BRITISH STANDARD

BS 6779-1:1998
Incorporating Amendment No. 1

Highway parapets for bridges and other structures —

Part 1: Specification for vehicle containment parapets of metal construction

ICS 93.040

British Standards

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee B/509, Road equipment, to Subcommittee B/509/1, Road restraint systems, upon which the following bodies were represented:

Aluminium Federation
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

This British Standard, having been prepared under the direction of the Sector Board for Building and Civil Engineering, was published under the authority of the Standards Board and comes into effect on
15 March 1998

First published August 1987
Second edition March 1990
Third edition April 1992
Fourth edition March 1998

The following BSI references relate to the work on this British Standard:
Committee reference B/509/1
Draft for comment 96/102247 DC

ISBN 0 580 28307 0

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 67 and a back cover.

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Amendments issued since publication

Amd. No.	Date	Comments
14290	21 March 2003	Deletion of Annex F

Contents

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BS 6779 has been prepared under the direction of Subcommittee B/509/1 and is a revision of the 1992 edition, which is withdrawn.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

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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_1	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:

a) level of containment;

b) height of parapet;

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

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 **8.2**c).

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.

a) *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.

b) *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°.

c) 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 mm	Non-load carrying members and secondary elements of load carrying mm	Infilling panels, bars and mesh mm	Clips, covers, fixings etc. 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 then 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/mm^2);

σ_{ya} is the minimum yield strength of the anchorage material (N/mm^2);

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*

Anchorages 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 $U = -10$ °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 BS EN 10034	Dimensions, sectional properties and tolerances on shape
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	
ISO metric precision hexagon bolts, screws and nuts	BS EN 24014 BS EN 24017 BS EN 24032 BS EN 24035 BS EN 20898-1	
Metric washers	BS 4320	
Metric spring washers	BS 4464	
Corrosion resistant stainless steel fasteners	BS 6105	
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:		Properties, chemical composition, material condition and dimensional tolerances
Aluminium alloy	BS EN 485-1	
Carbon steel	BS 1449-1	
Stainless steel	BS 1449-2 : 1983, Grades 316 S31 and 316 S33	
Fasteners (see Note 2):		Dimensions, sizes and tolerances
ISO metric black hexagon bolts, screws and nuts	BS EN 24016	Chemical composition and physical properties
	BS EN 24018	
	BS EN 24034	
	BS EN 20898-1	
	BS EN 20899-2	
ISO metric precision hexagon bolts, screws and nuts	BS EN 24014	
	BS EN 24017	
	BS EN 24032	
	BS EN 24035	
	BS EN 20898-1	
Metric washers	BS 4320	
Metric spring washers	BS 4464	
Corrosion-resistant stainless steel fasteners	BS 6105	
High strength friction grip bolts, nuts and washers	BS 4395-1	

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.

8 Additional design requirements for parapets for particular applications

NOTE This clause deals with those applications that call for requirements such as pedestrian protection in addition to vehicular containment. The usual need is to fill gaps in open parapets, such as post and rail types.

Because cladding made to parapets for the purpose of meeting those requirements could affect performance in respect of vehicle containment, appropriate standard treatments are given for the most common requirements. These are considered to be satisfactory for the situations described and care should be taken if there are any departures to ensure that additional hazards are not created.

8.1 General requirements for infilling and additional members

Infilling or additional members for particular applications shall conform to the following.

a) There shall be no footholds or projections exceeding the dimensions permitted in **6.3** on the traffic face where pedestrians have access.

b) All cladding shall be securely fixed and shall not be easily detached.

c) No reflective surfaces shall be used that might create a hazard for users of any road or railway.

8.2 Requirements for particular types of infilling

The following requirements for particular types of infilling shall be observed.

a) *Vertical bars*. Vertical bar infilling spanning between effective longitudinal members shall conform to the following and be in accordance with Figure B.3.

