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Barriers in and about buildings – Code of practice

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Contents

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Foreword

Publishing information

This British Standard is published by BSI and came into effect on 31 March 2011. It was prepared by Subcommittee B/208/1, *Stairs and walkways – Industrial stairs*, under the authority of Technical Committee B/208, *Stairs and walkways*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 6180:1999, which is withdrawn.

Information about this document

This is a full revision of the standard, and introduces the following principal changes:

- inclusion of Table 2.
- changes to the rules on deflection, given in **6.4.1**.

In view of the variety of materials available for barrier construction and the wide range of possible uses for barriers, this British Standard does not attempt to standardize methods of design but refers instead to existing structural design codes. Clause **4** allows users freedom to choose materials and methods of design and construction not specifically mentioned in this code, subject to the provision of research data and test results.

The safety factors implicit in this British Standard provide adequate levels of protection in the circumstances given. However, in the case of multifunction buildings, for example, the recommendations should be considered with reasoned judgement to provide a suitable design.

Annex A and Annex B are normative.

Use of this document

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

Attention is drawn to the fact that statutory legislation such as the Building Regulations 2010 [1] (applicable to England and Wales), the Building (Scotland) Regulations 2004 [2], the Building (Amendment) Regulations (Northern Ireland) 2010 [3], the Safety of Sports Grounds Act 1975 [4], Fire Safety and Safety of Places Sports Act 1987 [5], the Safety of Places of Sport Regulations 1988 [6], the Football Spectators Act 1989 [7] and the Regulatory Reform (Fire Safety) Subordinate Provisions Order 2006 [8] might impose more stringent requirements in certain circumstances.

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

Presentational conventions

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

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

Contractual and legal considerations

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

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

1 Scope

This British Standard gives recommendations and guidance for the design and construction of temporary and permanent barriers to be provided in and about buildings and places of assembly, such barriers being positioned and designed to protect persons from various hazards and to restrict or control the movement of persons or vehicles.

This British Standard applies to:

a) barriers that indicate routes;

b) barriers capable of stopping or diverting moving vehicles within areas where vehicle speed is restricted to a maximum of 16 km/h (4.44 m/s, 10 mile/h);

c) walls, glazing and other elements of buildings or structures where such elements act as protective barriers;

d) areas other than spectator areas of sports halls and buildings used for spectator sports.

This British Standard does not apply to:

1) barriers for resisting impact from vehicles travelling at speeds greater than 16 km/h, e.g. bridge parapets beyond the curtilage of a building, or highway safety barriers (see BS 6779);

2) barriers used in building operations and works of engineering construction;

3) safety barriers, with or without opening gate features, for the protection of children up to 24 months, where the safety requirement is covered by a specific safety standard, e.g. BS EN 1930;

4) permanent means of access to machinery (see BS EN ISO 14122, all parts);

5) barriers used in spectator areas of sports halls, and buildings used for spectator sports (see BS EN 13200, all parts).

2 Normative references

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

BS 476-7, *Fire tests on building materials and structures – Part 7: Method of test to determine the classification of the surface spread of flame of products*

BS 952-1, *Glass for glazing – Part 1: Classification*

BS 1449-1 (all parts), *Steel plate, sheet and strip – Carbon and carbon-manganese plate, sheet and strip*

BS 3416, *Specification for bitumen-based coatings for cold application, suitable for use in contact with potable water*

BS 3987, *Specification for anodic oxidation coatings on wrought aluminium for external architectural applications*

BS 4592-0, *Industrial type flooring and stair treads – Part 0: Common design requirements and recommendations for installation*

BS 4842, *Specification for liquid organic coatings for application to aluminium alloy extrusions, sheet and preformed sections for external architectural purposes, and for the finish on aluminium alloy extrusions, sheet and preformed sections coated with liquid organic coatings*

BS 4921:1988, *Specification for sherardized coatings on iron or steel*

BS 5350 (all parts), *Methods of test for adhesives*

BS 6100 (all parts), *Glossary of building and civil engineering terms*

BS 6206, *Specification for impact performance requirements for flat safety glass and safety plastics for use in buildings* [1)]

BS 6262 (all parts), *Glazing for buildings*

BS 6496, *Specification for powder organic coatings for application and stoving to aluminium alloy extrusions, sheet and preformed sections for external architectural purposes, and for the finish on aluminium alloy extrusions, sheet and preformed sections coated with powder organic coatings*

BS 7668, *Weldable structural steels – Hot finished structural hollow sections in weather resistant steels – Specification*

BS 8221 (all parts), *Code of practice for cleaning and surface repair of buildings*

BS 8417, *Preservation of timber – Recommendations*

BS EN 572-3, *Glass in building – Basic soda lime silicate glass products – Part 3: Polished wire glass*

BS EN 572-6, *Glass in building – Basic soda lime silicate glass products – Part 6: Wired patterned glass*

BS EN 1011-1, *Welding – Recommendations for welding of metallic Materials – Part 1: General guidance for arc welding*

BS EN 1011-2*, Welding – Recommendations for welding of metallic Materials – Part 2: Arc welding of ferritic steels*

BS EN 1090-1, *Execution of steel structures and aluminium structures – Part 1: Requirements for conformity assessment of structural components*

BS EN 1090-2, *Execution of steel structures and aluminium structures – Part 2: Technical requirements for the execution of steel structures*

BS EN 1930, *Child care articles – Safety barriers – Safety requirements and test methods*

BS EN 1982, *Copper and copper alloys – Ingots and castings*

BS EN 1991-1-1:2002, *Eurocode 1: Actions on structures – Part 1-1: General actions – Densities, self-weight, imposed loads for buildings*

BS EN 1991-1-4, *Eurocode 1: Actions on structures – Part 1-4: General actions – Wind actions*

BS EN 1992 (all parts), *Eurocode 2 – Design of concrete structures*

BS EN 1993 (all parts), *Eurocode 3 – Design of steel structures*

BS EN 1995 (all parts), *Eurocode 5 – Design of timber structures*

BS EN 1996 (all parts), *Eurocode 6 – Design of masonry structures*

BS EN 1999 (all parts), *Eurocode 9 – Design of aluminium structures*

[1)] This British Standard only applies to plastics materials.

BS EN 10025 (all parts), *Hot rolled products of structural steels*

BS EN 10029, *Specification for tolerances on dimensions, shape and mass for hot rolled steel plates 3 mm thick or above*

BS EN 10088-2, *Stainless steels – Part 2: Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes*

BS EN 10088-3, *Stainless steels – Part 3: Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes*

BS EN 10143, *Continuously hot-dip metal coated steel sheet and strip – Tolerances on dimensions and shape*

BS EN 10210 (all parts), *Hot finished structural hollow sections of non-alloy and fine grain structural steels*

BS EN 10216-5, *Seamless steel tubes for pressure purposes – Technical delivery conditions – Part 5: Stainless steel tubes*

BS EN 10217-7, *Welded steel tubes for pressure purposes – Technical delivery conditions – Part 7: Stainless steel tubes*

BS EN 10219-1, *Cold formed welded structural hollow sections of non-alloy and fine grain steels – Part 1: Technical delivery requirements*

BS EN 10219-2, *Cold formed welded structural hollow sections of non-alloy and fine grain steels – Part 2: Tolerances, dimensions and sectional properties*

BS EN 10253-1, *Butt-welding pipe fittings – Part 1: Wrought carbon steel for general use and without specific inspection requirements*

BS EN 12163, *Copper and copper alloys – Rod for general purposes*

BS EN 12164, *Copper and copper alloys – Rod for free machining purposes*

BS EN 12167, *Copper and copper alloys – Profiles and rectangular bar for general purposes*

BS EN 12206-1, *Paints and varnishes. Powder coating of aluminium alloys for architectural purposes – Part 1: coatings prepared from coating powder*

BS EN 12600, *Glass in building – Pendulum test – Impact test method and classification for flat glass*

BS EN 13200 (all parts), *Spectator facilities*

BS EN 15644, *Traditionally designed prefabricated stairs made of solid wood – Specifications and requirements*

BS EN ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods (ISO 1461:2009)*

BS EN ISO 2063, *Thermal spraying – Metallic and other inorganic coatings – Zinc, aluminium and their alloys*

BS EN ISO 2560, Welding Consumables – *Covered electrodes for manual metal arc welding of non-alloy and fine grain steels – Classification*

BS EN ISO 6158, *Metallic coatings – Electrodeposited coatings of chromium for engineering purposes*

BS EN ISO 7599, *Anodizing of aluminium and its alloys – General specifications for anodic oxidation coatings on aluminium (ISO 7599:2010)*

BS EN ISO 14122 (all parts), *Safety of machinery*

DD CEN/TS, *Prefabricated timber stairs – Mechanical test methods*

PD 6484, *Commentary on corrosion at bimetallic contacts and its alleviation*

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS 6100 (all parts) and the following apply.

3.1 barrier
element of building or structure, permanent or temporary, intended to prevent persons from falling and to retain, stop or guide persons or vehicles

3.2 datum
finished level on which people may stand on a floor, roof, wide parapet, balcony, ramp, pitch line of stairs, etc.

NOTE See Figure 1.

3.3 design level
level at which the horizontal force on the barrier is assumed to act for the purposes of design

NOTE See Figure 1.

3.4 juliette balcony
balcony which does not project from the side of a building and takes the form of a barrier in front of full-length openable doors

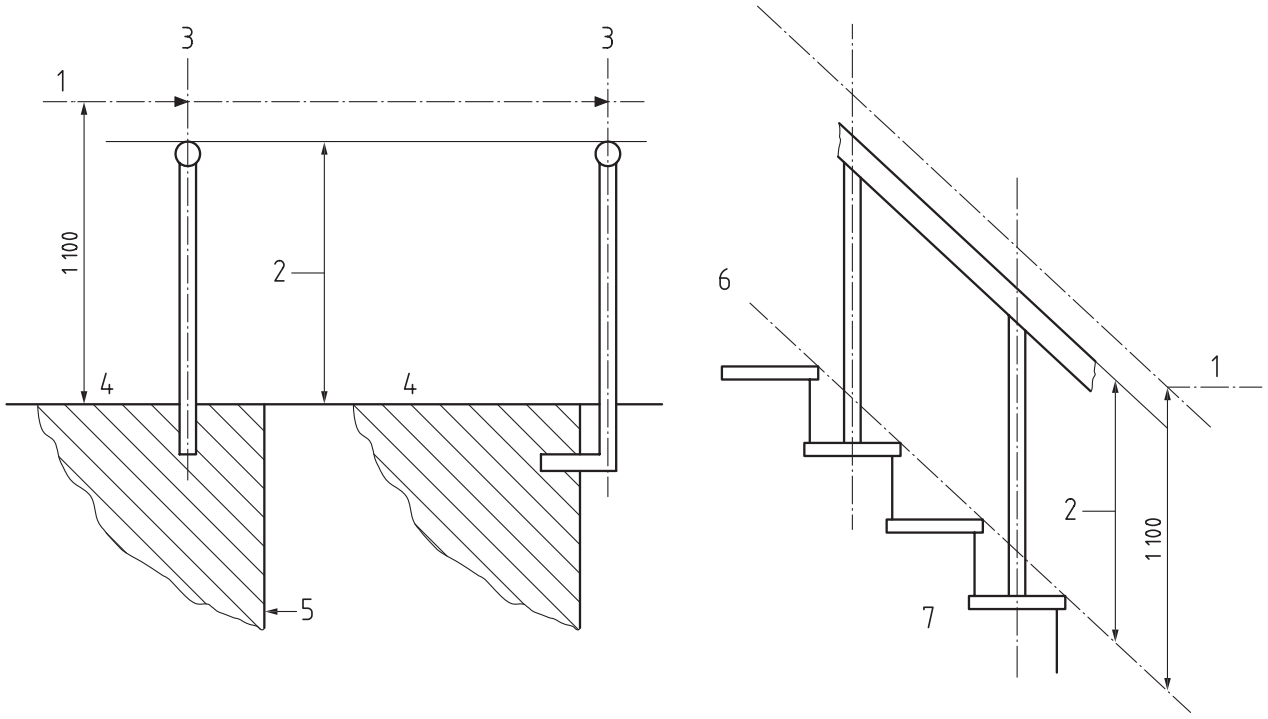
NOTE These are sometimes also referred to as "Juliet" balconies.

