the structure, including expansion joints, parapets and services, should take into consideration the effect of any change in geometrical configuration of the bearings.

5.15.3 *Movement indicators.* Movement indicators may be provided to help with routine inspection.

5.16 Materials. The design strength to be used for a given material and limit state is obtained by dividing the characteristic strength by the appropriate partial safety factor γm for the material being used. Unless otherwise stated γm should be taken as 1.0 for the serviceability limit state. For the ultimate limit state it should be as stated in the relevant clauses.

5.17 Bearing schedule. It is desirable to list the required bearing characteristics in a consistent and comprehensive manner. A typical schedule for this purpose is set out in appendix A.

6 Particular recommendations for roller and rocker bearings

6.1 General

6.1.1 *Function.* Roller bearings provide for translation in the direction of rolling only. Single rollers and rockers permit rotation about the line of contact, but multiple rollers require another element to provide for rotation.

6.1.2 *Curved surfaces.* Any individual curved contact surface should have only one radius.

6.1.3 *Surfaces in contact.* Surfaces in contact should have the same nominal strength and hardness.

6.1.4 *Length of rollers.* The length of a roller should not be less than its diameter.

6.1.5 *Guidance of rollers.* Mechanical guidance should be provided to ensure that the axis of rolling is maintained in the desired orientation. Where gearing is used, the pitch circle diameter of the gear teeth should be the same as that of the rollers.

6.1.6 *Prevention of sliding.* Provision should be made to, prevent contact surfaces of rocker bearings sliding one on the other.

6.2 Allowable loads on steel and cast iron roller and rocker bearings

6.2.1 *Design limit state.* Contact surfaces of roller and rocker bearings should be designed to meet the provisions of this Section of Part 9 at the serviceability limit state only. An allowance of $\gamma m = 1.0$ has been made in **6.2.2** to **6.2.5**.

NOTE   The ability of curved surfaces and plates to withstand deformation under load is dependent upon the hardness of the material of which they are made. There is not a constant relationship between hardness and yield stress of steel but there is between hardness and ultimate strength.

6.2.2 *Cylinder on curved surface.* The design load effect per unit length on a cylinder of radius R running in a concave seating of radius R_1 should not exceed

$$\frac{18\sigma_u{}^2}{E}\left(\frac{R_1 R}{R_1 - R}\right)$$

where

σ_u is the nominal ultimate tensile strength of the material;

E is the modulus of elasticity of the material.

6.2.3 *Cylinder on flat surface.* The design load effect per unit length on a cylinder of radius R in contact with a flat surface should not exceed

$18R\sigma_u{}^2/E$

where σ_u and E are as defined in **6.2.2**.

6.2.4 *Sphere in spherical seating.* The vertical design load effect on a spherical surface of radius R in a concave seating of radius R_1 should not exceed

$$\frac{170\sigma_u{}^3}{E^2}\left(\frac{R_1 R}{R_1 - R}\right)^2$$

where σ_u and E are as defined in **6.2.2**.

6.2.5 *Sphere on flat surface.* The vertical design load effect on a spherical surface of radius R in contact with a flat surface should not exceed

$170R^2\sigma_u{}^3/E^2$

where σ_u and E are as defined in **6.2.2**.

6.3 Flat-sided rollers. If movement requirements permit, flat-sided rollers may be used. Such rollers should be symmetrical about the vertical plane passing through the centre. The minimum width should not be less than one-third of the diameter or such that the bearing contact does not fall outside the middle third of the rolling surface when the roller is at the extremes of movements determined in accordance with **5.15**. Flat-sided rollers can be mounted at closer centres than the circular rollers of the same load capacity, resulting in more compact bearings.

6.4 Non-cylindrical rollers. A single roller type of bearing with differing radii for the upper and lower curved surfaces of the roller can be designed using the appropriate expression given in **6.2.2** and **6.2.3**. In all such designs, careful consideration should be given to the overall stability of the bearing. In particular, where the movement of the structure causes the line joining the upper and lower bearing contact points to depart from the vertical, a check should be made to ensure that the resulting horizontal force is resisted. Where the design of the bearing is such that horizontal movement is accompanied by a small vertical movement, the vertical movement should always be upward for horizontal movement either side of the central position to ensure stability of the structure.

6.5 Multiple rollers. For bearings having more than two rollers, the limiting values of design load effect should be taken as two-thirds of the value given by the expression in **6.2.3**.