The product of the nominal yield stress, or 0.2 % proof stress and the plastic modulus of the vertical bars forming the infilling shall be not less than the moment induced by a nominal point load Q_k of 10 kN applied in any direction multiplied by the appropriate γ_{fL} and γ_{f3} factors from Table 7.

Each end connection to the longitudinal members shall develop at least half the strength of the infilling bar in bending and tension acting simultaneously and the strength of the bar in shear acting separately. The longitudinal member at the connection shall not fail by local buckling due to forces applied by the infilling.

b) *Wire mesh and expanded metal for applications not over or adjacent to railways*. Wire mesh and expanded metal shall have apertures with a perimeter not exceeding 200 mm. The minimum metal thickness shall be in accordance with Table 2 and the maximum metal thickness shall not exceed the required minimum thickness by more than 1.5 mm.

Expanded metal shall be supplied in a deburred and pressure roll flattened condition so that the strands are in the same plane as the sheet.

c) *Wire mesh and expanded metal for railway applications*. Wire mesh and expanded metal sheet shall have a minimum metal thickness in accordance with Table 2 and the maximum metal thickness shall not exceed the required minimum thickness by more than 1.5 mm.

Wire mesh infill shall have apertures not exceeding 25 mm × 25 mm.

Expanded metal sheet infill shall have openings not exceeding 45 mm × 20 mm and shall be fixed vertically with the long dimension horizontal. It shall be supplied in a deburred and flattened condition so that the strands are in the same plane as the sheet.

d) *Solid panels for low and normal containment parapets*. Solid infill panels shall present a smooth surface to the traffic face. Joint gaps shall not exceed 3 mm. The minimum metal thickness shall be in accordance with Table 2. The maximum metal thickness shall not exceed the required minimum thickness by more than 1 mm generally and 2 mm in the case of acoustic barriers and high containment cladding in aluminium (see Notes 1, 2, 3 and 4).

For high containment parapets the cladding panels shall be lapped in the direction of the adjacent traffic flow and the consequent outstand accepted. The solid infilling panel shall be fixed to each effective longitudinal member at a distance of 150 mm between centres with stainless steel, structural, blind rivets or equivalent with an ultimate tensile and shear capacity of not less than 10 kN. The cladding shall be fixed, with the top of the panel a minimum of 10 mm and a maximum of 40 mm below the top of the rail.

e) *Environmental barriers*. On occasions it will be necessary to combine an environmental barrier with a vehicle parapet with or without pedestrian access. Noise or light attenuation requirements may give variable heights and thicknesses of infill and each case shall be considered on its merits observing the general requirements of this clause.

NOTE 1 A grit-blasted finish or a patterned surface with maximum depth of 1 mm or any other type of anti-dazzle coating may be used on solid panels to offset the risk of dazzle (see Note 3).

NOTE 2 Solid infill may also be used for anti-splash or anti-dazzle purposes.

NOTE 3 Deeply corrugated infill panels can present a hazard on vehicle impact. They should not be located on the traffic face.

NOTE 4 Wind loading should be considered where solid infill is used (see Annex B).

8.3 Applications not over or adjacent to railways

8.3.1 The following requirements shall be observed.

a) *Pedestrian protection*. Mesh or solid infill shall extend from not more than 25 mm above the plinth at the traffic face to the full height of the parapet with the exception that vertical bar infill may be used for low containment parapets.

b) *Livestock protection*. Vehicle pedestrian parapets on accommodation bridges required to contain livestock, including horses, shall be of a minimum height of 1.5 m. This height shall be achieved by the use of an additional "non-effective" longitudinal member. Infilling shall be provided in accordance with **8.2**.

NOTE In some cases on bridges carrying farm accommodation roads, it has been considered reasonable to provide low level of containment, 1.5 m high, full height mesh type parapets (L/1.5/M). Such roads are provided to restore severed access to farms and are not public highways. They are not usually of such a standard as to allow high approach speeds, the bridges are generally narrow, restricting the angle of impact possible, and they are mainly used by drivers familiar with the road. Three such parapets are in current use and are included in the list in Annex F.