3.5 manifestation
technique for enhancing a person's awareness of the presence of transparent glass areas

3.6 safety glass/plastics material
glass or plastics sheet material which remains unbroken or achieves a specified resistance or fails in a prescribed manner when tested in accordance with a relevant technical standard

3.7 top rail
structural rail which might also act as a handrail

Figure 1 **Datum, barrier height and design height**



Key

1 Design level
2 Barrier height
3 Horizontal load
4 Datum = FFL
5 Edge of floor
6 Datum = pitch line
7 Stairs

NOTE In design, the horizontal uniformly distributed line load acts at a height of 1.1 m above datum level, irrespective of the actual height of the element.

4 Materials, components and methods of design and construction

*NOTE Recommendations for the detailed design and construction of barriers using various materials, components and methods are given in Clause **7** to Clause **13**.*

Where materials, components and methods of design and construction are not specifically covered by these clauses or by any other British Standard, the designer should either be satisfied that the materials and methods to be employed are such as to ensure durability, integrity and a level of performance at least equal to that recommended in this British Standard, subject to the provision of research data and test results, or a test assembly should be built to test the material, component or method under consideration.

The test assembly should be representative, as to materials, workmanship and details, of the design and construction for which approval is desired, and should be built under conditions representative of the conditions in the actual building construction or curtilage involved.

The interaction of different materials used (e.g. bimetallic corrosion) should be considered in construction.

All coatings and decorative finishes to the barrier should not be composed of or contain toxic materials.

5 Preliminary considerations

5.1 Barrier design

In the assessment of the need for a barrier and the type of barrier to be provided, the designer should give consideration to the likely hazards, the building use and the risks to building users.

Where, in a building, more than one use of the building is anticipated, either the barrier design should be chosen to suit the worst case, or more than one type of barrier should be provided, as appropriate, to the location.

Where the hazard is a change in level, pedestrian guarding should be erected in dwellings where the difference in adjacent levels is greater than 600 mm. Guarding should also be erected in buildings other than dwellings where there is a difference greater than 380 mm, to take account of the greater number of building users and their possible lack of familiarity with the layout.

NOTE Guarding is covered by the Building Regulations and the appropriate technical documents for England and Wales [1], Scotland [2] and Northern Ireland [3].

5.2 Glazed elements

Where walls, glazing or other elements of buildings or structures perform the functions of barriers, the designer should either:

a) ensure that these elements satisfy the criteria given in this British Standard; or

b) provide additional barriers designed in accordance with this British Standard.

5.3 Hazard reduction

The barrier adopted should be designed so as to minimize the risk of persons falling, rolling, sliding or slipping through gaps in the barrier.

In dwellings and other buildings which can be accessed by children under the age of 5, gaps in a barrier or infill should not be large enough to permit a sphere of 100 mm diameter to pass through, making due allowance for deflection under load.

NOTE 1 Except inside dwellings and common stairs in blocks of flats, this does not apply to the triangular opening formed by the tread and riser and the bottom edge of the barrier or infill, if that bottom edge is not more than 50 mm above the pitch line.

The barrier and infill should be constructed so that a child cannot easily climb it. These recommendations should also be applied to barriers for stairs and landings which give access to the building.

NOTE 2 In non-domestic buildings, manifestation could be applied to clear glass barriers or infill panels that reach the floor (or nearly reach the

*floor), at an appropriate height to make them visible to children whose eye level is below the top of the barrier (see **8.1.1**).*

Where a higher standard of safety is thought necessary, consideration should be given to the requirements of BS EN 1930.

5.4 Critical structural elements

The designer should consider the use of barriers to protect critical structural elements where there is a risk that vehicle impact could cause structural damage, e.g. around any cast iron column.

NOTE This is particularly important in buildings where pallet or fork lift trucks are used.

6 Design criteria

6.1 General

Barriers should be designed to resist the most unfavourable likely imposed loads and wind loads separately (see **6.3**) without unacceptable deflections or distortions (see **6.4**).

NOTE 1 Barrier heights are also covered by the Building Regulations [1], [2], [3]. The barrier height above datum is defined in Figure 1.

The minimum heights for each barrier location should be as given in Table 1.

The height of barriers installed on top of low parapet walls should be measured from the top of the parapet and not at walk level.

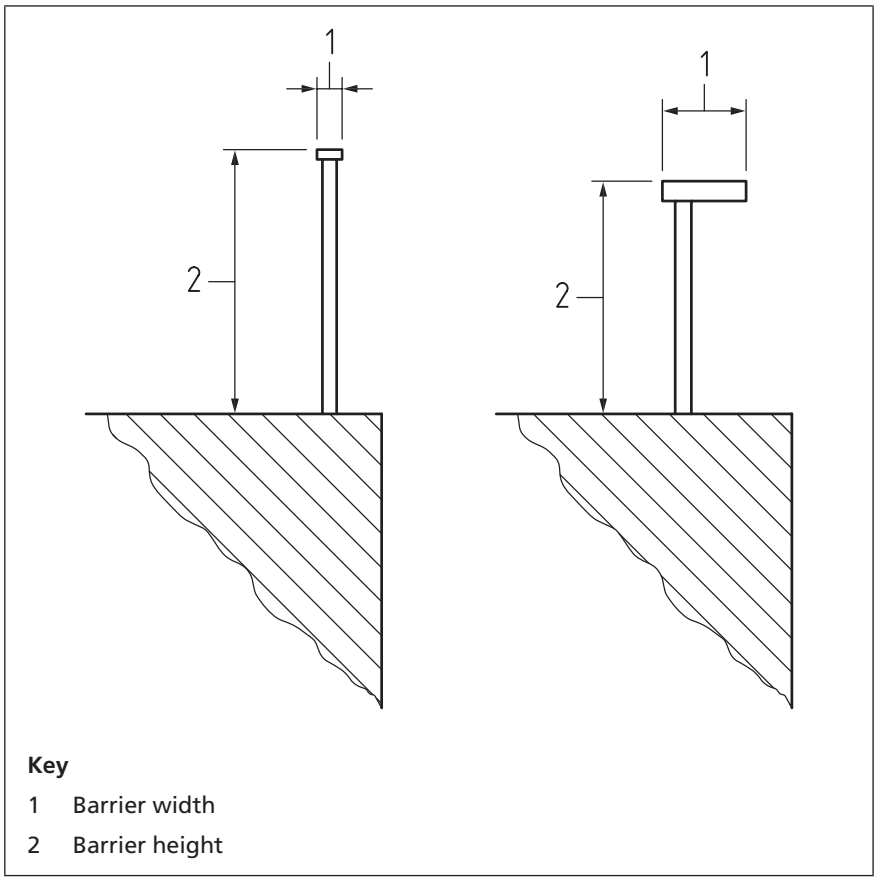
NOTE 2 Where a low parapet wall could constitute a step, it might reduce the effectiveness of the barrier.

Table 1 **Minimum barrier heights**

Use	Position	Height
Single-family dwelling	a) barriers in front of a window	800 mm
	b) stairs, landings, ramps, edges of internal floors	900 mm
	c) external balconies including Juliette balconies, edges of roofs	1 100 mm
All other uses	d) barrier in front of a window	800 mm
	e) stairs	900 mm
	f) balconies and stands, etc. having fixed seating within 530 mm of the barrier	800 mm
	g) balconies and stands, etc. having fixed seating within 530 mm of the barrier, provided the sum of the barrier width and the barrier height is greater than 975 mm	750 mm
	h) other positions including Juliette balconies	1 100 mm

*NOTE See also **6.8** on sight lines and Figure 2.*

Figure 2 **Height and width of barriers in front of fixed seating**



6.2 Design procedures

For barriers other than vehicle barriers, either permissible stress or limit state design procedures should be used, according to the recommended procedure given in the British Standard appropriate for the material to be used, treating the loads given in Table 2 as:

a) working loads, for permissible stress design;

b) characteristic loads, for limit state design.

When using limit state design, the partial safety factors for loads and materials should be those recommended by the appropriate British Standard for the relevant material. The strength of the barrier should be designed as ultimate limit state (ULS) and the deflection as serviceability limit state.

In designing barriers to resist equivalent static loads, such as those due to vehicular impact (see **6.3.2** and **6.4.2**), the permissible stress procedure should not be used. In such cases, a limit state approach based on the partial safety factors for load and materials appropriate to accidental damage or misuse should be used. Where a standard makes no specific provision for design against impact loads, decisions should be made regarding the possible reduction of the overall factor of safety, according to the relative influence of dynamic loads compared with static loads on the properties of the material.

The designer should also be aware that the equivalent static force concept is related to an assumed mean deceleration. Validation tests on barriers constructed from the materials normally used in vehicle barriers, such as steel, aluminium, or reinforced concrete, show good correlation with calculated values. However, the performance of barriers constructed from other materials should be established in order to determine the equivalent static force against which they should be designed.

NOTE Information on the forces resulting from vehicle impact into yielding barriers is available from research papers published by the Transport Research Laboratory [9].

Table 2 **Minimum horizontal imposed loads for parapets, barriers and balustrades**

Type of occupancy for part of the building or structure	**Examples of specific use**	**Horizontal uniformly distributed line load (kN/m)**	**Uniformly distributed load applied to the infill (kN/m^2)**	**A point load applied to part of the infill (kN)**
Domestic and residential activities	(i) All areas within or serving exclusively one single family dwelling including stairs, landings, etc. but excluding external balconies and edges of roofs	0.36	0.5	0.25
	(ii) Other residential, i.e. houses of multiple occupancy and balconies, including Juliette balconies and edges of roofs in single family dwellings	0.74	1.0	0.5
Offices and work areas not included elsewhere, including storage areas	(iii) Light access stairs and gangways not more than 600 mm wide	0.22	—	—
	(iv) Light pedestrian traffic routes in industrial and storage buildings except designated escape routes	0.36	0.5	0.25
	(v) Areas not susceptile to overcrowding in office and institutional buildings, also industrial and storage buildings except as given above	0.74	1.0	0.5
Areas where people might congregate	(vi) Areas having fixed seating within 530 mm of the barrier, balustrade or parapet	1.5	1.5	1.5
Areas with tables or fixed seatings	(vii) Restaurants and bars	1.5	1.5	1.5
Areas without obstacles for moving people and not susceptible to overcrowding	(viii) Stairs, landings, corridors, ramps	0.74	1.0	0.5
	(ix) External balconies including Juliette balconies and edges of roofs. Footways and pavements within building curtilage adjacent to basement/sunken areas	0.74	1.0	0.5

Table 2 **Minimum horizontal imposed loads for parapets, barriers and balustrades** *(continued)*

Type of occupancy for part of the building or structure	Examples of specific use	Horizontal uniformly distributed line load (kN/m)	Uniformly distributed load applied to the infill (kN/m^2)	A point load applied to part of the infill (kN)
Areas susceptible to overcrowding	(x) Footways or pavements less than 3 m wide adjacent to sunken areas	1.5	1.5	1.5
	(xi) Theatres, cinemas, discotheques, bars, auditoria, shopping malls, assembly areas, studio. Footways or pavements greater than 3 m wide adjacent to sunken areas.	3.0	1.5	1.5
	(xii) Grandstands and stadia [A)]			
Retail areas	(xiii) All retail areas including public areas of banks/building societies or betting shops	1.5	1.5	1.5
Vehicular	(xiv) Pedestrian areas in car parks, including stairs, landings, ramps, edges or internal floors, footways, edges of roofs	1.5	1.5	1.5
	(xv) Horizontal loads imposed by vehicles [B)]			

A) See requirements of the appropriate certifying authority.

B) See Annex A.

6.3 Loading

6.3.1 General

Minimum horizontal imposed loads appropriate to the design of parapets, barriers, balustrades and other elements of structure intended to retain, stop or guide people, should be determined in accordance with Table 2, which recommends a uniformly distributed line load for the barrier and a uniformly distributed and point load applied to the infill. These are not additive and should be considered as three separate load cases, all loads being determined according to the type of occupancy which reflects the possible in-service conditions.