7 Particular recommendations for knuckle and leaf bearings

7.1 General

7.1.1 *Function.* Knuckle and leaf bearings provide for rotation. Leaf bearings can be designed to resist uplift.

7.1.2 *Curved surfaces.* Any individual contact surface should have only one radius.

7.1.3 *Mating surfaces.* Mating surfaces should be turned and fitted.

7.1.4 *Separation of parts.* Horizontal forces applied to curved sliding surfaces tend to separate the contact surfaces of the bearing. Therefore, a check should be made to ensure that this tendency is adequately resisted by the coincident vertical loads. The calculations for the destabilizing horizontal force and the restoring vertical force should be based on the requirements for overturning specified in **4.6** of BS 5400-2:1978.

7.2 Pins. Pins should be of sufficient length to ensure that all parts connected thereby bear fully on them. Where the end of a pin is to be threaded, the threaded length of the pin should be turned to a smaller diameter and provided, where necessary, with a pilot nut to protect the thread.

7.3 Allowable bearing pressures for knuckle and leaf bearings

7.3.1 *Design limit state.* Contact surfaces of knuckle and leaf bearings should be designed to meet the provision of this Section of Part 9 at the serviceability limit state only.

7.3.2 *Bearing pressures.* With metal-to-metal contact, the bearing pressure on the projected contact area (length of seating × diameter of pin) due to the design load effects should not exceed:

   a) one-half of the nominal yield stress of the weaker material or 120 N/mm^2, whichever is the lesser, for all grades of steel;

   b) 30 N/mm^2, for phosphor-bronze;

   c) 25 N/mm^2, for leaded bronze.

These limiting values allow for a value of γm = 1.0

8 Particular recommendations for plane sliding bearings

8.1 Function. Plane sliding bearings normally provide for translation only; rotation can be permitted in accordance with **8.4**.

8.2 Sliding surfaces. This Section of Part 9 only provides design criteria for pure PTFE sliding on stainless steel.

8.3 Arrangement of sliding surfaces. Whenever possible, sliding bearings should have the larger of the sliding surfaces positioned above the smaller so that the sliding surfaces are kept clean.

8.4 Prevention of rotation. Flat sliding surfaces should not be used to accommodate rotation other than about an axis perpendicular to the plane of sliding. Other provision should be made for rotation about an axis in the plane of sliding.

9 Particular recommendations for sliding elements with PTFE

9.1 Surfaces mating with PTFE. Surfaces mating with PTFE should normally be stainless steel or hard anodized aluminium alloy; in all cases they should be harder than the PTFE and be corrosion resistant.

The mating surface should normally form the upper component and overlap the PTFE at the extremes of movement, determined in accordance with **5.15**.

9.2 Location of PTFE

9.2.1 *General.* PTFE should be located either by confinement or by bonding. In either case is is essential that it is backed by a metal plate. The rigidity of this plate should be such that the plate retains its unloaded shape and resists shear forces under all loading conditions. The PTFE should be bonded or mechanically restrained in situations where the sliding surfaces can separate.

9.2.2 *Confined PTFE.* Confined PTFE should be recessed into the metal backing plate. The shoulders of the recess should be sharp and square to restrict the flow of PTFE. The thickness of the PTFE and its protrusion from the recess should be related to its maximum plan dimension in accordance with Table 4.

9.2.3 *Bonded PTFE.* The thickness of bonded PTFE sheet should be related to its maximum plan dimension in accordance with Table 5.

9.3 Allowable sliding bearing pressures for pure PTFE

9.3.1 *Design limit state.* Flat and curved PTFE sliding surfaces should be designed to meet the provisions of this Section of Part 9 at the serviceability state only. An allowance for γ_m = 1.0 has been made in **9.3.2**.

Table 4 — Dimensions of confined PTFE

Maximum dimension of PTFE (diameter or diagonal)	Minimum thickness	Maximum projection above recess
mm	mm	mm
≤ 600	4.5	2.0
> 600, ≤ 1 200	5.0	2.5
>1 200, ≤ 1 500	6.0	3.0

Table 5 — Thickness of bonded PTFE

Maximum dimension of PTFE (diameter or diagonal)	Minimum thickness
mm	mm
≤ 600	1.0
> 600, ≤ 1 200 (max.)	1.5

9.3.2 *Maximum sliding contact pressures.* For pure PTFE in bearings the average pressure and the extreme fibre pressure should not exceed the values given in Table 6.