8.3.2 Non-effective longitudinal members shall be designed to withstand a horizontal ultimate loading of 1.4 kN/m and the parapet posts shall be checked to prove that they are capable of providing support for the consequent effects.

This loading shall not be considered co-existent with the loading required for vehicle containment.

In the case of application to a high containment parapet, the post extensions to carry the non-effective rail shall be designed sufficient for this purpose only.

NOTE A too strong extension of the post could interfere with the performance of the parapet.

8.4 Applications over or adjacent to railways

8.4.1 For all applications reference shall be made to Railtrack or other appropriate authority.

8.4.2 Minimum requirements for construction of parapets over or adjacent to railways, intended for Railtrack use, are summarized in Table 5.

Table 5 — Minimum requirements for construction of parapets over or adjacent to railways

Type of road	Type of railway					
	Without overhead electrification and where electrification is not likely			With overhead electrification or where electrification is likely		
	Minimum height of parapet	Infill		Minimum height of parapet	Infill	
		Type	Minimum height		Type	Minimum height
	m		m	m		
Motorways and situations where pedestrians are excluded	1.25	Rail mesh [see **8.2**c)] [N/1.25/r], [H/1.50/r] or solid infill [see **8.2**d)] [N/1.25/b], [H/1.50/b]	0.6	1.25	Rail mesh [see **8.2**c)] [N/1.25/R], [H/1.50/R] or solid infill [see **8.2**d)] [N/1.50/B], [H/1.50/B]	Full height of parapet
Other, i.e. pedestrians may be present	1.50	Solid infill [see **8.2**d)] [N/1.50/B], [H/1.50/B]	Full height of parapet	1.50	Solid infill [see **8.2**d)] [N/1.50/B], [H/1.50/B]	Full height of parapet
	Infill shall extend from not more than 3 mm above the plinth at the traffic face. The faces of the parapet shall not have ledges or projections upon which a person could stand. As an alternative for the outer face access shall be denied by suitable means.					

NOTE 1 Square brackets thus [ ] contain the relevant designation (see Clause **5**).

NOTE 2 The need and requirements for high containment will be determined by specific reference to Railtrack or other Railway Authority.

NOTE 3 Additional requirements in respect of height are likely for bridleways and locations subject to vandalism.

NOTE 4 Members used to achieve the minimum height requirement of 1.25 m, 1.5 m or above should be effective longitudinal members.

NOTE 5 For post and rail systems based on the dynamically tested 1.0 m high parapet, members used to achieve the minimum height requirement of 1.25 m, 1.5 m or above should be of the same section as the effective longitudinal members used in the dynamically tested parapet. See **10.1.5**.

NOTE 6 Consideration may be given where limited extension of height is required (e.g. 1.5 m to 1.8 m) to the provision of a light section shaped plate of steeple coping profile continuously attached to the top rail. At locations subject to vandalism, a major increase in height may call for mesh screening inclined away from the traffic face and positioned such that it cannot be struck by an errant vehicle.

9 Construction

9.1 Design requirements

9.1.1 *General*

Valid detailed design calculations in accordance with this clause and detailed drawings depicting these designs shall be produced for any parapet system. These, together with successful performance under dynamic test in accordance with Clause **10**, are required for a parapet system to be deemed to conform to this part of BS 6779 (see **10.1.1**). Currently approved systems as listed in Annex F are exempt from this requirement.

NOTE 1 Because of interactions under dynamic impact it is not considered that a successful parapet can be produced by design alone. Equally, because a single vehicle has to be chosen as the test vehicle, a successful test alone cannot guarantee that the parapet will perform to its reasonably expected level of resistance against the whole population of vehicles on the roads. In particular, because the chosen test vehicle for normal and low containment is a saloon car of low centre of gravity, a parapet could produce a successful test but have very low resistance to the overturning effect on a vehicle with a higher centre of gravity. Thus a design conforming with the following is required to ensure that parapets have a balanced resistance and that as much of their general strength is mobilized in as wide a range of impacts as is practical.

