

Highway parapets for bridges and other structures —

Part 1: Specification for vehicle containment parapets of metal construction

ICS 93.040

Committees responsible for this British Standard

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- Association of Consulting Engineers
- Association of County Councils
- Association of Safety Fencing Contractors
- British Cement Association
- British In-situ Concrete Paving Association
- British Precast Concrete Federation Ltd.
- County Surveyors' Society
- Department of Transport (Highways Agency)
- Institution of Civil Engineers
- Motor Industry Research Association
- National Fencing Training Authority
- Railtrack
- Royal Society for the Prevention of Accidents
- Transport Research Laboratory
- UK Steel Association

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Foreword

This part of BS 6779 has been prepared under the direction of Subcommittee B/509/1 and is a revision of the 1992 edition, which is withdrawn.

The other parts already published in the series are:

— *Part 2: Specification for vehicle containment parapets of concrete construction;*

— *Part 3: Specification for vehicle containment parapets of combined metal and concrete construction.*

The other part so far planned in the series is:

— *Part 4: Specification for vehicle containment parapets of masonry and composite masonry and concrete.*

The principal changes from the 1992 edition are that this edition brings the normal containment vehicle impact characteristics into line with a number of proposals agreed for CEN standards, and has been updated to include modifications and changes made in Part 2 and Part 3. Specifically, the centre of gravity of the test vehicle for normal and low containment has been lowered to reflect the present design of saloon cars. Such a test vehicle may not produce significant force in the top rail(s) of the post and rail configurations which are in general use for normal and low containment metal parapets. The Committee intends that these parapets retain their overall resistance to impact from the whole vehicle population, including higher vehicles, as this has contributed to their good safety performance over the past 30 years. It has therefore been necessary to modify and make mandatory, design requirements for post and rail configurations which were previously included for guidance. The production of design calculations conforming with these requirements, which it is strongly advised should be independently certified, is now included in the performance requirements.

The clause dealing with materials of construction has been extended, particularly with regard to the mechanical testing of production material, and the need to relate, as far as possible, the material used in production to that used in the dynamic test. Also, the requirements for welding, workmanship and production inspection and testing are more detailed.

The arrangement of clauses has been altered to be consistent with Part 2 and Part 3.

This standard allows a number of options for the purchaser/supplier, who should indicate to the supplier/purchaser which of the options he requires. Annex C forms a checklist of the items which the purchaser/supplier needs to consider.

Parapets are generally required to have an acceptable appearance, and not to impose such weight or force on the edge of a bridge or structure as to add unduly to its structural requirements.

All or any of these requirements may be in conflict in any particular circumstance, and a judgement as to the solution providing the best overall balance then has to be made.

NOTE A CEN standard for road restraint systems is being developed.

It contains a number of requirements in addition to those in this standard, e.g.:

- i) two vehicle tests are required for high containment parapets; and may be required for normal containment parapets;
- ii) there is a requirement to meet ASI, THIV and PHD levels;
- iii) there is a requirement to produce a comprehensive, dynamic test report (see D.8).

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 does not of itself confer immunity from legal obligations.

Introduction

This part of BS 6779 specifies requirements for parapets of metal construction to provide specified levels of vehicle containment on highways. These parapets are installed on bridges, retaining walls or other structures.

Parapets of concrete, composite concrete and masonry construction or combined concrete and metal construction are not covered in this part of BS 6779.

Containment levels are related to defined vehicle impacts and normal, high and low levels of containment are specified. Containment levels are further discussed in Annex A.

There is a vast and ever changing range in size, shape and configuration of vehicles and, inevitably, not all vehicles conforming to the parameters for characteristic impacts would have precisely the same effect on any particular parapet.

There is therefore some imprecision in the specification of the vehicles and hence in the characteristic impacts and levels of containment, but the selected levels are considered to be the best practically available.

The main objectives of the forms of parapets defined in this part of BS 6779 are:

- a) to provide specified levels of containment to limit penetration by errant vehicles;
- b) to protect highway users and others in the vicinity by redirecting the errant vehicles with minimum deceleration forces onto a path as close as possible to the line of the parapet and to reduce the risk of the vehicle overturning.

NOTE In the case of low containment parapets with vertical infill, the vehicle tends to be arrested rather than redirected (see A.5).

The difficulty of predicting response to dynamic effects makes it impossible to give complete theoretical design criteria which could be guaranteed to produce satisfactory designs. In consequence, full-scale acceptance testing using a vehicle with appropriate impact characteristics is required for the approval of new designs. The required methods for dynamic testing are given in Annex D and the criteria for acceptance of tests in Clause 10. In the case of low and normal containment parapets the saloon car test vehicle is unlikely to impact the upper rail(s) of a 1 m or higher parapet with any severity and the converse could occur when a high containment parapet is impacted by an HGV. To ensure that parapets produce an overall balanced resistance to the whole population of vehicles, valid design calculations conforming to Clause 9 are required for all post and rail designs.

1 Scope

This part of BS 6779 specifies requirements for the design, materials, construction (including storage, transportation and installation) and testing of vehicle containment parapets of metal construction not less than 12 m in length (see Note 2). The parapets covered in this part are mounted on plinths not greater than 100 mm high and are intended to provide specified levels of containment for vehicles on highways.

NOTE 1 For barriers in and about buildings, see BS 6180. For pedestrian parapets and guard rails, see BS 7818. For safety fences and barriers for highways, see BS 6579.