9.3.3 *Contact area.* For calculation of pressures, the contact surface may be taken as the gross area of the PTFE without deduction for the area occupied by lubrication cavities. In the case of curved surfaces, the gross area should be taken as the projected area of the contact surface.

Table 6 — Allowable sliding bearing pressures for pure PTFE

Design load effects	Maximum average contact pressure		Maximum extreme fibre pressure	
	Bonded PTFE	Confined PTFE	Bonded PTFE	Confined PTFE
	N/mm^2	N/mm^2	N/mm^2	N/mm^2
Permanent design load effects	20	30	25	37.5
All design load effects	30	45	37.5	55

9.4 Thickness of stainless steel sliding surfaces. The thickness of stainless steel sheet should be related to the difference between the PTFE and stainless steel dimension in the direction of movement in accordance with Table 7.

Table 7 — Thickness of stainless steel sheet

Dimensional difference between PTFE and stainless steel	Minimum thickness of stainless steel
mm	mm
≤ 300	1.5
> 300, ≤ 500	2.0
> 500, ≤ 1 500	3.0
NOTE A dimensional difference in excess of 1 500 mm requires special consideration.	

9.5 Fixing of stainless steel sheet

9.5.1 *General.* Stainless steel sheet should be attached to its backing plate by continuous welding along the edges or by fasteners supplemented by either peripheral sealing or full area bonding. It is essential that the method adopted ensures that the stainless steel sheet remains flat throughout its service life and interface corrosion cannot occur. The method of attachment should be capable of resisting the frictional force set up in the bearing, in the serviceability limit state.

9.5.2 *Attachment by welding.* The backing plate should extend beyond the edges of the stainless steel sheet to accommodate the weld and the two should be attached by a continuous fillet weld along the edges. The weld should not be proud of the stainless steel sheet.

9.5.3 *Attachment by fasteners.* Corrosion resistant fastenings compatible with the stainless steel should be used for securing the edges of the stainless steel sheet. They should be provided at all corners and along the outside edge outside the area of contact with the PTFE sliding surface with a maximum spacing of:

150 mm, for sheet 1.5 mm thick;

300 mm, for sheet 2.0 mm thick;

600 mm, for sheet 3.0 mm thick.

10 Particular recommendations for elastomeric bearings

10.1 General

10.1.1 *Function.* Elastomeric bearings can accommodate translational movements in any direction and rotational movements about any axis by elastic deformation. They should not be used in tension.

10.1.2 *Basis of design.* The basis of the design is that the elastomer is an elastic material, the deflection of which under a compressive load is influenced by its shape. Where reinforcing plates are included in the bearing they should be bonded to the elastomer to prevent any relative movement at the steel/elastomer interface.

10.1.3 *Design recommendations.* The design of elastomeric bearings should be such that:

a) their geometry satisfies the following conditions:

1) the maximum strain of the elastomer due to translational movement does not exceed the limits given in **10.2**;

2) the thickness of plain pad or strip bearings should not be less than 9 mm, to cater for irregularities in the seating surface;

3) the cover of elastomer to the steel interleaving plates in laminated bearings should be a minimum of 4.5 mm to all edges that would otherwise be exposed and a minimum of 2 mm to the contact surfaces; these values may need to be increased if there is a possibility of serious biological or chemical attack;

b) they can resist the applied loads without exceeding:

1) the mean pressure on plain pad or strip bearings given in **10.5**;

2) the maximum strain at any point in laminated bearings given in **10.6**;

3) the tensile stresses in the reinforcing plates given in **10.7**;

4) the stability criteria given in **10.8**;

c) their design movements satisfy the following conditions;

1) the vertical deflection calculated in accordance with **10.9** does not exceed the value specified by the Engineer;

2) the rotation of the bearing does not allow separation at the contact surfaces between the bearing and the structure; this may be deemed to be satisfied if the recommendations of **10.10** are met;

3) the force exerted on the structure by the bearing resisting translational movement calculated in accordance with **5.14.2.6** does not exceed the value specified by the Engineer;

d) either they do not slip under the applied forces when checked in accordance with **10.11** or they are mechanically fixed to the structure above and below.

10.1.4 *Design limit state.* Elastomeric bearings should be designed to meet the provisions of this Section of Part 9 at the serviceability limit state only.