Parapets, components, attachment systems and anchorages shall be designed by the application of limit state principles. The limit state to be adopted shall be the ultimate limit state using appropriate partial factors. For impact loading, components of post and rail parapets shall be designed in accordance with Annex B.

NOTE 2 Guidance on the derivation of design loads, load factors and materials factors, together with an indication of the relevant design code/specification to be used is given in Table 6.

NOTE 3 Appropriate limit state requirements for aluminium alloys are given in BS 8118.

NOTE 4 To prevent undue accidental forces being transmitted to the main structure, the resistance of the posts or other members providing vertical support shall be limited so that their ultimate failure strength shall not be greatly in excess of that required to resist the designated impact. [See **9.3**b)].

9.1.2 *Design loading values*

9.1.2.1 The design load Q^* (in kN) shall be determined from the following:

$$Q^* = \gamma_{fL}\gamma_{f3}Q_k$$

where

- Q_k is the nominal load (in kN);
- γ_{f3} is the factor, as given in Table 7, which takes account of inaccurate assessment of the effects of loading and unforeseen stress distribution in the parapet;
- γ_{fL} is a factor, as given in Table 7.

NOTE The accurate determination of design load effects of vehicular impact by theoretical methods alone is not easily achieved and therefore dynamic testing is essential for proving parapet designs. The value of γ_{f3} should reflect any uncertainty with regard to determination of load effects and may be modified on the basis of these tests. Values of γ_{f3} and associated loading effects for design details based on tested configurations are given in Annex B.

9.1.2.2 *Design of parapets conforming to tested configurations*

Post and rail configurations are detailed in Figure B.1, Figure B.2, Figure B.3, Figure B.4 and Figure B.5. Annex B gives nominal loads and methods of application derived for these configurations. These shall be used for any new designs conforming to these configurations.

9.1.2.3 *Design of parapets for other configurations*

Where similar deflections are required to those of tested configurations, the same total design loads shall be used.

NOTE Where the parapet is expected to be stiffer, greater forces will be generated. BS 6779-2 gives loadings derived for concrete parapets and interpolation between the two extremes will have to be made.

The vertical distribution of the load shall be equally shared across all members in the traffic face.

Should testing prove the design assumptions to be inadequate, the parapet shall be modified and re-tested.

9.1.2.4 *Wind loading*

Wind loading shall be considered the nominal load and shall be derived from BS 5045-1.

NOTE 1 The wind loading need not be considered co-existent with the impact loading.

NOTE 2 Where large areas of solid sheeting, e.g. environmental barriers, are fixed to a parapet, the effect of wind loading on members may be more critical than the loading imposed by vehicular impact. Infilling panels and fixings should be designed for wind loading in all cases.

9.1.2.5 *Attachment systems and anchorages*

In the design of attachment systems and anchorages, the nominal load shall be taken as the load transmitted at collapse by the parapet, induced by transverse forces distributed equally between the effective longitudinal members. The nominal load shall be based on the lesser of either the ultimate moment of resistance at the critical section of the parapet post and the co-existent shear, or the calculated ultimate shear resistance at the critical section of the parapet post and the co-existent moment depending on the failure mode.

The resistance of the parapet post shall be determined either by calculation or test and adjusted for minimum properties (see Table 7).

9.1.2.6 *Design of bedding grout*

The adequacy of the bedding grout shall be assessed under the effect of the factored loads for attachment systems in Table 7. These have been derived by elastic methods using the short-term modulus of concrete as defined in BS 5400-4 and a maximum bearing stress on the concrete or grout of 0.5 f_{cu}, where f_{cu} is the characteristic concrete cube strength.