Horizontal uniformly distributed line load should be applied at design height as presented in Table 1 or at design level (1 100 mm) for barriers higher than the design height.

Uniformly distributed load should be applied to the area below the design height.

Point load should be applied at the most onerous point anywhere on the barrier structure.

*NOTE 1 Additional recommendations for glazing in barriers are given in Clause **8**.*

NOTE 2 For clarity, the design level (the level at which the horizontal uniformly distributed line load ought to be considered to act) is shown in Figure 1.

6.3.2 Imposed loading due to vehicles

When designing barriers to resist vehicular impact, an estimate of the characteristic mass *m* of the vehicle should be made. Ideally, this should be determined statistically. If this is not possible, the characteristic mass should be taken to be equal to the maximum mass anticipated.

Annex A should be used to estimate the equivalent static force *F* for a given characteristic mass and displacement.

Simplified design recommendations for car parks should allow for a characteristic mass of 1.5 t to be taken for car parks designed for vehicles not exceeding 2.5 t in mass.

NOTE 1 A graphic interpretation derived from these recommendations is given in Annex A.

NOTE 2 Further information to enable the designer to derive equivalent static forces for cases where different parameters apply is given in Annex A.

The anticipated area and position of contact should be used in calculating the ultimate strength of the barrier if the pattern of vehicle or barrier deformation can be reliably predicted.

The assumed distribution of the impact force and the design level at which it is applied should be related to the likely area and position of initial contact.

NOTE 3 Angular impacts might give rise to additional forces directed along the line of the barrier. Where the construction of the barrier is such that frictional contact between it and the vehicle is likely to be high, or such that projections might restrain the vehicle, these additional forces can reach three times the lateral applied forces.

NOTE 4 Annex A provides data for vehicles impacting at 20° to a barrier.

6.3.3 Wind loads

External barriers should be designed to resist the wind loads given in BS EN 1991-1-4.

6.4 Deflection

6.4.1 Barriers for the protection of people

Barriers for the protection of people should be of adequate strength and stiffness to sustain the applied loads given in Table 2. In addition, a barrier that is structurally safe should not possess sufficient flexibility to alarm building users when subject to normal service conditions. Therefore, for serviceability considerations, the limiting condition for deflection appropriate for a barrier for the protection of people is that the total horizontal displacement of the barrier at any point from its original unloaded position should not exceed the deflection limits determined from the relevant structural design code (where applicable) for the material used, or 25 mm, whichever is the smaller.

Where the infill of a barrier is subjected to imposed loads given in Table 2, or if appropriate, other calculated design loads, the displacement of any point of the barrier should not exceed L/65 or 25 mm, whichever is the smaller where L is the given in **8.3**, **8.4** or defined in **8.5**. A suitable fracture load, factored by a minimum partial safety factor of 4.0 (as recommended in BS 4592-0) should be obtained from the material manufacturer when considering glass barrier design.

6.4.2 Vehicle barriers

Barriers designed to resist vehicular impacts might be distorted by such impacts but should remain substantially in place.

6.5 Fixings, attachments and anchorage

The strength of fixings, attachments and anchorage securing the barrier to a substrate should be adequate to sustain a loading greater than that to which the barrier will be subjected. All joints should be designed to provide the full strength of the members being joined. To that end, where any uncertainty exists with regard to the strength of any component in the fixing, the design loading factors should be increased by 50%.

Fixing design should take particular account of the material into which the fixing is placed, the spacing between fixings, the edge distance, and where the substrate is concrete, the position of reinforcement. Reliance on the pull-out capacity of a single fixing should be avoided.

NOTE 1 The recommendation of an additional load factor of 1.5 is intended to ensure that under an extreme load condition, barriers give an indication of failure by deflection distortion and not by total collapse, as would be brought about by a failure of the fixing, attachment or anchorage system.

Where the design strength of a proposed system of fixing to an existing substrate cannot be determined with reasonable accuracy by theoretical consideration, load testing should be used to validate the design.

NOTE 2 A factor greater than 1.5 on barrier load design might also be appropriate.

6.6 Safety details

6.6.1 General

The finished barrier should have no sharp edges or projections that could cause injury to persons or damage to clothing.

Infill panels and balusters are intended to provide support and protection to the user, and should be designed to restrain people without causing additional injury from sharp edges, thin sections, open-ended tubes, projecting details, etc.

The ends of barriers on unlit access roads should be provided with reflectors or reflective markings.

The designer should be aware of the need to provide maintenance of the barrier to sustain levels of safety and performance. Consideration should be given in the design of the barrier to the possibility of tampering or vandalism.

6.6.2 Vehicle barriers

The designer should, wherever possible, avoid introducing projections on the vehicular face of the barrier and should also consider ways of redirecting vehicles in such a way as to cause minimum damage after impact.

6.7 Support from adjacent construction

The designer should ensure that any construction or structure acting as support for barriers is of adequate strength and stability to sustain all applied loads safely without excessive stress, deflection or distortion.

6.8 Sight lines

When designing barriers in places such as theatres, cinemas and concert halls, sight lines as well as safety aspects should be considered.

NOTE 1 This applies particularly to barriers protecting balconies or parts of balconies having fixed seating within 530 mm of the barrier. The relationship between the height and width of a barrier affects both sight lines and safety. A lower, wider barrier might provide the same degree of protection as a higher, narrower barrier.

NOTE 2 Where the barrier is not in front of fixed seating (e.g. at the end of the gangway) the normal design criteria apply.

7 Concrete

All concrete used in the construction of barriers should be in accordance with the recommendations of BS EN 1992 (all parts).

When concrete is used to form the external face of barriers, the designer should take into account the mode or modes of failure that any envisaged overload would cause and provide appropriate reinforcement so as to prevent the spread of debris to a dangerous extent; the use of fibres in the concrete might be helpful in this respect.

Special consideration should be given to the ultimate strength and strain behaviour of the fixings for pre-cast concrete elements in protective barriers. The designer might choose to design the barrier so that restraints in one zone fail before those in another. In such a case, the restraints designed to fail last should be capable of resisting the residual forces after applying the partial safety factors recommended in **6.2**.

8 Glass

8.1 Application

8.1.1 General

Glass should not be used for vehicle protection barriers.

There are certain situations, particularly under some lighting conditions, where the presence of transparent glass is not readily evident and suitable manifestation should be provided in accordance with BS 6262 (all parts), using the design criteria given in Clause **6**.

NOTE 1 Glass totally above the barrier height is outside the scope of this British Standard.

NOTE 2 Glazing in buildings is covered by the Building Regulations and the appropriate technical documents in England and Wales [1], Scotland [2] and Northern Ireland [3].

8.1.2 Types of barrier incorporating glass

There are three common types of barrier that use glass.

a) *Full height barrier*. Where glass forms part or whole of a wall element, the barrier should be designed in accordance with this British Standard if any part of the glass comes below the minimum barrier height (see Table 1).

*NOTE 1 For specific guidance on glass full height barriers see **8.3** and for impact resistance see **8.6**.*

Where there is a risk of falling, and the barrier contains an opening window which extends below a line 800 mm from the floor, either the opening should be restricted to a maximum width of 100 mm or it should be protected by a suitable barrier at least 800 mm high.

b) *Barrier with a glass infill panel*. In this type of barrier, the main frame of the barrier (i.e. top rail and baluster) should be designed to withstand the loads applied to the top rail and the glass should be used to form the infill panels. It should be noted that the glass provides no support to the main frame.

*NOTE 2 For specific guidance on glass infill panels see **8.4** and for impact resistance see **8.6**.*

c) *Free-standing glass protective barrier*. In this type of barrier, the glass should be designed to withstand the design loads. Each glass plate should be clamped to the structure along its bottom edge, the handrail attached to the top edge of the glass and there should be no balusters.

In the event that a free-standing barrier is supplied without a handrail, each panel should be able to withstand the appropriate design load.

Any individual point that is damaged and unable to meet the criteria should be replaced with interim guarding awaiting immediate replacement.

*NOTE 3 For specific guidance on free-standing glass barriers see **8.5** and for impact resistance see **8.6**.*

NOTE 4 This British Standard applies to vertical glazing and glass within 15 degrees of vertical.

8.2 Materials

8.2.1 Glass types

The type of glass should be chosen to suit the design of the protective barrier.

NOTE 1 Glass types are defined in BS 952-1.

NOTE 2 Laminated safety glass can be used for all barriers where the glass is used fully framed.

For the use of laminated glass, where the glass is not fully framed, the manufacturer should be consulted.

Toughened glass and laminated toughened glass classified to BS EN 12600 should be used for all barriers where the glass is fully or partially framed or is free-standing [see **8.1.2**c)].

Wired safety glass conforming to BS EN 572-3 or BS EN 572-6 should not be used in the types of barrier described in **8.1.2**b) and **8.1.2**c), but might be used in full-height barriers where the glass is used fully framed. The manufacturer should be consulted for advice on the use of wired or annealed glass in fully framed full height barriers.

The selection of glass should include consideration of the post-breakage behaviour.

NOTE 3 Monolithic toughened glass might fall from its retention system if broken in free-standing and infill barriers. Additional protection might be required if this type of glass is used above areas of fixed seating.

8.2.2 Working of glass

The size, position and shape of holes and notches in toughened glass, and the production of shapes other than rectangles, should be decided after consultation with the manufacturer, as shaping, drilling, cutting etc. should be undertaken prior to toughening.

8.2.3 Fixing of glass

Contact between glass and any other hard material (including other glass parts) should be prevented. Rubber gaskets or other glazing materials should be used with frame sections. The frame section should give a minimum of 15 mm edge cover to the glass unless it can be shown by test or calculation that the frame will retain the glass under load while conforming to **6.4**.

The frame and/or fastenings should be designed so that they do not tend to distort the glass panel. This is particularly important with bolted connections, which can exert considerable forces on the glass, where particular attention should be paid to the alignment and position of the fasteners in order to avoid unnecessary stresses being developed.

The glass, framing system and connections of barriers and infill panels should be capable of sustaining and safely transmitting the design loads to the supporting structure.

8.3 Design of glass in full height protective barriers

NOTE 1 The design of the glass depends on its relation to the minimum barrier height as given in Table 1.

Glass partly or totally below the minimum barrier height should be designed to satisfy the appropriate design criteria given in Clause **6**. Any part of a glass pane below the minimum barrier height should sustain the infill loads. Where there is glass at the minimum barrier height given in Table 1, the glass should also sustain the line load applied at the design level (see **6.3**).

The deflection of the glass should be as recommended in **6.4.1**.

For advice on the glass size relative to the glass type, support system, loadings and thickness the manufacturer should be contacted.

NOTE 2 Glazing methods which do not support the glass on all four edges might require smaller sizes or thicker glass.

NOTE 3 Glass totally above the design level is outside the scope of this British Standard (see Figure 1).

8.4 Design of glass infill panels

8.4.1 Design criteria

Infill panels should be designed to satisfy the appropriate design criteria given in Clause **6**.

8.4.2 Fully framed infill panels

The deflection of the glass in fully framed infill panels should be as recommended in **6.4.1**.

8.4.3 Two-edge framed infill panels

The deflection of the glass in two-edge framed infill panels should be as recommended in **6.4.1**, taking *L* as the distance between the supports.

8.4.4 Clipped infill panels

The clips should be positioned around the periphery of the infill panel, at a maximum spacing of 600 mm. Each clip should be not less than 50 mm in length and should give a minimum depth of cover to the glass of 25 mm.

8.4.5 Bolt fixing of glass infill panels

Where glass is supported by bolted connections through holes in the glass, toughened glass should be used.

Bolted connections for infill panels should be made in accordance with Annex B.

8.4.6 Position of infill panels relative to the main frame

Infill panels should be fully contained within the supporting structure. In order not to apply unintended loads to the infill panels, they should have handrails above the glass or attached to the side to which the public have access.

8.5 Design of free-standing glass protective barriers

8.5.1 Design criteria

The glass should be designed to satisfy the appropriate design criteria given in Clause **6**.

The deflection of the glass should be no greater than 25 mm at any point.