NOTE 2 The containment characteristic of metal parapets is generally provided through absorption of the energy of the vehicle impact by progressive collapse of the support system over a length of parapet. A parapet of less than 12 m length may not provide the specified level of containment.

2 References

2.1 Normative references

This British Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on page 71. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this British Standard only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

2.2 Informative references

This British Standard refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

3 Definitions

For the purposes of this part of BS 6779, the following definitions apply.

3.1

vehicle restraint system

installation to provide a level of containment for an errant vehicle which may be used to limit damage or injury to users of the highway

3.2

highway parapet

a barrier at the edge of a bridge, or on top of a retaining wall or similar structure, associated with a highway

3.3

safety fence

a vehicle restraint system provided for the protection of users of the highway consisting of horizontal beams or wire ropes mounted on posts

3.4

vehicle parapet

highway parapet that acts as a vehicle restraint system

3.5

vehicle pedestrian parapet

vehicle parapet with additional safety provisions for pedestrians and animals

3.6

front face of a parapet

the parapet face nearest to the traffic

3.7

plinth

a continuous upstand on the edge of a structure upon which a parapet is mounted

3.8

main structure

any part of the bridge, retaining wall or similar structure upon which a parapet is mounted, including the plinth

3.9

adjoining paved surface

the paved area on the traffic side of a parapet, immediately adjacent to the plinth or base of the parapet

3.10

attachment system

the system of attachment of the parapet to the anchorage, usually consisting of holding-down bolts

3.11**anchorage**

that part contained within the main structure to which the parapet is directly fixed by means of the attachment system

NOTE For example, a cast-in anchorage cradle in a reinforced concrete edge beam and plinth.

3.12**datum for height considerations**

the highest level of footway, verge, carriageway or any other part of the road construction within 1.5 m of, and on a line at right angles to, the traffic face

NOTE This will normally be the adjoining paved surface, excluding the plinth height.

3.13**effective longitudinal members**

those longitudinal members of a post and rail type parapet that become effective in restraining a vehicle in an impact

3.14**non-effective longitudinal member**

an additional longitudinal member above or below the effective longitudinal members provided to give additional height to a parapet for the protection of pedestrians or animals or to support environmental barriers, sheet infilling panels, or mesh infilling panels

3.15**traffic face of a parapet**

a vertical plane containing the front face of the main longitudinal member and the front face of the plinth

3.16**infilling panel**

a non-structural panel used to cover the spaces between members on the front face of a parapet to safeguard pedestrians

NOTE Where required, infilling panels may also be used as a protection against splash and/or noise.

3.17**vertical infill bar**

infilling vertical members providing protection to pedestrians and animals by infilling between longitudinal members

3.18**safety barrier**

a vehicle restraint system provided for the protection of users of the highway that is continuously in contact with its supporting foundation

3.19**transition system**

an arrangement for connecting dissimilar and/or different capacity protective systems

3.20**wheel penetration**

the maximum dynamic penetration of the lower outside face of any tyre or wheel measured perpendicular to the original traffic face of the parapet system

4 Symbols

The following is a list of symbols used in this part of BS 6779 to represent variables. Other symbols used for designation purposes are listed in Table 1.

a	mean lateral deceleration (m/s^2);
b	distance of the centre of gravity of the vehicle from the side (m);
c	distance of the centre of gravity of the vehicle from the front (m);
D	nominal bolt diameter (mm);
F	mean impact force (kN);
f_k	characteristic (or nominal) strength of the material;
k_z	ratio of the test strength to the theoretical strength;
K_I	factor k_z at critical stress condition;
L	distance between centreline of supports (m);
m	vehicle mass (kg);
n	number of effective longitudinal members;
Q^*	design load (kN);
Q_k	nominal load (kN);
R^*	design resistance;
S^*	design load effect;
z	sum of barrier deflection and depth of vehicle crumpling (m);
v	approach velocity (m/s);
γ_{FL}	partial load factor;
γ_{F3}	partial factor for load effect;
γ_{m}	material factor;
σ_{vb}	minimum ultimate tensile strength of bolt material (N/mm^2);
σ_{ya}	minimum yield strength of anchorage material (N/mm^2);
θ	angle of path of vehicle (degrees).

5 Designation of vehicle parapets

For the purposes of an abbreviated description, vehicle parapets shall be designated by three characters indicating:

- level of containment;
- height of parapet;
- type and height of infill.

Where appropriate, designations shall be supplemented by relevant information, e.g. materials, protection, infill treatment, anchorage type (see Annex C). Designation details are set out in Table 1.

Table 1 — Designation of vehicle parapets

Item	Designation	Clause
a)	Levels of containment N = normal level of containment L = low level of containment H = high level of containment	6.1 6.1.1 6.1.2 6.1.3
b)	Overall height of parapet 1.00 = 1 m height 1.25 = 1.25 m height 1.50 = 1.50 m height etc.	6.2 Figure B.1, Figure B.2, Figure B.3, Figure B.4 and Figure B.5
c)	Infill for parapets not over railways O = no infill M = mesh infill to full height m = mesh infill to part height W = solid infill to full height w = solid infill to part height S = environmental barrier V = vertical bar X = special design Infill for parapets over railways B = solid infill to full height b = solid infill to part height R = rail mesh to full height r = rail mesh to part height X = special design	8.2 b) b) d) d) e) a) 8.2 d) d) c) c)
NOTE Examples of designation: N/1.00/O indicates a parapet of 1 m height above the datum, of normal level of containment to 6.1.1 and with no infill component. N/1.25/r indicates a parapet of 1.25 m height above the datum, of normal level of containment to 6.1.1 and with rail mesh infill to part height to 8.2c .		