Table 6 — Limit state design information

Design check to be carried out	System type	Material to be used	Load derived from	Load factor derived from	Materials factor derived from	General design code
Wind loading	All	Steel	BS 5400-2	Table 7	BS 5400-3	BS 5400-3
Wind loading	All	Aluminium	BS 5400-2	Table 7	BS 8118-1:1991, Table 3.1	BS 8118-1
Impact loading	Post and rail systems	Steel	Annex B	Table 7	**B.2.1**	BS 5400-3
Impact loading	Post and rail systems	Aluminium	Annex B	Table 7	**B.2.1**	BS 8118-1
Impact loading	Non-post and rail systems	Steel	Design to achieve performance for selected containment to BS 6779-1		Table 8	BS 5400-3
Impact loading	Non-post and rail systems	Aluminium	Design to achieve performance for selected containment to BS 6779-1		Table 8	BS 8118-1
Other loads	All	Steel	BS 6779-1 where applicable or to suit	Table 7	Table 8	BS 5400-3
Other loads	All	Aluminium	BS 6779-1 where applicable or to suit	Table 7 where applicable or to suit	Table 8	BS 8118-1
Attachment system	Post and rail only	**6.4.2**	**9.1.2.5**	Table 7	BS 5400-3	BS 5400-3
Anchorages	Post and rail only	**6.4.2**	**9.1.2.5**	Table 7	BS 5400-3	BS 5400-3

Table 7 — Values of γ_{fL} and γ_{f3} for post and rail systems only

Element	Loading	γ_{fL}		γ_{f3}
		Low and normal containment	High containment	All containments
Parapet components	Vehicle impact	1.0	1.0	1.0
	Wind loading	1.2	1.2	1.1
	Other loads	1.2	1.2	1.0
Attachment system	Capacity of parapet post determined by calculation	1.5	1.4	1.0
	Capacity of parapet post determined by post test mean values less two std. deviations	1.2	1.2	1.0
Anchorage	Capacity of parapet post determined by calculation	1.8	1.6	1.0
	Capacity of parapet post determined by post test mean values less two std. deviations	1.4	1.5	1.0

9.2 Design resistance value

The design resistance of the element R^* shall be defined as:

$$R^* = \frac{f(f_k)}{\gamma_m}$$

where

- f is a "function of";
- f_k is the characteristic (or nominal) strength of the material;
- γ_m is a partial factor on material strength.

Values for f_k and γ_m are given in Table 8.

Table 8 — Values of f_k and γ_m

Material/component	f_k	γ_m
Steel (excluding stainless steel nuts, bolts and washers)	As given in BS 5400-3	
Stainless steel nuts, bolts and washers	As given in BS 6105 or BS 1449-2, as appropriate	1.2
Aluminium extrusions and plate (including weld affected areas)	BS 8118	1.2
Aluminium castings	0.2 % proof stress as given in BS 1490	1.3
Concrete plinths	As given in BS 5400-4	

9.3 Verification of design adequacy

For a satisfactory design, the following relationship should be satisfied prior to verification by dynamic testing:

$R^* \geq S^*$

where

$S^* = \gamma_{f3}$ (effects of $\gamma_{fL}\, Q_k$)

i.e.

$$\left[\frac{f(f_k)}{\gamma_m}\right] \geq \gamma_{f3} \text{ (effects of } \gamma_{fL}\, Q_k).$$

Values of Q_k can be found from Table B.2. γ_{f3} and γ_{fL} are found from Table 7.

NOTE The γ_{f3} values given in Table 7 should be substituted for the values given in BS 5400-3.

In addition, for bending resistance of the lower third of the design height of the posts, or other members providing vertical resistance:

— in general $R^* \leq 1.4\, S^*$ (but $R^* > S^*$);

— for high containment parapets only, for at least one section of this section of parapet $R^* \leq 1.1\, S^*$ (but $R^* > S^*$).

9.4 Workmanship, inspection and testing

9.4.1 *General*

9.4.1.1 *Workmanship in aluminium alloy and steel*

Workmanship in aluminium alloy shall be carried out in accordance with BS 8118-2. Workmanship in steel shall be carried out in accordance with BS 5400-6.