8.5.2 Handrail attachment

Where the barrier protects a difference in level greater than 600 mm, a handrail should always be used unless a laminated toughened glass construction is used that would remain in-situ if a panel fails. Continuous fixing should be used for fixing the handrail to the glass, or individual fixings where calculations or tests demonstrate that component failure will not occur.

The handrail should be attached to the glass in such a manner that, should a glass panel fracture, the handrail:

a) will remain in position;

b) will not fail if the design load is applied across the resulting gap.

NOTE Condition b) can be relaxed where the glass pane is an end pane and protects a difference in level of 600 mm or less, for example at the foot of a flight of stairs. In cases where an end pane protects a difference in level greater than 600 mm, there would normally be some adjacent structure to which the handrail could be attached, thus enabling it to meet condition b).

8.5.3 Structural movement

The structural movement due to live or dead loads or creep of the structure to which a barrier pane is clamped should be not greater than 2 mm over the length of any barrier panel, if more than two bolts are used to clamp that panel.

8.5.4 Fixing clamps

The attachment of the fixing clamps to the structure should be capable of withstanding the turning moment induced at the fixing clamps.

NOTE Advice on fixing clamps is given in Annex B.

8.6 Impact resistance and containment

8.6.1 General

In addition to resisting the design loads given in Clause **6**, glass below the minimum barrier height (see Table 1) should also be able to resist impact forces appropriate to whether the barrier indicates a route or protects people from a hazard (see Clause **5**).

*NOTE Specific recommendations are given in **8.6.2** and **8.6.3**. Also see [5, 6, 7].*

8.6.2 Glass in barriers that only indicate a route

The glass in barriers that only indicate a route should be selected to resist the appropriate design loads given in Clause **6** and for its impact performance with the safety glazing recommendations given in BS 6262 (all parts).

8.6.3 Glass in barriers that protect people from hazards

8.6.3.1 Glass in full height barriers

The glass in full height barriers should be selected to resist the appropriate design loads given in Clause **6** and for its impact performance in accordance with the safety glazing recommendations given in BS 6262 (all parts).

8.6.3.2 Barrier with glass infills or free-standing balustrades

8.6.3.2.1 General

The glass in barriers with glass infills or free-standing balustrades should be selected to resist the appropriate design loads given in Clause **6**, and to provide containment, i.e. it should meet the recommended impact class (see **8.6.3.2.2**) without penetration.

8.6.3.2.2 Impact classes

It should be noted that the energy level of an impact varies according to the position of the barrier relative to the unhindered distance a body can travel in a direction perpendicular to the surface of the protective barrier (for free path) (see **11.5**). The impact classes that should be used are:

a) minimum of Class 3 to BS EN 12600 for a free path up to 1 500 mm; and

b) Class 1 to BS EN 12600 for a free path greater than 1 500 mm.

NOTE BS EN 12600 classifies all toughened glass as Class 1 as an impact safety glass showing safe breakage when impact tested. It also classifies glass with a three-digit code using the last digit to represent the impact drop height where the glass either does not break or breaks like laminated glass and resists penetration.

The following recommendations should be followed for the selection of toughened glass so that it provides containment (e.g. it will not break) at the recommended impact class:

- minimum Class 3 to BS EN 12600 and at least 6 mm toughened for a free path ≤1 500 mm;
- Class 1(C)1 or 1(B)1 to BS EN 12600 and at least 10 mm toughened for a free path >1 500 mm.

Guidance on the resistance of other types of safety glass, e.g. laminated glass, should be sought from the manufacturer.

8.7 Maintenance

All glass should be regularly cleaned and fixings should be checked for corrosion and loosening.

9 Masonry

9.1 General

All unreinforced masonry used in the construction of barriers, both separately and in conjunction with other materials, should be designed and constructed in accordance with BS EN 1996, using the design criteria given in Clause **6**.

Special consideration should be given to the design of any masonry wall expected to resist vehicle impact.

9.2 Damp-proof courses

Damp-proof courses at the base of masonry walls should provide the necessary adhesion across joints to achieve the recommended strength.

9.3 Wall ties

Where cavity walls, collar jointed walls or grouted cavity walls act as protective barriers, the separate leaves should be connected by wall ties as recommended in BS EN 1996 (all parts), as appropriate. Special consideration should be given to the durability of certain wall ties when used in conditions of severe exposure. In such conditions stainless steel wall ties should be used.

9.4 Copings

Copings should be designed to remain in place when the barrier is subject to the design load. Where vandalism is likely to occur, the copings should be securely anchored to the masonry, using suitable fixings. Copings should also be designed so as to deter people from standing on, or walking along, the top of the wall.

NOTE BS 4729 and BS 5642-2 give requirements for masonry coping units.

9.5 Maintenance

Masonry designed in accordance with the recommendations of this Clause should require little maintenance. Cleaning and surface repair of masonry should follow the recommendations in BS 8221 (all parts).

10 Metals

*COMMENTARY ON CLAUSE **10***
This Clause provides recommendations for most common metals used for barriers. However, other metals not covered by this Clause might also be suitable subject to the provision of research data and test results.

10.1 Aluminium

10.1.1 General

Aluminium alloys for use in barriers should be designed in accordance with BS EN 1999 (all parts) using the design criteria given in Clause **6**.

NOTE Aluminium alloy components can be clipped, hinged, slid or slotted together, and, in addition, slots or grooves can be incorporated to accept bolt heads, screw threads or other fixing devices.

10.1.2 Choice of alloys

10.1.2.1 Wrought aluminium alloys

Barriers should be constructed using wrought aluminium alloys conforming to BS EN 1999 (all parts).

NOTE For further information on the suitability for specific uses of structural wrought aluminium alloys, including durability, see BS EN 1999 (all parts).

10.1.2.2 Aluminium casting alloys

Barriers should be constructed using cast aluminium alloys conforming to BS EN 1999 (all parts).

Aluminium alloy castings should only be used as load bearing elements of barriers after adequate testing for the production of the castings has been performed.

10.1.3 Surface finish

*COMMENTARY ON **10.1.3***
Five main types of surface finish exist for architectural aluminium.

a) Mill finish (as manufactured).

b) Anodized finishes, natural and coloured, all of which can be textured by mechanical and/or chemical means.

c) Applied finishes.

d) Textured finish.

e) "As cast" finish (as manufactured).

10.1.3.1 Mill finish and "as cast" finish

*COMMENTARY ON **10.1.3.1***
Surface treatment for mill finish and "as cast" finish aluminium is generally unnecessary to maintain structural performance. However, the appearance of the metal changes with time, becoming duller and darker to a degree that is dependent on the atmospheric pollution.

Since the surfaces can roughen under these conditions, an anodized finish should be used for the top rail.

10.1.3.2 Anodizing

*COMMENTARY ON **10.1.3.2***
Anodizing artificially thickens the natural oxide film and may be used either to preserve the natural appearance of the metal or to add decoration in the form of colour or in conjunction with textured finishes.

Anodizing should be used for applications in which the retention of a good appearance is important and, in particular, where aluminium has been chosen to fulfil a decorative function.

NOTE 1 The anodic coating is hard and gives the surface of the aluminium increased resistance to wear and abrasion, which increases with film thickness.

Coating thickness grades appropriate to different applications should be in accordance with Table 3.

NOTE 2 Colour anodizing is available in a large range of colours suitable for both indoor and outdoor use. The colour resulting from anodizing aluminium is dependent on the alloys used, and different components anodized by the same process might not colour match.

NOTE 3 Matt, satin, polished and brushed surface effects can be obtained by the use of an appropriate treatment.

NOTE 4 The application of heat to the aluminium at any stage of fabrication is likely to affect locally the resultant appearance shown by anodizing and this in turn might affect the choice of jointing method and of alloy.

Reference should be made to BS 3987 or BS EN ISO 7599.

Table 3 **Recommended typical coating thickness and applications**

Thickness	Application
5–10 μm	Interior domestic
15–20 μm	Some external architectural and industrial applications [A)]
25 μm	External architectural, industrial and hard-wearing applications

[A)] Where subject to frequent maintenance washing.

10.1.3.3 Applied finishes

Where possible, stoved paints or powder coatings, which provide the most durable type of applied finish, should be used; however, it should be noted that these are factory-applied coatings and there could be occasions where it might be necessary to use site-applied air-drying paint (e.g. where minor repairs to damage from erection are carried out or if the fabricator supplies the barrier in an unpainted condition).

Reference should be made to BS 4842, BS 6496 or BS EN 12206-1.

10.1.3.4 Textured finish

Texture may be given to the material, depending on the form, either mechanically (e.g. impressed, embossed, bead-blasted or brushed) or chemically (e.g. etched).

NOTE The material could also be mechanically, chemically or electrochemically polished.

10.1.4 Fabrication

10.1.4.1 Bending and forming

NOTE Aluminium alloys can be manipulated by all conventional equipment and are available in a wide range of tempers with varying formability.

Cold bending and forming should be used; hot working should not be undertaken without first seeking the advice of the manufacturer.

10.1.4.2 Punching and shearing

Aluminium should be punched and sheared in the normal way, the finished edges being, as with other metals, cleaner with the harder alloys.

10.1.4.3 Machining

It should be noted that aluminium presents no special machining problems, the harder alloys being preferred, providing the accepted tool geometry, lubrication and machining speeds are followed.

10.1.4.4 Bolting and riveting

Normal bolting and riveting processes should be used for aluminium. Austenitic stainless steel nuts, screws, washers and bolts should be used as a preference, but suitable aluminium fixings can be used or steel fasteners other than stainless steel, though they should be hot-dip galvanized to conform to BS EN ISO 1461 or sherardized to conform to Class 1 of BS 4921:1988.

NOTE Further information is available in BS EN 1999 (all parts).

10.1.4.5 Adhesives

Adhesives should be used to bond aluminium to metallic and non-metallic surfaces. Surface preparation and bonding conditions are very important, and the adhesive manufacturer's recommendations should be strictly followed.

For methods of test for adhesives, reference should be made to BS 5350 (all parts).

10.1.4.6 Welding

Welding materials, workmanship and protection should conform to BS EN 1999 (all parts).

10.1.5 Assembly and fixing

10.1.5.1 General

For general guidance on assembly and fixing, reference should be made to BS EN 1999 (all parts).

10.1.5.2 Strength of fasteners and welds

Mechanically fastened and welded joints should be designed in accordance with BS EN 1999 (all parts).

10.1.5.3 Site fixing

Where posts are set into concrete, the lower end of the post should be given two coats of bituminous paint conforming to BS 3416 or hot bitumen. This coating should extend 75 mm above the top of the concrete.

Where posts are bolted to concrete, the underside of the bases should be given two coats of bituminous paint conforming to BS 3416.

NOTE 1 Additional protection to the aluminium at the holding down bolts can be given by the use of plastic sleeves and washers to isolate the aluminium from the holding down bolts.

NOTE 2 See also BS EN 1999 (all parts).

10.1.6 Maintenance

10.1.6.1 Mill finish and "as cast" finish

Abrasive cleaners should not be used to remove natural or oxide applied protective coatings.

NOTE 1 Periodic washing with soapy water to remove dirt and grime helps to preserve the original appearance of the metal for a time, but does not prevent eventual weathering to a shade of grey that is dependent on the atmospheric environment.

NOTE 2 Guidance on the cleaning of aluminium is given in BS 6270-3.

10.1.6.2 Textured finishes

Maintenance of textured finishes, including removal of stains, should be as recommended by the aluminium manufacturers.

10.2 Copper and copper alloys

10.2.1 General

Copper and copper alloys for use in barriers should be designed to meet the design criteria in Clause **6**.

NOTE Copper and copper alloys are available in a wide range of forms and are generally easily formed, machined and joined by conventional techniques.

10.2.2 Choice of alloys

10.2.2.1 Wrought copper alloys

Wrought copper alloys should conform to BS EN 12163, BS EN 12164 and BS EN 12167 which include a wide range of brasses, free machining brasses, high tensile brasses (manganese bronzes) and aluminium bronzes.

NOTE Of these the most frequently used for architectural applications are CZ 130, CZ 110, CZ 121 and CZ 131. Aluminium bronzes commonly recommended are CA 104 and CA 106.