6 General design

6.1 Levels of containment

6.1.1 Normal level of containment

Normal level of containment shall be that required to resist penetration from the following vehicle impact characteristics:

Vehicle	Saloon car;
Mass	1 500 kg;
Height of centre of gravity	480 mm to 580 mm;
Angle of impact	20°;
Speed	113 km/h (70 mile/h).

NOTE The normal level of containment is suitable for general use.

6.1.2 Low level of containment

Low level of containment shall be that required to resist penetration from the following vehicle impact characteristics:

Vehicle	Saloon car;
Mass	1 500 kg;
Height of centre of gravity	480 mm to 580 mm;
Angle of impact	20°;
Speed	80 km/h (50 mile/h).

NOTE The low level of containment is for use in lower speed restricted urban situations (see A.5).

6.1.3 High level of containment

High level of containment shall be that required to resist penetration from the following vehicle impact characteristics:

Vehicle	Four axle rigid HGV;
Mass	30 000 kg;
Height of centre of gravity	1.65 m;
Angle of impact	20°;
Speed	64 km/h (40 mile/h).

NOTE The high level of containment is for use only in extremely high risk situations (see A.9).

6.2 Minimum height

The height of parapets of normal and low levels of containment shall be not less than 1.00 m measured above datum. The height of parapets of high level of containment shall be not less than 1.50 m above datum.

NOTE Particular applications may require greater heights of parapet to be used (see Clause 8).

6.3 Freedom from projections and depressions

6.3.1 Metal rails and posts

6.3.1.1 Metal rails shall present smooth surfaces on the traffic face and on the top and bottom faces and be free from sharp edges or corners on the front face. The minimum projected vertical depth shall be 50 mm for normal and low containment and 100 mm for high containment.

6.3.1.2 Projections and depressions on these faces and on tops of posts shall only be allowed at joints in rails and at connections to posts and shall be within the following limits.

- Front face and top and bottom faces within 15 mm of the front face:* a maximum of 15 mm including the heads of any fastenings, which shall be of a well rounded shape.
- Top face and bottom faces beyond 15 mm from the front face:* a maximum of 25 mm including the heads of any fastenings.

NOTE In the case of round or near round sections the front face for this purpose shall be taken as the forward arc subtending 120° centred about the horizontal and the top and bottom faces as adjacent arcs each subtending 60°.

- Tops of posts, including any caps or straps, shall not project above the level of the top of the top rail by more than 16 mm and the heads of any fastenings to the top of the post shall not project above the top face of the top rail by more than 35 mm, making allowance for sloping rails.

6.3.2 Infills and fixings

Infills shall be of one of the types allowed under Clause 8 and shall be fixed closely to the traffic faces of the rails. Heads of fixings shall not project more than 10 mm forward of the traffic face of the infill and shall be of a well rounded shape.

6.3.3 *Post to rail fixings*

Post to rail fixings shall be contained within the limits for projections and depressions specified in 6.3.1.2.

6.4 *Durability*

6.4.1 *General*

NOTE Parapets are likely to be directly affected by de-icing salts, traffic fumes and other contaminants. The use of corrosion-resistant materials, or of steel galvanized in accordance with BS 729, where this can be achieved, is suitable. A 60 year life with routine maintenance is desirable.

6.4.1.1 *Accessibility for maintenance*

Adequate clearance or means of access shall be provided around all parts requiring maintenance.

6.4.1.2 *Mixing different materials*

Parts requiring maintenance against corrosion shall not be incorporated into a parapet which is generally constructed of corrosion-resistant materials. This requirement shall not preclude galvanized steel mesh being used on aluminium or steel parapets, nor the use of stainless steel bolts and washers with aluminium parapets.

6.4.1.3 *Vandalism*

The need of the parapet to resist vandalism shall be taken into account in its design. It shall be ensured that fixings and fasteners are not so easily loosened as to allow parts of the parapet to be wilfully removed simply and quickly using minimal tools, or to be easily damaged by a single kick or a series of kicks.

6.4.1.4 *Repair and replacement*

Parts or sections of parapets may need to be repaired or replaced after impact damage and design details shall take this into account.

6.4.2 *Base plates, attachment systems and anchorages*

The following requirements shall be observed.

- a) Aluminium which is to be in contact with concrete or mortar shall be coated with at least two applications of bituminous coating solution conforming to BS 3416 or with hot-dip bitumen, applied to a clean, degreased surface.
- b) Metal-to-metal contact between dissimilar materials shall be avoided where possible by the use of non-metallic sleeves, washers or coatings to prevent galvanic corrosion.
- c) Unfilled holes, annular spaces, gaps, etc. where water could collect and freeze or cause local deterioration shall not be present.
- d) Holding-down bolts shall be of stainless steel, grade A4 - 80 to BS 6105. When required, stainless steel washers shall conform to BS 4320 and be made from stainless steel strip grade 316 S 31 or 316 S 33 conforming to BS 1449-2.
- e) All parts of cast-in cradle anchorages, or cast-in or drilled individual anchorages within 80 mm of the upper surface of the plinth or coping, or where the parts are threaded to receive the stainless steel holding down bolt, shall be made of stainless steel grade 316 S 31 or 316 S 33 to BS 970-3, grade 316 S 33 to BS 6744, or grade A4 to BS 6105.

6.4.3 Metal posts and rails and/or other parts

6.4.3.1 General

The minimum thickness of section of all metal parts shall be in accordance with Table 2.