10.2 Shear strain. The shear strain ϵ_q of the elastomer due to translational movement should not exceed 0.7, as given by the expression

$$\epsilon_q = \delta_r / t_q$$

where

δ_r is the maximum resultant horizontal relative displacement of parts of the bearing obtained by vectorial addition of δ_b and δ_1;

δ_b is the maximum horizontal relative displacement of parts of the bearing in the direction of dimension b of the bearing due to all design load effects (see Figure 3);

δ_1 is the maximum horizontal relative displacement of parts of the bearing in the direction of dimension l of the bearing due to all design load effects (see Figure 3);

t_q is the total thickness of the elastomer in shear.

10.3 Shape factor

10.3.1 *General.* The shape factor S is a means of taking account of the shape of the elastomer in strength and deflection calculations. It is the ratio of the effective plan area of an elastomeric slab to its force-free surface area and is calculated as given in **10.3.2** to **10.3.4**.

NOTE   The factors associated with the effective thickness of the elastomer t_e in the expressions given in **10.3.2** to **10.3.4** allow for the fact that some slip will take place on faces restrained by friction only.

10.3.2 *Plain pad bearings.* For plain pad bearings,

$$S = A / l_p t_e$$

where

A is the overall plan area of the bearing;

l_p is the force-free perimeter of the bearing, including that of any holes if these are not later effectively plugged;

t_e is the effective thickness of elastomer in compression, which is taken as $1.8t$;

t is the actual thickness of elastomer.

NOTE   For a rectangular bearing without holes,
$l_p = 2(l + b)$
where
l is the overall length of the bearing;
b is the overall width of the bearing.

10.3.3 *Strip bearings.* For strip bearings,

$$S = b/2t_e$$

where b and t_e are as defined in **10.3.2**.

10.3.4 *Laminated bearings* (see Figure 3). For laminated bearings, the shape factor S for each individual elastomer layer is given by the expression

$$S = A_e/l_p t_e$$

where

A_e is the effective plan area of the bearing, i.e. the plan area common to elastomer and steel plate, excluding the area of any holes if these are not later effectively plugged;

l_p is as defined in **10.3.2**;

t_e is the effective thickness of an individual elastomer lamination in compression; it is taken as the actual thickness, t_i, for inner layers, and $1.4t_i$ for outer layers;

t_i is the thickness of an individual elastomer layer.

NOTE   For a rectangular bearing without holes,
$A_e = i_e b_e$ and
$l_p = 2(l_e + b_e)$
where
l_e is the effective length of the bearing (= length of reinforcing plates);
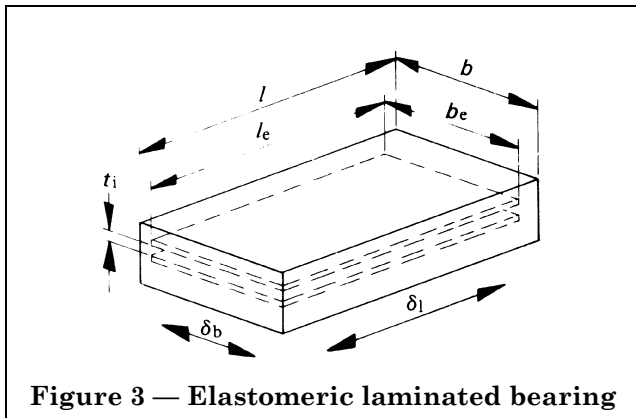b_e is the effective width of the bearing (= width of reinforcing plates).

Figure 3 — Elastomeric laminated bearing

10.4 Moduli of elastomer. The shear modulus G should normally be obtained experimentally. Table 8 gives typical values of G and also an appropriate value for the bulk modulus E_b.

Table 8 — Typical elastomer moduli

Nominal hardness (see note)	Shear modulus, G	Bulk modulus, E_b
IRHD	N/mm^2	N/mm^2
50	0.6	
60	0.9	2 000
70	1.2	
NOTE Values of hardness in the above table are in accordance with BS 903-A26.		

The variation of the shear modulus with low temperatures should be established by testing. For temperatures below 0 °C, the values of G may, in the absence of test data, be taken as equal to the values in Table 8 multiplied by

$$1 - \frac{T}{25}$$

where T is the minimum shade air temperature (in °C).

NOTE T is negative for temperatures below 0 °C; the increased value of G applies only when variations in load and displacement take place at low temperature.