10.2.2.2 Casting alloys

Large and intricate shapes should generally be made as castings. Materials should conform to BS EN 1982.

NOTE 1 Brasses suitable for castings include SCB3 (sandcasting), DCB1 and DCB3 for die castings and arsenical brass, which is ideal for brazing. High tensile brasses such as HTB1 are stronger and also have good corrosion resistance.

NOTE 2 Gunmetals such as LG2 can be used where a copper colour is required combined with good machinability. Aluminium bronzes such as AB1 and AB2 are very strong and have good corrosion resistance, especially in marine environments.

10.2.3 Surface finish

It should be noted that copper and copper alloys can be finished to a high standard and polished if required and that many proprietary treatments are available to preserve the finish. These processes should be employed with due regard to their suitability for use with copper alloys.

10.2.4 Fabrication

Welding should only be used with tin bronzes and aluminium bronzes and to a limited extent with brasses, but these materials can be readily brazed or soldered.

NOTE All wrought copper alloys can be bent and formed to an extent depending on their cold ductility. Most can also be hot formed by extrusion or hot stamping or forging. All copper alloys can be readily machined provided the suitable tools, feeds and speeds are used. Where rapid screw threading is required, special free machining alloys are available.

10.2.5 Corrosion

If copper alloys are in contact with other metals, attention should be given to the possibility of bimetallic corrosion in damp environments.

NOTE 1 Copper alloys are generally more noble than most other metals, which means that the metals in contact are more likely to corrode.

Care should be taken to ensure that all fasteners are made of copper alloys since steel fasteners may rust.

When considering bimetallic corrosion reference should be made to PD 6484.

NOTE 2 All copper and copper alloys have excellent resistance to corrosion in dry atmospheres; a slight tarnish is likely to appear but corrosion is unlikely. In the absence of dampness, little further oxidation is likely to take place, depending on the conditions.

10.3 Steel

10.3.1 General

Steel for use in protective barriers should be designed to meet the design criteria given in Clause **6**.

NOTE Stainless steel could be used where an attractive appearance and/or great durability are required. Weather resistant steels could also be used.

10.3.2 Choice of steels

The following steels should be used for the construction of protective barriers.

a) Carbon and low alloy steels conforming to BS 1449-1, BS EN 10219-1, BS EN 10219-2, BS 7668, BS EN 10025 (all parts), BS EN 10029, BS EN 10143, BS EN 10210 (all parts) and BS EN ISO 2560.

b) Stainless steel conforming to BS EN 10088-2 for plate, sheet and strip, BS EN 10088-3 for bar and rod, BS EN 10216-5 for seamless tube and BS EN 10217-7 for welded tube.

   1) The grades of austenitic stainless steel which are recommended for external use are:

      i) 1.4301 (formerly known as 304S16); this is the most commonly used grade;

      ii) 1.4306 (formerly known as 304S11); the reduced carbon content makes this the most suitable for hot working or welding, as subsequent heat treatment might be unnecessary;

      iii) 1.4401 (formerly known as 316S31 and 316S33); additional molybdenum enhances the resistance of this grade to pitting corrosion, which makes it the grade which should be used in aggressive environments, e.g. by the coast;

      iv) 1.4404 (formerly known as 321S11); the reduced carbon content of this molybdenum bearing grade makes it suitable for hot working or welding, as subsequent heat treatment might be unnecessary;

v) 1.4541 (formerly known as 321S31); the titanium in this grade acts as a weld stabilizer and permits the elimination of subsequent heat treatment;

NOTE 1 Ductile grades of austenitic stainless steel work harden rapidly when manipulated.

2) The grades of ferritic stainless steel that are recommended for external use are:

i) 1.4016 (formerly known as 430S17); and

ii) 1.4113 (formerly known as 434S17).

Mechanical jointing methods should be used for ferritic grades.

NOTE 2 Austenitic grades are suitable for welding or mechanical jointing.

10.3.3 Design

For the purposes of the design of commonly used weldable structural steels, the allowable stresses recommended by or the limit state design methods of BS EN 1993 (all parts) should be used.

10.3.4 Fabrication

NOTE 1 The weldable quality steels facilitate rapid and easy fabrication.

Where, for example, flat panel work is involved, or long lengths of rail over posts are being constructed, the welding sequence should be chosen to avoid distortion of the finished article.

NOTE 2 Solid sections, such as rounds or flat bar, can be bent readily to fairly tight radii, particularly when hot, but there are limits to the bending capabilities of hollow sections.

NOTE 3 For rectangular hollow sections, the minimum radius also depends upon the relationship between the width of the face in the plane of bending and the thickness.

The minimum hot bending radius should be as given in Table 4 (see also Figure 3).

NOTE 4 The use of standard formers to suit the various diameters enables tubes to be bent cold to a radius of 3.5 to 4 times their outside diameter. Sand filling or, in small diameters, resin filling that can subsequently be melted out, help to maintain the circular cross-section when bending to small radii.

It is possible to obtain ready-formed elbows conforming to BS EN 10253-1 with ends bevelled for welding and these should be used where tighter radii than can be obtained by normal bending are required.

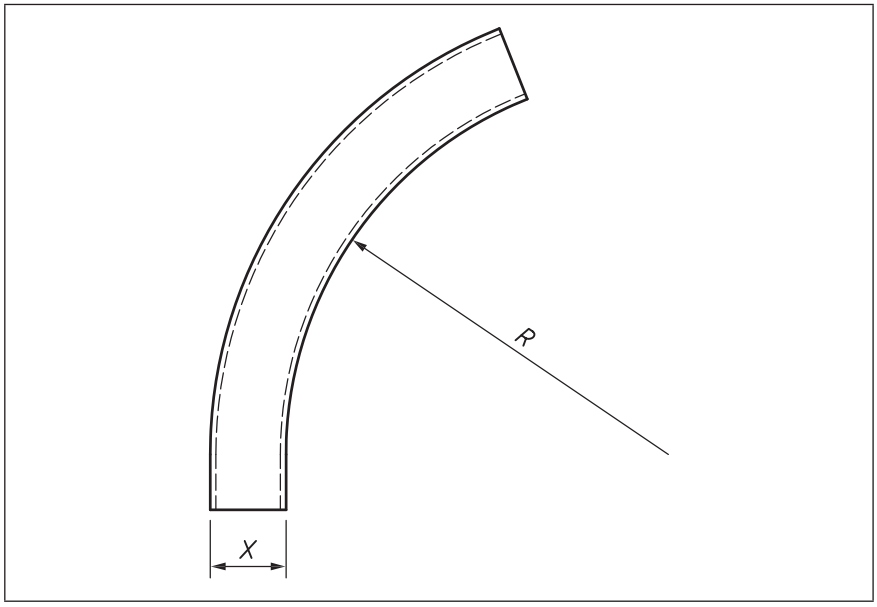
Hot-dip galvanized sections should not be bent hot, and cold bending is not generally recommended. If cold bending is essential, the radius should be not less than 12*X*, where *X* is the width of the face.

The materials, workmanship, fabrication and installation of steelwork should be in accordance with BS 1090-1, BS EN 1090-2, and BS EN 1993 (all parts).

Table 4 **Preferred minimum hot bending radius for rectangular hollow steel sections**

Width of face, *X*	**Thickness**	**Preferred minimum hot bending radius, *R***
mm	mm	mm
20	2.5	100
30	2.5	150
40	2.5	200
50	3.2	230
60	5.0	230
70	5.0	230
80	5.0	240
90	5.0	270
100	5.0	300
120	5.0	360
150	5.0	450
180	6.3	540
200	6.3	600
250	6.3	750
300	8.0	900
350	8.0	1 050
400	10.0	1 200

Figure 3 **Preferred minimum hot bending radius for rectangular hollow steel sections**



10.3.5 Protection against corrosion

10.3.5.1 General

Carbon and low alloy steel protective barriers should be finished by one of the processes described in **10.3.5.2** to **10.3.5.3**.

NOTE For further guidance on protective coating of steel structures see BS 5493.

10.3.5.2 Metal coating

The steel should be hot-dip galvanized to conform to BS EN ISO 1461 or sprayed with zinc or aluminium to conform to BS EN ISO 2063.

NOTE 1 Alternatively pre-galvanized or pre-coated steel strip is available.

If chromium plating is used it should conform to BS EN ISO 6158.

NOTE 2 Paint or plastics coatings can be applied to the finished metal coatings to give colour or additional protection. Where this is done, each coating extends the life of the other. However, care needs to be taken to select a specification to suit the environmental conditions.

10.3.5.3 Fasteners and fittings

Fasteners and fittings should be of stainless steel, or should be hot-dip galvanized to conform to BS EN ISO 1461, sherardized to conform to Class 1 of BS 4921:1988, or coated with a suitable plastics material. Thin zinc plated or cadmium plated coatings should not be used for external exposure without additional protection.

10.3.6 Site fixing

NOTE Typical site fixings are shown in Figure 4.

All welding should conform to BS EN 1011-1 and BS EN 1011-2. Manual metal-arc welding is most commonly used.

Where metal coated protective barriers have standards set in concrete or in the ground, these should be painted with bituminous solution conforming to type 1 of BS 3416 as shown in Figure 4a) and b).

10.3.7 Maintenance

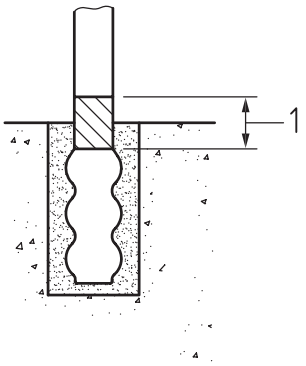
Maintenance recommendations, and the frequency with which barriers should be inspected, are be governed by environment, usage, incidence of malicious damage and the protection applied.

NOTE 1 For further information see BS 5493.

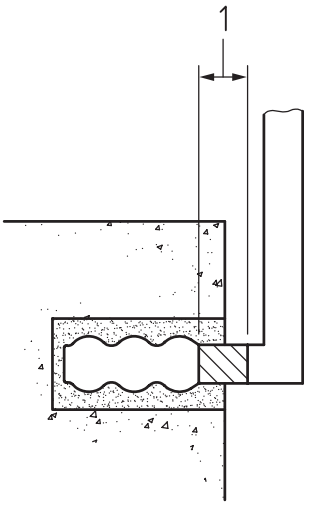
Protective barriers assembled entirely from metal-coated steel and situated in normal environments should not require any maintenance for a very long period. They should, however, be inspected regularly and the residual coating thickness should be measured.

NOTE 2 For guidance see BS EN ISO 3882.