Table 2 — Minimum thickness of members, infill panels and other components

Material	Section	Minimum thickness			
		Primary load carrying members	Non-load carrying members and secondary elements of load carrying	Infilling panels, bars and mesh	Clips, covers, fixings etc.
		mm	mm	mm	mm
Steel	Hollow sections, galvanized inside and outside or fully sealed	3	3	3	3
	All other sections	4	3	3	3
Aluminium alloy	All	3	1.2	3	1.2
Stainless steel	All	2	1	2	0.5

6.4.3.2 Steel

Steel parapets shall be constructed of the materials specified in 7.1 and shall be treated with a suitable protective system in accordance with the intended parapet environment and life requirement.

NOTE 1 Suitable protective systems are described in BS 5493 or may be obtained from the Highways Agency.

NOTE 2 The purchaser should state his requirements for the protective system to be used, as indicated in Annex C.

6.4.3.3 Aluminium

Aluminium parapets shall be constructed of the materials specified in 7.2.

NOTE The aluminium alloys specified in 7.2 are satisfactory for all the usual exposure conditions but undue corrosion has been found to occur where salt can accumulate and the normal cleansing effects of weather are absent. An example is a parapet on the multi-level junction shielded by a bridge structure. In such cases protective coatings should be considered.

6.4.3.4 Hollow sections

Hollow sections shall be either drained to prevent corrosion and damage occurring due to the freezing of water which may accumulate inside them, or completely sealed, with all joints being made with continuous welds of structural quality.

Holes for galvanizing and/or drainage shall have a diameter not greater than one-twelfth of the circumference of the member, with a minimum diameter of 8 mm prior to galvanizing (or 6 mm if not galvanized) and a maximum diameter of 15 mm. Holes shall not be spaced closer than 700 mm if they are to be left open.

NOTE 1 Consideration should be given to the effect on the strength of members of the design, location and making of the holes.

NOTE 2 Moisture can collect in a section not open to direct penetration by condensation of water vapour drawn in by the breathing effect caused by changes in air temperature and pressure.

NOTE 3 Where unsealed steel hollow sections are used, corrosion may take place internally. This has been found to affect a limited area around drainage holes, open ends, etc., the extent being to some degree affected by exposure conditions. Where hollow sections are hot-dip galvanized, the internal galvanizing will be sufficient protection against this.

6.4.3.5 Holes in baseplates

Drain holes in the baseplates of hollow sections shall have a diameter or width of (80 ± 5) % of the smallest internal dimension of the post to allow for the free flow of zinc during galvanizing.

6.5 Requirements at joints and at ends of parapets

6.5.1 *Post and rail type parapets*

6.5.1.1 *Joints for total movements 0 mm to 50 mm*

Joints providing continuity between lengths of rails or across expansion or rotational joints where the total longitudinal movement at rail level is 50 mm or less shall conform to the following.

- a) *Rails in tension.* The joint shall be capable of transmitting 60 % of the tensile strength of the theoretical gross rail section.
- b) *Rails in bending.* The joint shall be capable of transmitting the full maximum design requirement of the rail in bending at any extension of the joint.

6.5.1.2 *Joints for total movement greater than 50 mm*

Joints across expansion or rotational joints where the total longitudinal movement at rail level is greater than 50 mm shall conform to the following.

- a) *General.*
 - 1) *Rails in tension.* No requirement to transmit tension.
 - 2) *Rails in bending.* Joints shall be capable of transmitting the full maximum design requirement of the rail in bending at any extension up to the full design movement at the joint plus 100 mm.
- b) *Posts for low and normal containment.* Special end posts shall be provided at each side of the joint spaced as close together as practicable and not exceeding 1.5 m between centres (see 6.5.1.6).
- c) *For high containment.* Special end bays (see 6.5.1.7) shall be provided at each side of the joint. The end posts, either side of the joint, shall be spaced as close together as practicable and not exceeding 1.7 m between centres.

NOTE A shock transmission unit solution has been considered but has been found to need further development.

6.5.1.3 *Joints where complex movements take place*

Joints where significant movement takes place in a vertical or transverse horizontal direction shall, where possible, comply with 6.5.1.1 and/or 6.5.1.2. Where compliance with 6.5.1.1 and/or 6.5.1.2 is not possible, a discontinuity of the parapet is permissible. In such cases for low and normal containment, special end posts shall be provided at each side of the joint spaced as close together as is practicable and not exceeding 2.0 m between centres. For high containment, special end bays (see 6.5.1.7) shall be provided at each side of the joint. The end posts, either side of the joint, shall be spaced as close together as is practicable and not exceeding 2.0 m between centres. The gap between the ends of the rails shall not exceed the expected closing at the joint plus 25 mm.

NOTE It is emphasized that this discontinuity is only to be resorted to in extreme cases and it is most desirable that some form of bridging of the ends of the rails is devised to prevent, as far as is practicable, a vehicle which is in contact with a deflected length of parapet directly striking the end of an undeflected length.

When a bridging piece is used it shall be securely attached to the end of the rail on the approach side.