10.5 Design pressure on plain pad and strip bearings. The mean design pressure (i.e. V/A) on a plain pad or strip bearing should not exceed GS or $5G$, whichever is the lesser, where

V is the vertical design load effect;

A is the overall plan area of the bearing;

G is the shear modulus of the elastomer;

S is the shape factor of the elastomer slab.

10.6 Maximum design strain in laminated bearings. At any point in the bearing the sum of the nominal strains due to all load effects, ϵ_t, as given by the expression

$$\epsilon_t = k(\epsilon_c + \epsilon_q + \epsilon_\alpha)$$

should not exceed 5.0 (see note)

where

k is a factor equal to
1.5, for live load effects;
1.0, for all other effects (including wind and temperature);

ϵ_c is the nominal strain due to compressive loads, where ϵ_c is given by the expression
$$\epsilon_c = 1.5V/GA_1S$$

ϵ_q is the shear strain due to translational movements as defined in **10.2**;

ϵ_α is the nominal strain due to angular rotation, where ϵ_α is give by the expression
$$\epsilon_\alpha = (b_e{}^2\alpha_b + l_e{}^2\alpha_l)/2t_i\Sigma t_i$$

V and G are as defined in **10.5**;

A_1 is the reduced effective plan area due to the loading effect, where A_1 is given by the expression

$$A_1 = A_e\left(1 - \frac{\delta_b}{b_e} - \frac{\delta_l}{l_e}\right)$$

A_e is as defined in **10.3.4**;

δ_b and δ_l are as defined in **10.2**;

b_e is the effective width of the bearing (see Figure 3);

l_e is the effective length of the bearing (see Figure 3);

S is the shape factor;

α_b is the angle of rotation across the width, b, of the bearing (in radians);

α_l is the angle of rotation (if any) across the length, l, of the bearing (in radians);

t_i is the thickness of the individual layer of elastomer being checked;

Σt_i is the total thickness of elastomer in the bearing.

NOTE   5 is an empirical value which has been found from fatigue tests on three types of elastomeric bearing to best fit the limiting criterion for a strain calculated by the method given here. It should not be taken to reflect the ultimate strain of the material.

10.7 Reinforcing plate thickness. To resist induced tensile stresses under load, the minimum thickness of the steel plates in a laminated bearing should be

$1.3V(t_1 + t_2)/A_1\sigma_s$ but not less than 2 mm

where

V and A_1 are as defined in **10.6**;

t_1 and t_2 are the thicknesses of elastomer on either side of the plate;

σ_s is the stress in the steel, which should be taken as not greater than the yield stress, nor greater than

120 N/mm², for plates with holes;

290 N/mm², for plates without holes.

10.8 Stability

NOTE   Elastomeric bearings will be stable if the recommendations of **10.8.1** and **10.8.2** are satisfied.

10.8.1 *Plain pad and strip bearings.* For plain pad and strip bearings, the thickness should not exceed one-quarter of the least lateral dimension.

10.8.2 *Laminated bearings.* For laminated bearings, the pressure, V/A_1, should satisfy the expression

$V/A_1 < 2b_e GS'/3 \, \Sigma t_i$

The above criterion will be satisfied automatically if

$\Sigma t_i < b_e/4$

where

V, b_e, G, A_1 and Σt_i are as defined in **10.6**;

S′ is the shape factor for the thickest elastomer layer.

10.9 Vertical deflection

10.9.1 *General.* The vertical deflection of elastomeric bearings should be estimated from the expressions given in **10.9.2** to **10.9.4**. These expressions may be used to estimate the change in deflection between one-third of the total load and full load, with an accuracy of the order of ± 25 %.

NOTE 1   The actual deflection of a bearing includes an initial bedding down phase that can produce deflections of approximately 2 mm. Thereafter, the stiffness of the bearing increases with increasing load. Where the vertical deflection under load is critical to the design of the structure, the stiffness of the bearing should be ascertained by tests. However, a variation of as much as ± 20 % from the observed mean value may still occur. When a number of similar bearings are used at a support and the differential stiffness between the bearings is critical for the structure, a variation of compressive stiffness should be allowed in the design equal to either ± 15 % of the value estimated from **10.9.2** to **10.9.4** or ± 15 % of the mean value observed in tests.

NOTE 2   The calculations for the deflection of plain pad and strip bearings are likely to underestimate the deflection under permanent load and overestimate the deflection under transient loads.