9.4.1.2 *Laminar defects*

Steel base plates shall not have laminar defects exceeding the limits of BS 5996 for quality grade B2. If laminar defects are revealed during fabrication or ultrasonic testing, the base plate shall be rejected or tested for conformity.

9.4.1.3 *Cutting*

Flame cut surfaces on steel components shall be smooth and free from gutters.

Cutting of aluminium alloy components shall be carried out in accordance with BS 8118-2.

9.4.1.4 *Forming of holes*

Holes in steel components shall be drilled except that:

a) holes shall be punched full size in cleats and brackets where the thickness of the material does not exceed 12.5 mm and where the fabrication is not subject to repeated stresses;

b) oversize holes shall be flame cut.

Holes in aluminium alloy components shall conform to BS 8118-2.

9.4.1.5 *Tolerance on holes other than in base plates*

The diameter of holes or the width of slots shall be not more than 2 mm larger than the nominal size of the associated fastener, except where the material is to be galvanized. In this case, the diameter of the hole or width of slot may be increased by up to an additional 2 mm or 15 % of the nominal diameter of the fastener, whichever is the greater.

9.4.1.6 *Tolerance on holes in base plates*

The diameter of holes or the width of slots in base plates shall not be greater than 50 % larger or wider than the nominal size of the holding bolt.

9.4.1.7 *Washers*

Washers of sufficient bridging strength shall be provided to all fixings.

9.4.2 *Welding*

9.4.2.1 *General*

Arc welding of carbon manganese steels shall conform to BS 5135. Arc welding of aluminium alloys shall be in accordance with BS 3019-1 or BS 3571-1 as appropriate. Processes other than arc welding shall be subject to the approval of the purchaser. Welding of stainless anchorages shall be in accordance with BS 7475.

9.4.2.2 *Welding procedures*

The manufacturer shall produce and work in accordance with written and approved procedures, confirmed by testing, in accordance with BS EN 288-1, -2 and -3 for steel and BS EN 288-1, -2 and -4 for aluminium alloys for all production and repair welds. These shall be subject to reassessment after a period of 7 years. When applying BS EN 288-1, -2 and -3 the welding consumable and procedures used shall be such that the mechanical properties of deposited weld metal shall not be less than the respective minimum specified values of the parent metal being welded.

Weld procedures for aluminium alloy posts shall be verified by means of a static load test conducted not less than 3 days after welding in accordance with Annex F, and the acceptance criteria shall be as in **9.4.3.2.6.3**a) but adjusted for any differences between the actual and nominal metal thickness at the fracture line. The test shall be deemed to be invalid if the weld size is less than the nominal size or more than 15 % above it. Testing shall be by a laboratory appropriately accredited by UKAS for weld testing.

Approval shall be by an independent inspecting authority using registered welding engineers, registered welding quality engineers or equivalent to the satisfaction of the purchaser.

9.4.2.3 *Welder qualifications*

All welders shall hold certificates of approval to BS EN 287-1 for steel and BS EN 287-2 for aluminium alloys, obtained within the previous 2 year period, for all weld types which they produce.

Certificates of approval shall be from an independent inspection authority using personnel who are either registered as in **9.4.2.2** or appropriately certified in accordance with the Certification Scheme for Welding and Inspection Personnel (CSWIP). Tests shall be carried out by a laboratory accredited by the United Kingdom Accreditation Service (UKAS) for weld testing.

9.4.3 *Production inspection and testing*

9.4.3.1 *Non-destructive testing*

9.4.3.1.1 *Inspection personnel*

The manufacturer shall provide suitable personnel to carry out inspection of production welds as required by **9.4.3.1.2**, **9.4.3.1.3** and **9.4.3.1.4**. Personnel conducting visual inspection shall be certified by the Certification Scheme for Welding and Inspection Personnel (CSWIP) or equivalent at a competency level appropriate to the type of weld being inspected. Personnel conducting non-destructive testing (NDT) shall be certified by the CSWIP or equivalent appropriate to the equipment used and weld groups inspected. Evidence of training and qualification shall be retained and made available for examination when required.