6.5.1.4 Ends of parapets for normal and low containment

6.5.1.4.1 Parapets with safety fences

The treatment of the connection between safety fences and parapets is dependent on the permitted speed on the highway (see Note 1).

a) Where the permitted vehicle speed exceeds 80 km/h (50 mile/h), an open box beam safety fence shall be provided at the approach end of the parapet. It shall be made continuous with the parapet by a connection capable of transmitting a tensile force of 330 kN. In addition, the form and support of the safety fence shall be such as to provide a gradual transition in lateral stiffness that will safely redirect any impacting vehicle (see Note 2 and Note 3). Where the parapet can be struck from the opposing direction, such as on a single carriageway, a transition in the safety fence shall also be provided on the departure end.

b) Where the permitted vehicle speed is 80 km/h (50 mile/h) or less, and there is a safety fence present at the end of the parapet, it shall, except as provided for in the following, be made continuous with the parapet by a connection capable of resisting an ultimate tensile force of not less than 330 kN. Where such a connection is not practicable, a full height anchorage capable of resisting an ultimate tensile force of not less than 330 kN shall be provided to the safety fence, either close to the parapet or at the transition from a tensioned to an untensioned safety fence. A connection capable of resisting an ultimate tensile force of not less than 50 kN shall also be made with the parapet, having sufficient overlap to maintain support for a movement of 100 mm. The final parapet post shall be a special end post conforming to 6.5.1.6.

In all cases, the end panel or panels of the parapet shall be strengthened, as necessary, to resist the minimum ultimate tensile force of 330 kN or 50 kN, as appropriate (see Note 2).

Rails at the ends of parapets situated above the level of the safety fence, which could be struck by a vehicle, shall over-sail the final post of the parapet by a distance within the range 450 mm to 700 mm. Each shall be cranked back from the traffic face beyond the final post, or radiused, in a horizontal plane beyond the final post to give an angle of between 35° and 45° with the main axis of the rail so that the setback achieved is not less than 170 mm. The strength of the rail in bending shall be maintained to not less than 50 % of the normal rail strength.

NOTE 1 Safety fences provide protection to the end of the parapet and will normally be present on motorway or motorway type roads and on new major roads in rural areas.

NOTE 2 It will be necessary to have a special detail at the ends of the parapet where the safety fence is connected to it, to provide resistance to an ultimate tensile force of not less than 330 kN or 50 kN, as appropriate. Ideally, the safety fence connection should transmit the force into the main structure over a short length of parapet. In the case of a post and rail parapet, a suitable system is to connect the first two (or last two) parapet posts, which may be strengthened and be at closer centres than elsewhere in the parapet; advantage may be taken of the bending strength of this end bay to transfer the force effects directly into the main structure.

Alternatively, a suitable detail may be designed to transfer the force effects into the main structure over a number of bays through end and/or intermediate parapet posts. Rail expansion joints catering for movements in excess of ±10 mm should not be included in such a detail and special attention should be given to the rail-to-post connections.

On short span structures (of 12 m approximate total span), connections that are capable of resisting a minimum ultimate tensile force of 330 kN or 50 kN, as appropriate, may be made to the main and lower effective longitudinal members on the approach and departure ends of the parapet, provided that any expansion joints in the rails are capable of resisting the residual force effects at these joints.

Details of approved connections between the types of safety fence covered by BS 6579-1, -3, -4, -5, -6 and -7 and the existing post and rail parapet designs exempted from dynamic testing, as listed in Annex F, are given in BS 6579. These details do not necessarily cover all the preceding requirements of this clause but are deemed to satisfy as they have successfully withstood dynamic testing and have been proved in service.

NOTE 3 It will be necessary to have a special detail at the connection of the safety fence to the parapet, to provide a transition with increasing transverse stiffness. In the case of a post and rail parapet, a suitable system is to provide additional and stiffer support posts at closer centres than elsewhere in the safety fence.

6.5.1.4.2 Parapets without safety fences

Where there is no safety fence at the end of a parapet the following shall apply.

a) Such precautions as are practicable under the circumstances shall be taken to prevent errant vehicles colliding directly with the end of the parapet.

b) The final post at each end of the parapet shall be a special end post conforming to 6.5.1.6.

6.5.1.5 Ends of parapets for high containment

6.5.1.5.1 Parapets with safety fences

Where there is a safety fence present at the end of a parapet there shall be a suitable transition system to provide protection from impact to the end of the parapet.

NOTE Details are obtainable from the Department of Transport.

6.5.1.5.2 Parapets without safety fences

Where there is no safety fence at the end of a parapet the following shall apply.

- a) Such precautions as are practicable under the circumstances shall be taken to prevent errant vehicles colliding directly with the end of the parapet.
- b) The end bay of the parapet shall be a special end bay conforming to 6.5.1.7.

6.5.1.6 Special end posts for normal and low containment

A special end post shall have a design strength in the longitudinal direction equal to the design strength of an intermediate post in the transverse direction.

NOTE This may be achieved by the combination of two intermediate posts spaced as close together as is practicable and not exceeding 1 m between centres.

6.5.1.7 Special end bays for high containment where no transition is used

A special end bay shall be designed for the ends of high containment parapets capable of resisting and transmitting to the main structure 500 kN applied longitudinally at a level 200 mm below the top of the parapet.

NOTE The 500 kN figure was derived from dynamic testing.

6.5.2 Other parapet configurations

6.5.2.1 General

When parapet designs of configurations other than post and rail are being considered, the general principles embodied in 6.5.1 shall be followed, together with the requirements given in 6.5.2.

6.5.2.2 Joints

Joints shall conform to the following.

- a) *Joints for total movement 0 mm to 50 mm.* Adequate continuity shall be provided in tension and bending.
- b) *Joints for total movement greater than 50 mm.* Adequate continuity of bending shall be provided if necessary. For high containment, adequate anchorage or continuity shall be provided to resist tension.
- c) *Joints where complex movements occur.* Discontinuity is permitted, but the need for additional vertical stiffness and tension anchorage shall be assessed and this shall be provided if necessary.