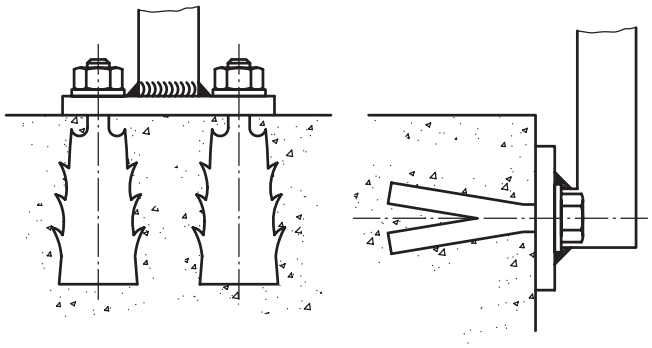
Figure 4 **Typical site fixing details for steel barriers**



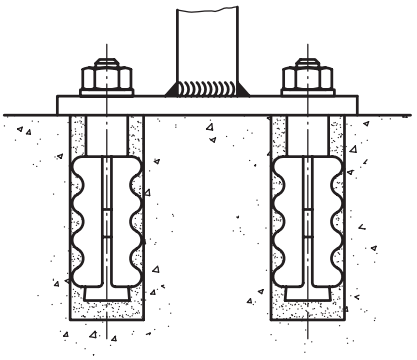
a) Standard set into preformed or cut mortice



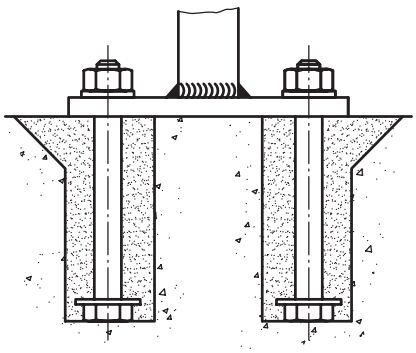
b) Standard set into preformed or cut mortice in side (pocket should be suitably reinforced)



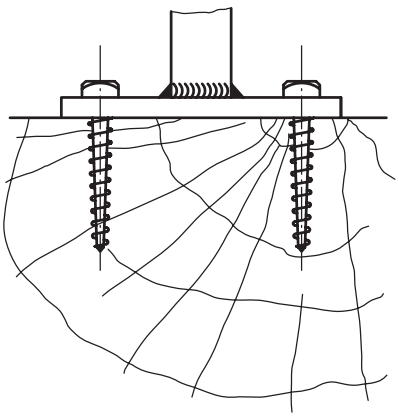
c) Preset bolts normally require slotted holes or similar tolerance in fixing plates



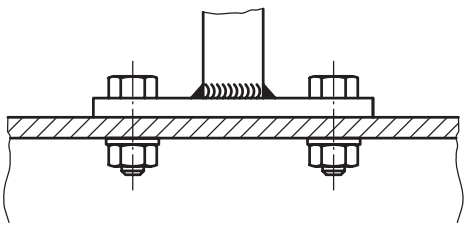
d) Expansion bolts in drilled holes



e) Caged foundation bolts in prepared holes to be filled when fixing



f) Coach bolts or suitable screws for fixing to timber



g) Standard bolted (or, alternatively, welded) to steelwork

Key

1 Approx. 20 mm bituminous solution

Maintenance painting should be scheduled when approximately 25 µm of coating remains on all parts of the surface, so as to retain the advantages of having a metal coating between the paint and the steel. When maintenance-painting a metal coating where there has been no rusting of the basis steel, the surface should first be thoroughly washed to remove soluble corrosion products and dried; most paint systems can be applied to a weathered metal coating. Where there has been some rusting of the basis steel, these areas should be thoroughly cleaned, causing as little damage as possible to the remaining metal coating.

NOTE 3 It is preferable to apply a compatible metal coating to the denuded areas before the whole surface is coated with a conventional paint.

Where no overall metallic protection has been given, or where reliance is placed solely on a painted finish, barriers are more vulnerable and should be inspected at frequent intervals. Affected areas should be thoroughly cleaned and repainted to the original specification.

Particular attention should be paid to joints, bolts, screws, etc., and also to fixing points where the barrier is in contact with concrete, mortar or other fixing materials, since these points are particularly susceptible to corrosive attack.

Checks should also be made for loosening of connections, particularly where fixings are subject to fluctuating loads and sustained high loads.

10.4 Cast iron

Cast iron, which is extremely brittle, should only be used for ornamental features.

10.5 Wrought-iron

*COMMENTARY ON **10.5***
Wrought iron is no longer available commercially. The term "wrought-iron" is often used loosely and incorrectly to describe a type of forming used for decorative gates and panels.

Any person specifying such materials should be cautious in the use of this term.

11 Plastics

11.1 General

*COMMENTARY ON **11.1***
Various plastics materials are suitable for use in barriers, either as structural members or infill panels or handrails. Plastics materials are particularly suitable for barriers subjected to corrosive environments. Since these materials are based on a number of dissimilar chemical raw materials, their basic properties differ widely from one another. Thus, in addition to the general information given in this clause, detailed information on the particular material to be used ought to be sought, as required, from appropriate industrial sources.

Plastics materials classified as low-level glazing in a building facade should be designed using the design criteria given in BS 6262 (all parts), ensuring adequate containment (see **8.6.1**). Other barriers of plastics materials should be designed to satisfy the design criteria given in Clause **6**. In addition, the material should not break when the barrier is subjected to the normal design loads that might be applied,

and should not be penetrated when subjected to the relevant impact test loads (see **11.5**).

11.2 Types of plastics

*COMMENTARY ON **11.2***
Plastics materials can be divided into two general groups, thermoplastics and thermosetting (thermoset) materials. Within these groups, there are various differing types of materials.

- *Thermoplastics comprise plastics materials that soften under the influence of heat, thus undergoing physical, but not chemical, change.*
- *Thermosetting (thermoset) materials comprise plastics materials that have undergone an irreversible chemical change during their manufacture. In their final form, these materials often incorporate reinforcing fibres, such as glass fibre or carbon fibre.*

Thermoplastics should not be used where high temperatures, exposure to UV light and/or low humidities are anticipated.

11.3 Structural members

Structural members made from plastics materials should only be made from reinforced thermosetting plastics.

NOTE Structural members can be fabricated as complete units or supplied as shaped rod or profile stock for subsequent fabrication and assembly.

11.4 Infill panels

11.4.1 General

Plastics infill panels for barriers should be manufactured both from thermoplastics (except as recommended in **11.2**) and suitably reinforced thermosetting materials.

11.4.2 Infill panels: thermoplastics materials

11.4.2.1 General

Thermoplastics infill panels should be manufactured from thermoplastics sheet stock, which can be unreinforced or suitably reinforced. The materials used should be safety plastics materials conforming to the impact performance requirements of BS 6206 (see **11.5**).

NOTE 1 Typical examples of such materials are acrylic, polycarbonate and rigid polyvinyl chloride (PVC).

NOTE 2 Reinforcement normally consists of wire or metal mesh reinforcement incorporated during manufacture. Other types of reinforcement can be included to give panels special properties, such as increased rigidity or improved fire resistance.

11.4.2.2 Design

A nominal additional safety factor of 1.5 should be applied to the design loads to allow for possible ageing effects after long-term weathering. Allowance should be made for the high coefficient of linear thermal expansion of thermoplastics infill panels and a clearance of 5 mm per metre length should be provided within the metal support frames.

11.4.2.3 Fixing

Direct fixing of bolts, screws or clips should not be used on acrylic panels and is not recommended for polycarbonate or PVC panels. Fixing should be by the use of metal profile framing fixed to the supporting section and top rail handrail. In the case of acrylic infill panels, edge supports should be over all of the exposed edges, i.e. full framing.

In the case of fully framed infill panels, the rebate depth of the thermoplastics sheet should be not less than 20 mm per metre length. In the case of two-edge framing only, i.e. non-acrylic panels, the minimum rebate depth should be not less than 35 mm per metre length.

Neoprene, butyl or similar suitable rubber profile section should be used to frame the thermoplastics panel within the metal frame. PVC profile section or flexible mastic sealant should not be used.

All metal fixings should be protected from corrosion.

11.4.2.4 Workmanship

All cut edges should be free from cracks, chips or rough edges. Acrylic panels, in particular, should never be cold bent. When panels of polycarbonate or PVC are cold bent on site, the manufacturer's recommendations should be followed, with particular reference to the minimum permitted radius of bend. Any thermoformed bending of all types of thermoplastics infill panels should be carried out by the application of heat in accordance with the manufacturer's recommended thermoforming practice.

11.4.3 Infill panels: thermosetting materials

11.4.3.1 General

The materials used for this type of infill panel should be safety plastics materials conforming to the impact performance requirements of BS 6206 (see **11.5**).

NOTE Infill panels based on thermosetting materials are normally based on unsaturated polyester resins reinforced with glass fibre in various forms. Such materials are commonly referred to as glass fibre reinforced plastics (GRP). Other reinforced thermosetting materials might include laminates made by either hot pressing sheets of paper laminated with phenol formaldehyde resins or by moulding infill panels from glass reinforced acrylic resins.

11.4.3.2 Reinforcing thermosetting plastics sheet materials

Infill panels made from GRP consist of a laminate of thermosetting polyester resin and glass fibre. The laminate should include an outer gel-coat layer designed to provide an exposed protective surface. This layer should be made from special unreinforced resin containing colourants and light-protecting additives.

NOTE 1 Gel coats usually provide a hard, high-gloss surface finish.

NOTE 2 The laminate can be made by contact moulding or matched die moulding. In contact moulding, the laminate can be prepared by the hand lay-up process, which consists of manual impregnation of glass matt with resin, or the sprayup process, in which resin, catalyst and chopped glass fibre strands are deposited on the mould surface in the correct proportions by spray gun or depositor. Matched die moulding can be used to produce moulded GRP infill panels that have specific design features

difficult to achieve using contact moulding, e.g. smooth surfaces on both sides, or particularly intricate designs incorporating locating lugs, bases or strengthening ribs.

11.4.3.3 Design

A nominal additional safety factor of 1.5 should be applied to the design loads, to allow for possible ageing effects after long-term weathering.

NOTE As GRP materials have a lower linear expansion coefficient than thermoplastics materials no special allowance needs to be made for expansion.

11.4.3.4 Fixing

The fixing of GRP infill panels should follow conventional practice. Panels should be fixed by bolts, screws, clamps or full framing.

NOTE Most commercially available sealants are suitable for sealing GRP infill panels. GRP sheets can be cut to shape.

All metal fixings should be protected from corrosion.

11.5 Impact testing

Where theoretical considerations are used to establish that the barrier is capable of meeting the design criteria given in Clause **6**, the designer should ensure that the materials used are appropriate. The plastics glazing sheet materials should be of a type that will conform to the impact test requirements for safety plastics materials given in BS 6206.

NOTE The impact energy level requirement is likely to vary according to the position of the barrier relative to the anticipated flight path of a falling body.

The energy level which should be considered depends upon the free path, i.e. the free distance a body can travel in a direction perpendicular to the surface of the barrier. The impact grades that should be used for barriers are Class C of BS 6206 for a free path of 600 mm up to 1 500 mm and Class A of BS 6206 for a free path greater than 1 500 mm (see **8.6.4**).

The designer should select materials that perform adequately when the barrier is subjected to the normal design loads likely to be applied and that are not penetrated when subjected to the appropriate impact test loads.

11.6 Flammability

The surface spread-of-flame classification of all plastics infill panels should be Class 3 or better when tested in accordance with BS 476-7.

NOTE Higher standards might be required in some locations to conform to building or other regulations.

The surface spread-of-flame of all plastics structural components should be Class 1 when tested in accordance with BS 476-7.

All plastics infill panels having a Class 2 or 3 surface spread-of-flame from BS 476-7 should have all exposed sheet edges protected by a metal frame.

11.7 Maintenance

11.7.1 Cleaning

Plastics infill panels and handrails should be cleaned with water and mild detergent only. Solvents or abrasive cleaners should not be used for cleaning.

11.7.2 Decoration

Plastics infill panels and handrails are provided pre-coloured and are not likely to need any form of decoration. Paint should not be applied to plastics panels. If secondary decoration is necessary, the manufacturer's recommendations should be sought.

Care should be taken during the repainting of any adjacent supporting structures to ensure that solvent-based paint removers or blow lamp flames do not come into contact with any plastics surface.

11.7.3 General inspection

Plastics infill panels should be inspected at least annually and checked for cracks or splits arising from impact or misuse. Damaged panels should be replaced and loose fixings tightened. To avoid damage to the panels, fixings shuld not be overtightened. Corroded fixings should be replaced immediately.

12 Timber

12.1 Materials

Timber used for barriers should conform to one of the strength classes and, preferably, types of species described in BS EN 1995 (all parts) and should be of a grade for which permissible stresses are given in this code.

NOTE Barriers can also be made from glued structural components of timber and wood-based panel products manufactured in accordance with BS 6446 and designed in accordance with BS EN 1995 (all parts).

12.2 Design

12.2.1 General

The design of all timber barriers should be in accordance with BS EN 1995 (all parts), where applicable.

Using the design criteria given in Clause **6**, the stresses used in the design should be those appropriate to the grade selected. The minimum horizontal imposed loads given in BS EN 1991-1-1:2002 should be considered to be of medium-term duration.

12.2.2 Joints

All joints in the timber should be designed in accordance with BS EN 1995 (all parts).

12.2.3 Fixing at base or termination of horizontal rails

Timber posts and horizontal rails for permanent barriers should not be set directly into concrete or masonry likely to be wet for significant periods, but should be provided with suitable metal shoes or extensions that keep the end grain of the timber at least 50 mm clear of surfaces.