9.4.3.1.2 *Visual inspection*

10 % of post to baseplate production welds shall be subject to visual inspection after cleaning prior to NDT and protective treatment. The relevant techniques in BS EN 970 shall be applied as appropriate. Weld surfaces shall be free of slag residues, sharp edges, cracks and lack of fusion, including overlap. All surfaces shall be free of weld spatter, arc strikes and contaminants. The throat dimensions of butt welds and the leg length and apparent throat dimensions of fillet welds, as measured by a welding gauge and taking into account lack of fit, shall be not less than those specified, except that local shortfalls up to 1 mm are acceptable, provided the average dimension over any 50 mm length is not less than the specified dimension. The toe angle shall be not less than 90°.

NOTE Isolated discontinuous porosity may be accepted provided it is not detrimental to the protective treatment.

Undercut shall not result in a section loss of more than 5 % over any 50 mm length of joint, nor shall its depth exceed 0.5 mm or 10 % of the thickness, whichever is less.

Where on visual inspection the presence of cracking or lack of fusion is suspected, testing by magnetic particle inspection or liquid penetrant inspection shall be carried out in accordance with BS 6072 or BS 6443 as appropriate.

9.4.3.1.3 *Magnetic particle inspection (MPI) and liquid penetrant inspection (LPI)*

MPI shall be applied in accordance with BS 6072 to joints in steel parapets selected in accordance with **9.4.3.1.5**, where any of the material thickness exceeds 20 mm. Liquid penetrant inspection in accordance with BS 6443 shall be applied to welds in aluminium alloy posts between the post and the base plate and any gusseting to the connection as selected in **9.4.3.1.5**.

NOTE To aid inspection, the profile of the joint may be dressed by burr grinding provided that the specified throat size and leg length is still maintained.

The surface of the weld shall be free of cracks, lack of fusion and slag.

9.4.3.1.4 *Ultrasonic testing*

Post to base plate joints selected in accordance with **9.4.3.1.5** shall be ultrasonically tested where the post is butt welded and is 8 mm thick or greater in the traffic face half of the post section or, if fillet welded, the leg length is greater than 12 mm nominal. The ultrasonic testing of steel shall be in accordance with BS 3923 and for aluminium in accordance with the principles in BS 3923. The weld shall be free of cracks. The height of buried slag and lack of fusion shall not exceed 3 mm and, within 6 mm of the outer surface, their individual lengths shall not exceed 10 mm. The resulting net throat area loss over any 50 mm length shall not exceed 5 %.

9.4.3.1.5 *Frequency of non-destructive testing (NDT)*

Joints for MPI, LPI or ultrasonic testing shall be selected as follows.

10 % of the manufacturer's production for each type of component (see **9.4.3.1.3** and **9.4.3.1.4**) shall be tested. If non-conformances are found, the scope of testing shall be doubled. If further non-conformity is found, the whole batch shall be tested.

NOTE Differences in either member cross-sectional shape, joint configuration or weld type constitute a change in component type. Variations in cross-section size or member length need not constitute a change in component type. Variations in parent metal thickness or weld throat dimension from the specified sizes on the sample selected for the destructive test may be included within the same type up to a limit of ±40 %.

9.4.3.1.6 *Reporting*

Inspection records for production welds shall be retained by the manufacturer for 3 years, and those covering the production periods relating to the components supplied shall be made available for examination.

9.4.3.1.7 *Non-destructive inspection of posts*

Where required by the purchaser, components for parapet posts and all completed parapet posts shall be subject to visual and dimensional inspection by the purchaser at the place of manufacture.

9.4.3.2 *Destructive testing*

9.4.3.2.1 *Supply of test components*

The manufacturer shall provide complete components or sample joints cut from components for destructive testing as selected by the purchaser. The basis of selection shall be as in **9.4.3.2.2**.