NOTE It is most desirable to provide some form of bridging (see 6.5.1.3)

6.5.2.3 Ends of parapets for normal and low containment with safety fences

Where a safety fence is provided at the ends of a parapet it shall, except as provided for in the following, be made continuous with the parapet by a connection capable of resisting an ultimate tensile force of at least 330 kN.

Where such a connection is not practicable, a full height anchorage capable of resisting an ultimate tensile force of at least 330 kN shall be provided to the safety fence, either close to the parapet or at the transition from a tensioned to an untensioned safety fence. A connection capable of resisting an ultimate tensile force of not less than 50 kN shall also be made with the parapet, having sufficient overlap to maintain support for a movement of not less than 100 mm.

Any part of the parapet that projects above the safety fence shall be cranked back from the traffic face to give an angle of between 35° and 45° with the main axis of the parapet, so that the setback achieved is not less than 170 mm, so as to avoid the possibility of an errant vehicle impacting directly with the end of the parapet. Adequate strength in bending shall be maintained to assist in deflecting an errant vehicle.

6.5.2.4 Ends of parapets with safety fences for high containment

In cases where safety fences are present, the best practicable adaptation of the system transition (see 6.5.1.5) shall be used where protection of the end of the parapet is required.

6.5.2.5 Ends of parapets without safety fences

Such precautions as are practicable under the circumstances shall be taken to prevent errant vehicles colliding directly with the end of the parapet, and suitable tension anchorage arrangements shall be made in the ends of the parapet.

6.6 Main structure, anchorages, attachment systems, bedding and plinths

6.6.1 General

The anchorages, attachment system and the main structure, including the plinth, shall be designed to resist without damage all loads which the parapet is theoretically capable of transmitting, up to and including failure, in any mode that may be induced by vehicular impact.

NOTE The design of parapet attachment systems and anchorages shall be such that removal and replacement of damaged sections of parapet may be readily achieved.

6.6.2 Main structure

The local and global effects of vehicular collision with the parapets to be considered in the design of the elements of the main structure and on the superstructure, bearings and substructure shall be as specified in Department of Transport Standard BD 37/88.

6.6.3 Fixings using base plates

Parapets that use base plates, such as post and rail systems, shall be fixed to the main structure via the base plates by stainless steel holding-down bolts engaging with an anchorage.

6.6.4 Engagement of holding-down bolts

NOTE 1 See also Note 1 to 9.8.4.

Each holding-down bolt shall have a length of engagement into the anchorage of not less than that given by the following expression:

$$0.7 \times \frac{\sigma_{vb}}{\sigma_{ya}} \times D$$

where

- σ_{vb} is the minimum ultimate tensile strength of bolt material (N/mm²);
- σ_{ya} is the minimum yield strength of the anchorage material (N/mm²);
- D is the nominal bolt diameter (mm).

NOTE 2 This is to ensure that bolt failure occurs prior to anchorage thread failure.

NOTE 3 If the type of holding-down bolt used requires an initial torque to be effective, this torque should be specified.

6.6.5 Anchorages in concrete main structures

Anchorage in concrete shall be either cast-in cradle anchorages, or cast-in or drilled individual bolt anchorages that are of purpose design or of proprietary manufacture. It shall be ensured that they will provide the necessary resistance taking into account the effect of possible overlap of stress cones from individual bolts.

NOTE 1 The concrete of the main structure may need additional local reinforcement to resist without damage the forces that may be transmitted from the parapet. The tensile strength of the concrete may be ignored in the calculation.

NOTE 2 Static testing of the proposed assembly may be considered advisable if other evidence is not available covering the particular application.

NOTE 3 It is good practice to grease internal threads of anchorages with a grease having a high resistance to flow/creep to assist with any need for renewal.

6.6.6 Bedding

Any bedding used, e.g. between base plates and plinth, shall be capable of permanently transmitting the loads involved, safely and without undue deformation. The finished bedding shall not contain voids and shall be resistant to penetration by water. It shall have a minimum thickness of 10 mm and a maximum thickness of 30 mm plus allowance for falls on the top of the plinth (see 9.8 and in particular Note 1 to 9.8.4).

6.6.7 Plinth

Where the main structure is of concrete, the parapet shall be mounted on a plinth having an upstand above datum of not less than 50 mm at the traffic face and not more than 100 mm at any point on the cross-section, and having its front edge in line with the traffic face of the parapet. The width of the plinth shall be a minimum of 450 mm for normal and low containment parapets and 600 mm for high containment.

6.7 Parapets of open-framed design

Parapets of open-framed design, such as post and rail, shall conform to the following.

- a) The effective longitudinal members shall not be so narrow or so shaped as to cause undue damage to an impacting vehicle.

NOTE A 50 mm overall depth with a blunt profile to the traffic face has been found satisfactory in existing designs for low and normal containment. A 100 mm overall depth has been found satisfactory for high containment design.

- b) Effective longitudinal members shall not be so widely spaced as to allow undue penetration by parts of impacting vehicles, and the supporting members shall be set far enough back from the traffic face to avoid direct impact from parts of vehicles that penetrate between longitudinal members.
- c) The top rail of a three rail system shall be of the same structural strength as the other two rails; minor variations (e.g. for mesh attachment) are permitted.

Figure B.1, Figure B.2, Figure B.3, Figure B.4 and Figure B.5 show the dimensions which have generally been found to be satisfactory in tests and in practice for various heights and containment levels of parapet.