10.9.2 *Plain pad bearings.* The total vertical deflection of a plain pad bearing, Δ, is given by the expression

$$\Delta = \frac{V_t}{5AGS^2} + \frac{Vt}{AE_b}$$

where

V, G and S are as defined in **10.6**;

t and A are as defined in **10.3.2**;

E_b is the bulk modulus of the elastomer.

10.9.3 *Strip bearings.* The total vertical deflection of a strip bearing, Δ, is given by the expression

$\Delta = Vt/5AGS^2$

where

V, G and S are as defined in **10.6**;

t and A are as defined in **10.3.2**;

10.9.4 *Laminated bearings.* The total vertical deflection of a laminated bearing, Δ, is given by the expression

$\Delta = \Sigma\delta$

where

$$\delta = \frac{Vt_i}{5A_e GS^2} + \frac{Vt_i}{A_e E_b}$$

δ is the vertical deflection of an individual layer of elastomer;

V, t_i, G and S are as defined in **10.6**;

A_e is as defined in **10.3.4**;

E_b is the bulk modulus of the elastomer.

10.10 Rotational limitation

NOTE   The rotational limitation is satisfied if the recommendations of **10.10.1** and **10.10.2** are satisfied.

10.10.1 *Plain pad and laminated bearings.* For plain pad and laminated bearings, the total vertical deflection, Δ, should satisfy the expression

$\Delta > (b_e\alpha_b + l_e\alpha_l)$

where b_e, α_b, l_e and α_l are as defined in **10.6**.

10.10.2 *Strip bearings.* For strip bearings, the total vertical deflection, Δ, should satisfy the expression

$\Delta > b_e\alpha_b/3$

where b_e and α_b are as defined in **10.6**.

10.11 Fixing of bearings. If there is insufficient friction to prevent relative movement between the bearing and the structure under the most adverse loading conditions, positive means of location should be provided. Friction may be considered adequate if:

under all loading conditions,

numerically, $H < 0.1(V + 2A_1)$;

and under permanent loads,

$V/A_1 > 1 + \dfrac{b}{l}$ for plain pad and strip bearings

$V/A_1 > 2$ for laminated bearings

where all the terms and their units are as follows:

H is the design force exerted by the bearing to resist translational movement (in N);

V is the vertical design load effect (in N);

A_1 is the reduced effective plan area as defined in **10.6** (in mm^2);

b is the overall width of the bearing (in mm) (see Figure 3);

l is the overall length of the bearing (in mm) (see Figure 3).

NOTE Positive means of location may limit the depth available for shear. This should be considered in the design of the bearing.

11 Particular recommendations for pot bearings

11.1 Function. Pot bearings provide for rotational movements.

11.2 Design. The stress in the elastomer in pot bearings due to the design load effects is limited by the effectiveness of the seal preventing it from extruding between the piston and the pot wall, but it should not exceed 40 N/mm^2 at the serviceability limit state. The lateral pressure exerted on the confining cylinder walls resulting from vertical loading on the elastomeric pad can be considered to be that produced by the pad acting as a fluid. Because details of pot bearings vary considerably and stress analysis is complex, their design should be verified by testing.

11.3 Rotation. The rotation of pot bearings about a horizontal axis should be limited so that the vertical strain induced at the perimeter of the elastomeric pad, at the serviceability limit state, does not exceed 0.15.

NOTE The thickness and hardness of the elastomer have a direct relationship with the resistance of pot bearings to rotation, as does the friction between the piston and the pot. The latter is increased by increased force acting on the bearing. Sufficient test results should be available for a given elastomer stress, hardness and thickness to enable the resistance of the bearing to rotation to be calculated; otherwise prototype tests should be made.

11.4 Seal. A sealing device should be provided to prevent the elastomer extruding between the piston and the pot wall. This seal should be effective under serviceablility limit state loadings.

12 Particular recommendations for guides

12.1 Function. Guides are used to constrain the movement of structures in a particular direction. They may be included in an independent guide bearing or form a part of a bearing performing other functions.

12.2 Sliding surfaces for guides

12.2.1 *PTFE facing*

12.2.1.1 *General.* Guides used for lateral restraint may be faced with unfilled or filled PTFE provided the frictional resistance to movement at the guides is either significantly smaller than that of the main bearing or the resulting frictional effects are taken into account. Commonly used materials for facing guides are:

a) unfilled PTFE;

b) PTFE filled with up to 25 % by mass of glass fibres;

c) lead filled PTFE in a bronze matrix;

d) PTFE reinforced with a metal mesh.