12.3 Fabrication

12.3.1 Moisture content

The moisture content of the timber should, as far as practicable, be appropriate to the position in which it is to be used.

NOTE 1 Guidance on moisture content is given in BS EN 1995 (all parts).

NOTE 2 In the case of glued assemblies, it might be necessary to fabricate a component at a lower moisture content and subsequently condition it to suit the assembly in which the component is to be used.

12.3.2 Preparation of timber

The surface finish to all barriers should be smooth and clear of any projection that could cause injury. Arrises should be rounded to reduce splintering. Top rails should be smooth finished and of a type of timber not liable to produce splinters in use. For traditional timber stairs BS EN 15644 should be followed, and for pre-fabricated stairs DD CEN/TS 15680 should be followed.

12.4 Assembly

The components of barriers should be connected to each other using the methods recommended in BS EN 1995 (all parts). If the barrier is to be prefabricated and subsequently assembled on site, a trial assembly should take place at the workshop before delivery.

12.5 Protective processes and finishes

12.5.1 Preservation

The preservation of timber barriers, where required, should be in accordance with BS 8417.

12.5.2 Finishes

Timber barriers should be finished with a paint system or a natural finish treatment.

NOTE For guidance on paint systems see BS 6150.

Whichever finish is used, it should be applied when the timber is at a suitable moisture content and in the correct climatic conditions for the particular method of finishing in accordance with industry practice and manufacturers' recommendations. The final coat should be applied on site after installation so that any accidental damage can be remedied.

12.6 Storage and handling

All materials and assemblies should be protected against exposure to the weather, wetting, damage, decay or insect attack prior to fixing on site. The storage temperature and humidity should be controlled to ensure that the moisture content of the timber remains reasonably constant.

Timber components and assemblies should not be delivered to the site until they are required for building in. Before leaving the workshop or factory they should be protected against damage during transportation.

12.7 Fixing on site

Care should be taken to avoid overstressing of members during fixing. All site-bolted joints should be inspected and all bolts should be carefully tightened without crushing the wood under the washers or plates. The fixing of barriers should take place as late as practicable in the construction of the building. Bolts and fixings should be checked for tightness before handing over and subsequently at the end of the maintenance period.

All metal fixings should be protected from corrosion.

12.8 Protection after fixing

Protective barriers should be safeguarded from damage by other trades. Temporary supports might be necessary if the assembly is fixed into wet joints and they should remain in place until all materials are fully set.

NOTE Special protection might be necessary for polished or stained finishes to ensure that other trades do not mark or damage the finish.

12.9 Maintenance

Certain finishes should be periodically cleaned and renewed in order to keep a good appearance. As some applied finishes are likely to crack and peel when used outside, these should be checked at regular intervals and renewed as necessary.

All joints and connections should be checked to see if movement exists within the joints. The screws and nails within the joint should be checked for corrosion, particularly if the protective system is damaged.

13 Composites

Where barriers are constructed from two or more different materials, the following should be taken into consideration.

a) The materials should be compatible in all ways (e.g. electrolytically and thermally).

b) Due allowance should be made for the possibility of differential movement.

c) Each element of construction should be designed in accordance with the appropriate Clause of this British Standard for the material from which it is made.

14 Installation

The installation of a barrier should be supervised by a suitably qualified person or persons, who should ensure that the design assumptions have been effectively implemented. Inspections and investigations should be carried out as necessary to establish the integrity of the materials and the elements of construction used.

Annex A (normative) Vehicle impact on barriers

A.1 Impact normal to the barrier

The designer should use the following expression, given in BS EN 1991-1-1:2002, Annex B, as a means to establish, to within a reasonable order of magnitude, the equivalent static force, *F* (in kN), transmitted to a barrier system:

$$F = \frac{0.5mv^2}{\delta_c + \delta_b}$$

where

m is the characteristic mass of vehicle in kilograms (kg);

v is the velocity of the vehicle prior to impact in metres per second (m/s);

δ_c is the deflection of the vehicle in millimetres (mm);

δ_b is the deflection of the barrier in millimetres (mm).

NOTE 1 For car parks, the force F can be distributed over a length of 1.5 m.

NOTE 2 In Figure A.1, this expression has been plotted graphically for unit vehicle mass and a velocity prior to impact of 16 km/h (4.44 m/s, 10 mile/h).

The total deformation shown in Figure A.1 should be taken to be the deformation of the vehicle, which could be assumed to be not less than 100 mm, plus the deformation of the barrier system, where this is designed to absorb impact energy by lateral displacement.

A.2 Impact at an angle to the barrier

For areas other than car parks where the impact on the barrier is likely to be at a shallow angle, since in most applications barriers are provided parallel to the direction of traffic, the order of magnitude of the equivalent static force, *F′* (in kN), transmitted at right angles to the barrier should be obtained from the expression:

$$F' = \frac{0.5m\left(v\sin\theta\right)^2}{c\sin\theta + b\left(\cos\theta - 1\right) + \left(\delta_c + \delta_b\right)}$$

where

θ is the angle of incidence between vehicle and barrier in degrees (°);

c is the distance of centre of gravity of the vehicle from the front end in millimetres (mm);

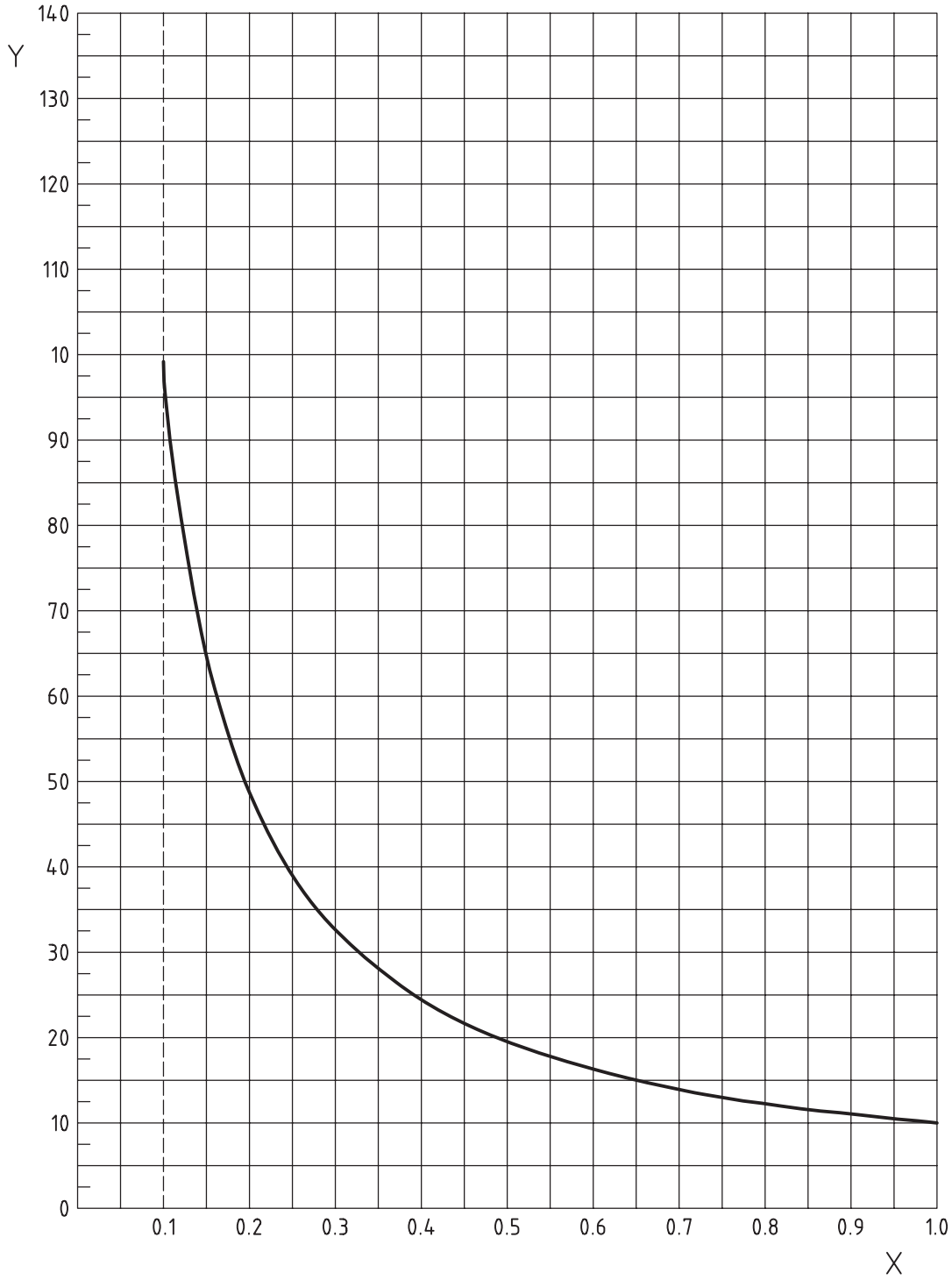
b is the distance of centre of gravity of the vehicle from the side in contact with the barrier in millimetres (mm); and

m, v, δ_c and δ_b are as defined in **A.1**.

NOTE 1 In Figure A.2, this expression has been plotted graphically for unit vehicle mass, an angle θ of 20° and a velocity prior to impact of 16 km/h (4.44 m/s, 10 mile/h). Two typical load deflection curves are shown, one for heavy goods vehicles (c = 3 960 mm, b = 1 200 mm) and the other for private motor cars (c = 2 200 mm, b = 860 mm). Figure A.2 applies only to vehicle speeds ≤16 km/h (10 mile/h).

NOTE 2 The above approach to impact problems has been adopted by the Transport Research Laboratory for establishing the validity of barrier systems.

Figure A.1 **Impact forces for vehicles impacting at right angles to a barrier**

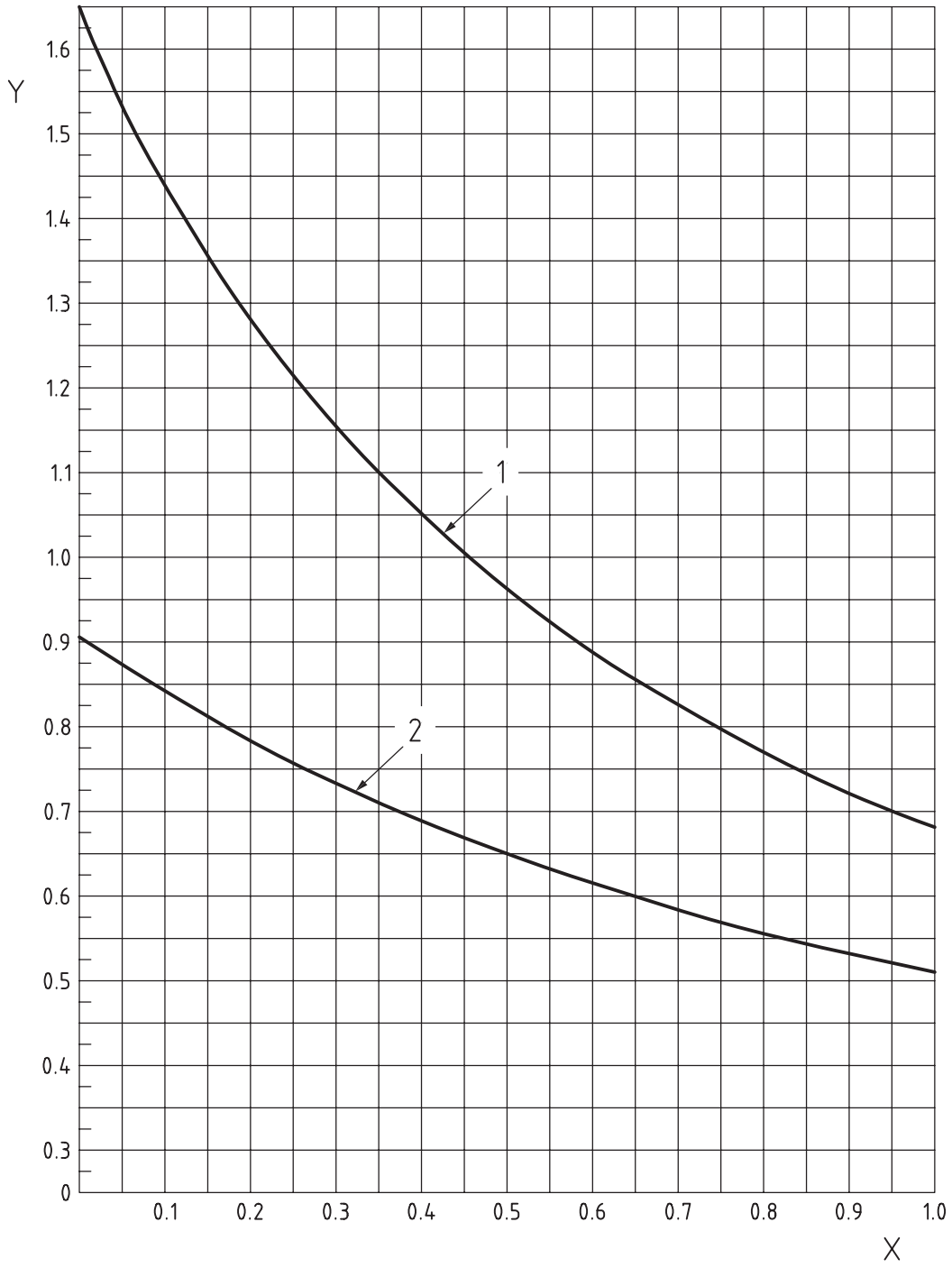


X Total deformation of vehicle and barrier, m

Y Coefficient of characteristic equivalent ultimate static force transmitted to barrier, *F/m*