7 Materials

NOTE There is a need to relate the materials used in the construction of production parapets to the materials used when the parapet system was approved by dynamic testing. It is acknowledged that materials can not be produced specifically for dynamic testing with all properties at the bottom of their range. The following requirements are, however, intended to limit the variance between production material and material used in the dynamic test.

7.1 Steel construction

7.1.1 General

Materials used for parapets, fixings, anchorages and attachment systems shall conform to Table 3.

7.1.2 Notch toughness

Steel used for all structural parts of parapets and anchorages shall have adequate notch toughness. This requirement shall be deemed to be satisfied provided the steel thickness conforms to 6.5.4 of BS 5400-3:1982 (using $U = -10\text{ }^{\circ}\text{C}$) as modified by Department of Transport publication BD 13/90.

7.1.3 Effective longitudinal members

The following requirements for effective longitudinal members shall be observed.

- a) The tensile strength of materials used in production parapets shall not be less than 90 % of the average tensile strength of the material used in the dynamic approval test. In addition, the tensile strength shall meet the minimum mechanical property requirements of 7.2.2.1.2.3.
- b) The average elongation of the materials used in production parapets shall not be more than 5 percentage points lower than the percentage elongation of the material used in the dynamic test, when measured by the same method. In addition, the elongation shall meet the minimum mechanical property requirements of the appropriate standard given in Table 3.
- c) The average thickness of sections used in production parapets at the recorded position shall not be less than 90 % of the thickness of the sections used in the dynamic approval test.

Table 3 — Materials of construction for steel parapets

Form of material	Current BS specification	Requirements
Hot rolled sections	BS 4-1	Dimensions, sectional properties and tolerances on shape
	BS EN 10034	
Hot rolled hollow sections	BS 4848-2	
Equal and unequal sections	BS 4848-4	
	BS EN 10056-2	
General purpose tubes	BS 1387	
Cold formed rolled hollow sections	BS 6363	Physical properties, chemical composition, dimensions and sectional properties, tolerances
Weldable structural steel (includes appropriate requirements for items above)	BS EN 10025 BS EN 10113 BS EN 10210-1	Technical delivery requirements, physical properties, chemical composition
Plate sheet and strip	BS 1449-1	Physical properties, chemical composition, material condition and dimensional tolerances
Carbon steel	BS EN 10130	
	BS EN 10131	
	BS EN 10051	
Stainless steel	BS 1449-2	
Bars and rods	BS 970-1 BS 970-3 BS EN 10083-1 BS EN 10083-2	Physical properties and chemical composition
Welded wire mesh	BS 4483	General requirements
Expanded metal	As for plate steel and strip	Physical properties, chemical composition, material condition and dimensional tolerance
Fasteners (see Note)		Dimensions, sizes, physical properties, chemical compositions, grades, tolerances and marking
ISO metric black hexagon bolts, screws and nuts	BS EN 24016 BS EN 24018 BS EN 24034 BS EN 20898-1 BS EN 20899-2	
	BS EN 24014	
ISO metric precision hexagon bolts, screws and nuts	BS EN 24017 BS EN 24032 BS EN 24035 BS EN 20898-1	
	BS 4320	
Metric washers	BS 4464	
Metric spring washers	BS 6105	
Corrosion resistant stainless steel fasteners		
High strength friction grip bolts, nuts and washers	BS 4395-1	
NOTE The standards listed in this table relating to the form of fasteners do not cover special bolts, nuts, screws, etc. which may be used for particular fixings where it is not possible to incorporate bolts, screws, etc. of standard dimensions or where special fixings are required to resist vandalism.		

7.2 Aluminium construction

7.2.1 General

Materials used for the construction of aluminium alloy parapets shall conform to Table 4.

7.2.2 Additional tests for aluminium alloy structural members

7.2.2.1 Mechanical testing of rail sections

7.2.2.1.1 Test piece selection

7.2.2.1.1.1 For batches of material consisting of five or more extruded lengths, cut a piece of material approximately 300 mm long from each of four extruded lengths within the batch, for tensile testing.

7.2.2.1.1.2 For batches of material consisting of up to four extruded lengths, cut a piece of material approximately 300 mm long from each extruded length, for tensile testing.

NOTE An extruded length is the product of one extrusion billet.

A batch shall consist of a maximum of 2 t of extruded product. All material in a batch shall be extruded from billet produced in the same cast and homogenized in the same furnace charge. All material in a batch, and its associated tensile test pieces, shall be precipitation heat treated in the same furnace charge. Where material is solution treated rather than press quenched, all material in a batch shall be solution treated in the same furnace charge. If tensile test pieces are cut prior to solution treatment they shall be included in the same furnace charge as the lengths from which they were taken.

7.2.2.1.2 Procedure

7.2.2.1.2.1 Carry out tests for either conductivity or hardness after precipitation heat treatment, using the following procedure. Test each test piece obtained from **7.2.2.1.1** for conductivity or hardness at its mid-point, on the traffic face of the section. Mark the reading obtained on the test piece. Test the front and back ends of all lengths of rail for conductivity or hardness on their traffic face and mark the readings on the rail.

7.2.2.1.2.2 Find the highest conductivity reading or the lowest hardness reading for a batch of material, including its associated test-piece lengths.

If a test piece length has the highest conductivity reading or the lowest hardness reading then machine a tensile test piece from it, in accordance with BS EN 10002-1.

If a length of rail has the highest conductivity reading or the lowest hardness reading, cut a length of approximately 300 mm from the end of the rail at which the reading is found. Machine a tensile test piece from this length, in accordance with BS EN 10002-1.