12.2.1.2 *Lubrication.* For this application, lubrication of PTFE should not be considered to reduce friction.

12.2.1.3 *Attachment.* It is essential that all PTFE should be securely attached to the guides; reliance should not be placed on bonding alone for pure PTFE.

12.2.2 *Unfaced surfaces.* For surfaces not intended to be in permanent contact, metal-to-metal contact may be permitted. The metal should be corrosion resistant.

12.3 Allowable bearing pressures on guides

12.3.1 *PTFE.* Under all serviceability design load effects, the average pressure on glass filled PTFE in guides should not exceed 45 N/mm^2, and on PTFE in a metal matrix 60 N/mm^2. Permissible values for other PTFE materials should be established by tests. In the absence of test data, the values for unfilled PTFE should be used.

For calculation of pressures, the contact surface may be taken as the gross area of the PTFE without deduction for the area occupied by any lubrication cavities.

12.3.2 *Bronze.* At the serviceability limit state, the contact bearing stress for bronze should not exceed 30 N/mm^2.

Appendix A Typical bridge bearing schedule

A.1 General. The purpose of a bridge bearing schedule (see Table 9) is to list the information normally required for the design of the bearings for a particular bridge. A drawing should accompany the schedule showing the layout of the bearings with identification marks, including a typical cross section of the bridge and particulars of any special locating requirements. Bearing functions should be indicated on the drawing by the symbols given in Table 10. When a particular type of bearing is envisaged it should be described in accordance with Table 1. When several types may satisfy the requirements set out in the schedule the items should be left open or possible alternative types listed.

Every item in the typical shedule should be considered, but some may not be applicable to a particular bearing. Only relevant information should be given and when an item in the schedule is not applicable this should be stated. Additional information should be added when special conditions exist.

An appropriately completed schedule should be suitable for inclusion in the tender documents. A similar schedule prepared by the bearing manufacturer would help the Engineer to select suitable bearings from a catalogue.

A.2 Information for Table 9. The following information gives guidance for completing each item in the typical bridge bearing schedule.

a) *Bearing identification mark.* Bearings with different functions or load-carrying requirements should be distinguished by a unique reference mark.

b) *Number off.* The quantity required of each particular mark of bearing should be stated.

c) *Seating materials.* The materials on which each outer bearing plate bears should be stated as it may affect the design and finish of these plates.

d) *Allowable average contact pressure on seating.* The allowable average pressure over the effective area of contact (see **5.10**) of seatings due to the maximum design load effect should be given.

e) *Design load effects.* The worst individual values of the design load effects should be given in the schedule. The most adverse combination of these values is usually sufficient for a satisfactory design of bearing. Only in special cases would greater economy be achieved by considering the actual coexistent values of load effects, in which case these should be given in detail.

f) *Translation.* Maximum translation movements of the bridge superstructure at a bearing should be determined and factored in accordance with **5.15**. Allowance should be made for any movement of the supporting structures.

Transverse and longitudinal movements are normally in a direction perpendicular and parallel to the longitudinal axis of the bridge span respectively. Where there is any likelihood of ambiguity (e.g in the case of skew spans) directions of movement should be clearly indicated on the accompanying drawing.

g) *Rotation.* The maximum irreversible and reversible rotational movements at the serviceability limit state that the bearing is required to accommodate should be given in radians. In the case of elastomeric bearings, the maximum rate, i.e. the ratio

$$\frac{\text{design rotation (in radians)}}{\text{coexistent design vertical load (in 100 kN)}}$$

should also be given.

h) *Maximum bearing dimensions.* The maximum size of bearing that can be accommodated should be stated, as this will give optimum flexibility in the design of the bearing.

i) *Tolerable movement of bearing under transient load.* The maximum movement that can be tolerated at the bearing under transient loads, in directions in which the bearing is meant to provide restraint, should be given.

j) *Allowable resistance to translation.* In the design of the structure, resistance to translation movements may be of significance and in that case the maximum acceptable horizontal force generated by the bearing should be given for the serviceability limit state. For elastomeric bearings, the values to be given are those for slowly applied movements at normal temperatures. (Any necessary extra allowance for low temperatures and rapidly applied movements should be made by the designer of the structure.)

k) *Allowable resistance to rotation.* In the design of the structure, resistance to rotation may be of significance and in that case the maximum acceptable moment of resistance generated by the bearing when subjected to the critical design load effects should be given for the seviceability limit state. Elastomeric bearings should be treated as in item j).

l) *Type of fixing.* Various means of fixing the bearings to the superstructure and substructure are available, appropriate to differenct types of bearing. Particular requirements, such as friction, bolts, dowels, keys or other devices, should be stated.