NOTE To obtain the equivalent static force on the barrier in Newtons, multiply the coefficient F/m by the characteristic mass of the vehicle in kilograms.

Figure A.2 **Typical impact forces for vehicles impacting at 20° to a barrier, at 16 km/h**



X Total deformation of vehicle and barrier, mm

Y Coefficient of characteristic equivalent ultimate static force normal to barrier, *F/m*

Key

1 Typical light good vehicle/private car

2 Typical heavy good vehicle

NOTE To obtain the equivalent static force on the barrier in Newtons, multiply the coefficient F/m by the characteristic mass of the vehicle in kilograms.

Annex B (normative) Bolt fixing of glass in barriers

B.1 Bolt fixing of infill panels

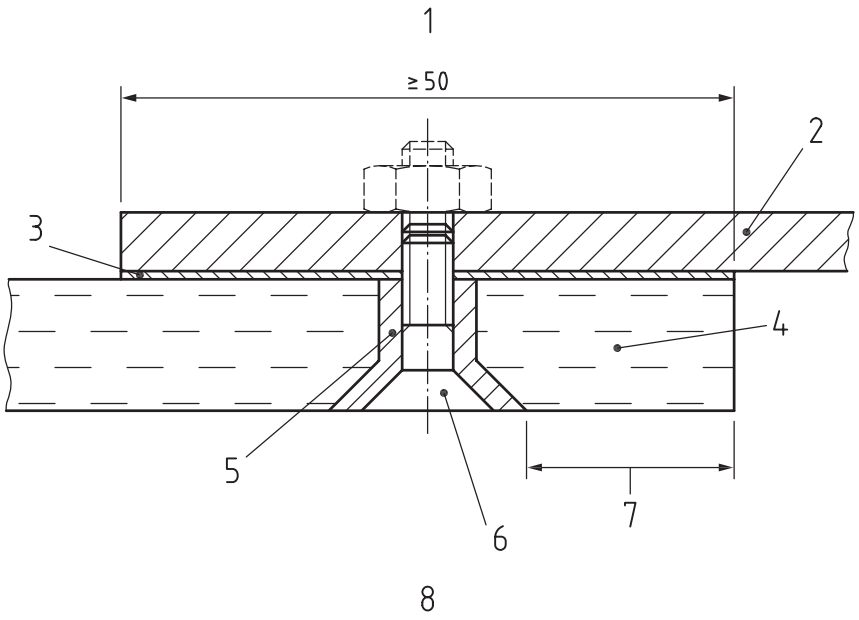
At the bolted connections there should be clamping plates and gaskets (see **8.2.3**) on both sides of the glass that provide a minimum of 50 mm diameter cover to the glass. These plates should be not less than 6 mm thick in steel or 10 mm thick in other suitable metals.

NOTE Where toughened glass of 10 mm thickness or greater and of maximum dimension less than 1 500 mm is used, an alternative acceptable fixing design is shown in Figure B.1. Using this alternative fixing, it is essential to consider tolerances in detail, since oversize holes in the glass cannot be used with this fixing system.

Where the length of a glass pane is greater than the span between the bolted connectors, giving rise to a cantilevered portion of the pane, the cantilevered portion should be less than one-quarter of the span between the bolted connectors.

Under the design loads, the barrier should be designed so that the relative in-plane movement of the bolted connections in the same panel is not greater than 2 mm.

Figure B.1 **Alternative bolt fixing arrangement for thick toughened glass infill panels**



Key

1 Side of drop being protected
2 ≥6 mm steel plate attached to balaster
3 Fibre gasket, 1.0 mm thick
4 ≥10 mm toughened glass
5 Close-fitting CSK nylon bush
6 CSK bolt screwed into steel plate or bolted through steel plate
7 ≥2 x glass thickness
8 Public access side

B.2 Base fixing of free-standing barriers

B.2.1 Point of fixing clamps

The fixing clamps on each side of the glass should be not less than 100 mm × 150 mm and should be made of a suitable metal of minimum thickness 12 mm.

There should be not less than two fixing clamps for every 1 m length of barrier.

NOTE Figure B.2a) shows a typical point-fixing clamp.

B.2.2 Continuous fixing clamps

The fixing clamps on each side of the glass should be not less than 100 mm wide and should be made of a suitable metal of minimum thickness 12 mm. The clamps should be continuous for the entire length of the glass pane and have a maximum bolt spacing of 500 mm.

NOTE Figure B.2b) shows a typical continuous fixing clamp.

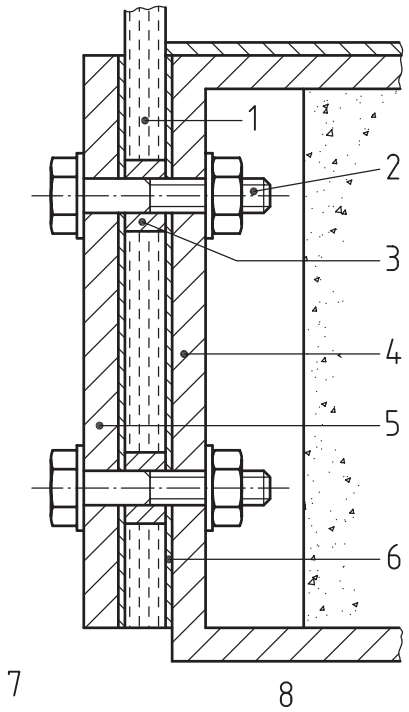
B.2.3 Other clamping systems

NOTE 1 Different clamping methods could be used, providing they provide effective continuous clamping over the length of the glass pane.

Where a clamping system that does not rely on bolts through the glass is used, the depth over which the clamping force operates should be not less than 75 mm, unless specific tests have been carried out to prove the integrity of the system and that it meets the design criteria given in Clause **6**.

NOTE 2 Figures B.2c) and B.2d) show some alternative clamping systems.

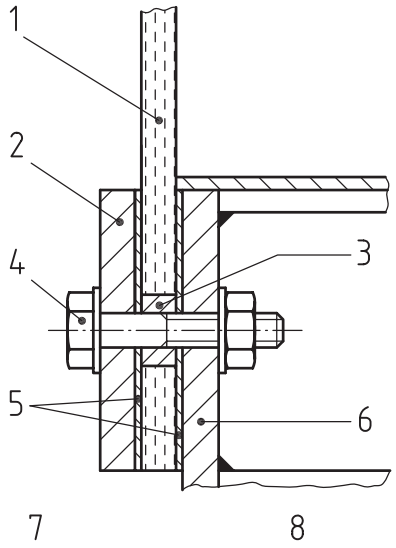
Figure B.2 **Typical clamping systems for free-standing toughened glass balustrades**



a) Point-fixing clamp

Key

1 Glass
2 M 16 bolts
3 3 mm thick bush hard fibre or nylon
4 ≥12 mm metal plate attached to structure at 500 mm centres
5 ≥12 mm plate min. 100 x 150 mm
6 1.0 mm thick fibre gasket
7 Side of drop
8 Public access side

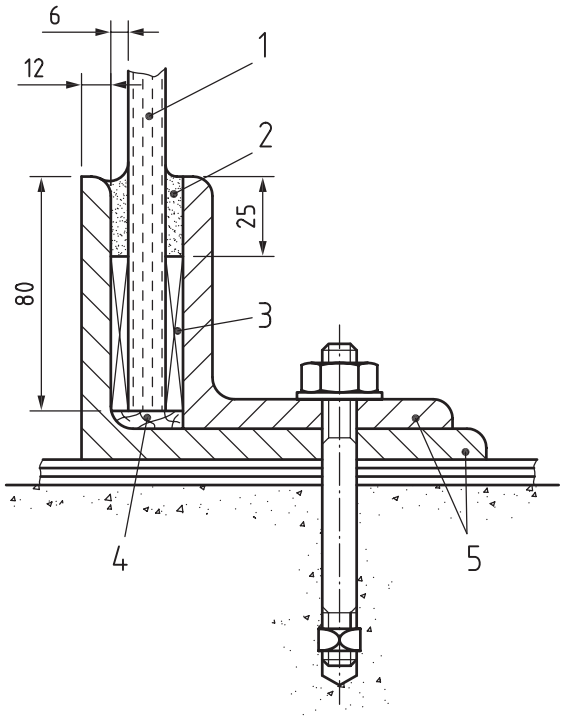


b) Continuous fixing clamp

Key

1 Glass
2 ≥12 mm metal plate continuous ≥ 100 mm wide
3 3 mm hard fibre or nylon bush
4 M 16 bolts at 500 mm centres
5 1.0 mm thick fibre gasket
6 ≥12 mm continuous metal plate attached to structure
7 Side of drop
8 Public access side

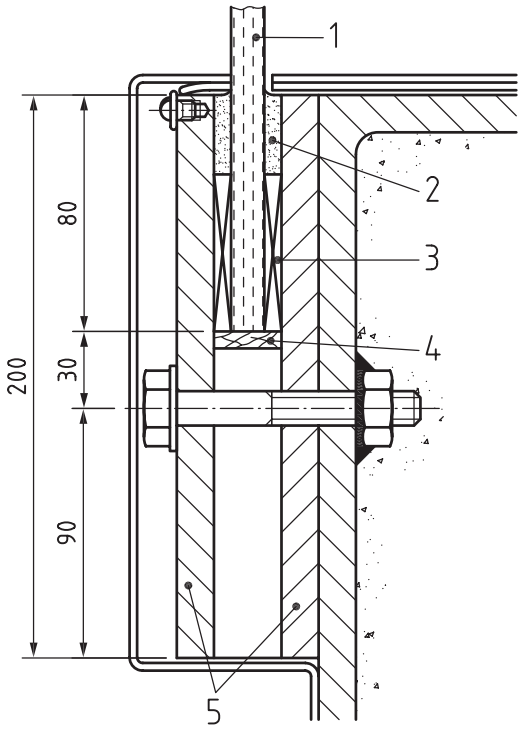
Figure B.2 **Typical clamping systems for free-standing toughened glass balustrades** *(continued)*



c) Alternative clamping system

Key

1 Glass
2 High modulus sealant
3 Hardwood, extruded silicone S/H 85° or epoxy polysulphide compound
4 Setting block
5 Continuous 12 mm thick angles



d) Alternative clamping system

Key

1 Glass
2 High modulus sealant
3 Hardwood, extruded silicone S/H 85° or epoxy polysulphide compound
4 Setting block
5 Continuous 12 mm thick plates

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