7.2.2.1.2.3 Test the tensile strength of the machined test piece in accordance with BS EN 10002-1 on a tensile test machine calibrated by the United Kingdom Accreditation Service (UKAS), or similar approved body.

7.2.2.1.3 Acceptance criteria

The test piece shall meet the minimum mechanical property requirements of BS 1474, and alloys shall have the additional minimum requirement of either 10 % elongation on 50 mm when measured by fitting the broken pieces of the test piece back together, or 9 % elongation on 50 mm when measured using an extensometer.

If the test piece in **7.2.2.1.2.3** fails to meet its minimum mechanical property requirements, carry out a re-test. If the failed test piece has been taken from a length of rail, discard the rail and select a new test piece as in **7.2.2.1.2.2** taking the next highest conductivity value or next lowest hardness value. Test this test piece as in **7.2.2.1.2.3**.

Repeat the above procedure until a test piece meets the minimum mechanical property requirements of BS 1474.

7.2.2.2 Drift testing of hollow sections

7.2.2.2.1 Test piece selection

For hollow sections, take a drift test piece of length approximately 150 mm from the front of every extruded length, adjacent to the front length of the hollow section. Mark the position of every cut length and test piece on the material.

NOTE An extruded length is the product of one extrusion billet. The front of the length is that which has been extruded first.

7.2.2.2.2 Procedure

Flare each drift test piece obtained from **7.2.2.2.1** using a conical or tapered steel mandrel with an angle of 30° to 60°. Force the mandrel into each test piece without shock. Apply a load to the test piece to cause a tear of sufficient length that the fracture surface may be visually examined.

7.2.2.2.3 Acceptance criteria

7.2.2.2.3.1 If the fracture surface of the test piece shows tearing or plastic type fracture across 100 % of its surface it shall be deemed to have passed and all material in the extruded length from which it was taken shall be deemed acceptable.

7.2.2.2.3.2 If the test piece splits down an extrusion weld and does not show tearing or plastic type fracture across 100 % of its fracture surface then it shall be deemed to have failed.

If there is only one member in the extruded length from which the test piece was taken, discard this.

If there is more than one member in the extruded length from which the test piece was taken, take a further drift test piece from the back end of the first member. Discard the remainder of the first member. If the new test piece passes then the remainder of the extruded length shall be deemed acceptable. If it fails then discard the remainder of the extruded length.

NOTE The front member is that which has been extruded first and the front of the member is the end that has been extruded first.

7.2.3 Effective longitudinal members

The following requirements for effective longitudinal members shall be observed.

- a) The tensile strength of the materials used in production parapets shall be not less than 90 % of the average tensile strength of the material used in the dynamic approval test. In addition, the tensile strength shall meet the minimum mechanical property requirements of **7.2.2.1.2.3**.
- b) The average elongation of the materials used in production parapets shall be not more than 5 percentage points lower than the percentage elongation of the material used in the dynamic test, when measured by the same method. In addition, the elongation shall meet the minimum mechanical property requirements of the relevant British Standard as given in Table 4. For aluminium alloy parapets, the elongation shall be measured using a sample with a gauge length of 50 mm (non-proportional sample).
- c) The average thickness of sections used in production parapets at the recorded position shall not be less than 90 % of the thickness of the sections used in the dynamic approval test.
- d) The metallurgical integrity of aluminium alloy sections shall be proven by drift testing in accordance with **7.2.2.2**.

Table 4 — Materials of construction for aluminium alloy parapets

Form of material (see Note 1)	Specification	
	BS number and designation	Requirements
Extruded sections	BS 1474:1987, alloys 6061, 6063, 6082, 6005A and 6060	Chemical composition, properties and tolerances
Drawn tube	BS 1471:1972, alloys 6061, 6063 and 6082	Chemical composition, properties and tolerances
Seam welded tube	BS 4300/1:1967, alloy 5251	Tolerances, properties and mechanical tests
Plate and sheet	BS EN 485-1:1994, alloys 1200, 3103 3105, 5083, 5251 and 6082 and 1050A	Chemical composition, properties and tolerances
Castings	BS 1490:1988, alloys LM6 and LM25	Chemical composition, properties and chemical tests
Welding filler rods and wire	BS 2901-4	Chemical composition, properties, diameters and tolerances
Welded wire mesh	BS 4483	General requirements
Expanded metal: Aluminium alloy Carbon steel Stainless steel	BS EN 485-1 BS 1449-1 BS 1449-2 : 1983, Grades 316 S31 and 316 S33	Properties, chemical composition, material condition and dimensional tolerances
Fasteners (see Note 2): ISO metric black hexagon bolts, screws and nuts ISO metric precision hexagon bolts, screws and nuts Metric washers Metric spring washers Corrosion-resistant stainless steel fasteners High strength friction grip bolts, nuts and washers	 BS EN 24016 BS EN 24018 BS EN 24034 BS EN 20898-1 BS EN 20899-2 BS EN 24014 BS EN 24017 BS EN 24032 BS EN 24035 BS EN 20898-1 BS 4320 BS 4464 BS 6105 BS 4395-1	Dimensions, sizes and tolerances Chemical composition and physical properties
NOTE 1 The physical properties of aluminium alloys may be modified by welding. A method of dealing with this effect for design purposes is given in BS 8118.		
NOTE 2 The standards listed in this table relating to the form of fasteners do not cover special bolts, screws, etc. which may be used for particular fixings where it is not possible to incorporate bolts, screws, etc. of standard dimensions or where special fixings are required to resist vandalism.		