If a proportion of the translational force is to be carried by friction, that proportion and the necessary surface condition should be stated.
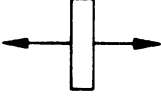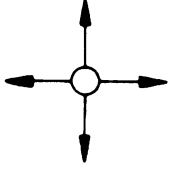
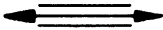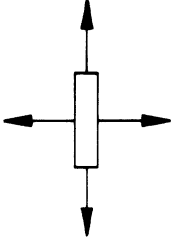m) *Special requirements.* Details of any special conditions, e.g. extreme exposure, high ozone concentration, limited access, non-horizontal seating, bearings not square to beams, temporary restraints, should be given. The highest and lowest temperatures and details of any special biological conditions to which the bearing may be exposed in service should be stated if they are different from those normally experienced in the UK.

Table 9 — Typical bridge bearing schedule

Bridge name or reference

Bearing identification mark							
Number off							
Seating material[a]		Upper surface					
		Lower surface					
Allowable average contact pressure (N/mm^2)		Upper face	Serviceability				
			Ultimate				
		Lower face	Serviceability				
			Ultimate				
Design load effects (kN)	Serviceability limit state		Vertical	max.			
				permanent			
				min.			
			Transverse				
			Longitudinal				
	Ultimate limit state		Vertical				
			Transverse				
			Longitudinal				
Translation (mm)	Serviceability limit state	Irreversible	Transverse				
			Longitudinal				
		Reversible	Transverse				
			Longitudinal				
	Ultimate limit state	Irreversible	Transverse				
			Longitudinal				
		Reversible	Transverse				
			Longitudinal				
Rotation (radians)	Serviceability limit state	Irreversible	Transverse				
			Longitudinal				
		Reversible	Transverse				
			Longitudinal				
	Maximum rate (radians/100 kN)		Transverse				
			Longitudinal				
Maximum bearing dimensions (mm)	Upper surface		Transverse				
			Longitudinal				
	Lower surface		Transverse				
			Longitudinal				
	Overall height						
Tolerable movement of bearing under transient loads (mm)		Vertical					
		Transverse					
		Longitudinal					
Allowable resistance to rotation under serviceability limit state (kN)		Transverse					
		Longitudinal					
Allowable resistance to translation under serviceability limit state (kN m)		Transverse					
		Longitudinal					
Type of fixing required		Upper face					
		Lower face					

State any other requirements on separate sheet.

[a] For example cement mortar, epoxy, mortar, in situ concrete, precast concrete, steel, timber.

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Table 10 — Symbolic representation of bearing functions

Symbol	Function	Symbol	Function
○	All translation fixed Rotation all round	▯	All translation fixed Rotation about one axis only
←○→	Horizontal movement constrained in one direction only Rotation all round	←▯→	Horizontal movements constrained perpendicular to rotational axis Rotation about one axis only
↔○↕	Horizontal movement in all directions Rotation all round	↕▯	Horizontal movement constrained parallel to rotational axis Rotation about one axis only
◁═▷	Movement constrained in one direction only No vertical load	↔▯↕	Horizontal movement in all directions Rotation about one axis only

NOTE   All bearings can support a vertical load unless otherwise indicated. Symbols represent plan view on bearing.

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Publications referred to

BS 240, *Method for Brinell hardness test.*

BS 240-1, *Testing of metals.*

BS 903, *Methods of testing vulcanized rubber.*

BS 903-A26, *Determination of hardness.*

BS 2789, *Iron castings with spheroidal or nodular graphite.*

BS 4360, *Specification for weldable structural steels.*

BS 5400, *Steel, concrete and composite bridges.*

BS 5400-1, *General statement.*

BS 5400-2, *Specification for loads.*

BS 5400-3, *Code of practice for design of steel bridges.*

BS 5400-4, *Code of practice for design of concrete bridges.*

BS 5400-5, *Code of practice for design of composite bridges.*

BS 5400-9, *Bridge bearings.*

BS 5400-9.2, *Specification for materials, manufacture and installation of bridge bearings.*

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