NOTE The purchaser should return the samples to the manufacturer after the tests are completed, together with a test report.

9.4.3.2.2 *Frequency of destructive testing*

The purchaser may have particular requirements (see Annex C), otherwise selection shall be carried out as follows.

a) *For orders containing less than 150 posts*. No test required, providing that records certified by an independent inspectorate, client or his representative, are produced of successful destructive testing carried out on posts of the same weld group within the previous 3 months. If no satisfactory record is available, one intermediate post.

b) *For orders of 150 to 300 posts*. One intermediate post.

c) *For orders exceeding 300 posts*. Two intermediate posts.

d) *For orders containing up to 150 shop welded splices and/or less than 50 site splices*. One shop splice and/or one site splice as appropriate unless successful destructive testing has been carried out within the last 3 months on a similar splice(s), where the splice to be tested was selected by an independent inspectorate, client or his representative and the welding is to be carried out by the same personnel.

e) *For orders containing more than 150 intermediate shop welded splices and/or site welded rail splices*. Two shop splices and/or two site splices as appropriate for each order.

9.4.3.2.3 *Acceptance criteria*

The general acceptance criteria shall be as specified in **9.4.3** except that the throat and leg dimension shall apply to the true rather than the apparent dimension.

9.4.3.2.4 *Non-conformance*

In the event that there is a non-conformity arising from a serious deviation in materials, preparation, assembly or welding procedure, the batch concerned shall be rejected and further production of the components affected stopped until such time as the fault has been corrected. A minor non-conformity shall only be accepted on the basis that further sampling and testing shows that the fault is not repetitive and in the view of the purchaser will not in that instance impair structural integrity.

If the problem can be traced to a particular manufacturing period, operator, piece of equipment or batch of materials and if proper traceability to individual batches of components can be assured, only those batches affected may be subject to rejection.

9.4.3.2.5 *Test reports*

The destructive test reports shall be retained by the manufacturer and recorded in a register for a period of 3 years. The destructive test specimens shall be retained for a period of 18 months. These shall be made available for examination on future contracts.

9.4.3.2.6 *Static destructive testing of posts*

9.4.3.2.6.1 *General*

Where required by the purchaser, production testing of a number of parapet posts shall be carried out in accordance with the procedure described in Annex E, in the presence of the purchaser.

9.4.3.2.6.2 *Selection of posts to be tested*

Where required by **9.4.3.1.7** and/or **9.4.3.2.6**, the requirements of **9.4.3.2.6.2** and **9.4.3.2.6.3** shall apply.

Posts to be tested shall be selected by the purchaser from the normal production batch(es) from which the order is to be fulfilled, at the place of manufacture.

At least 3 days from the time of manufacture shall be allowed before aluminium alloy posts are tested.

9.4.3.2.6.3 *Acceptance criteria*

Posts shall conform to the following.

a) The post shall sustain a moment of 1.05 times its theoretical moment of resistance (see **B.2.2**) at its critical section (usually the connection to the base plate), without failure.

b) The material thickness and effective weld throat sizes shall be within the tolerances specified (either British Standard tolerances or, where not applicable, the manufacturer's specified tolerances).

c) The external dimensions of the post shall be within the tolerances specified. Where no other tolerances are specified those specified in the appropriate British Standard shall apply.

d) The results of any dimensional examination and testing of the selected posts shall be recorded in a register to be kept by the manufacturer and certified by the representatives of the supplier. Any posts subjected to test shall be specifically marked and recorded for future identification.

All posts in the accepted batch or order shall be marked for identification by the representative of the purchaser.

NOTE 1 If hard stamping is used it is recommended that this is in the centre of the transverse edge of the base plate.

In the event that any of the acceptance criteria a), b) or c) are not met, a further two posts shall be selected from the batch by the purchaser's representative and tested for conformity. Provided that both posts conform with items a), b) and c), the batch shall be deemed to be acceptable.

In the event that one or both of the additional tests posts fail to comply with a), b) or c), the whole batch shall be deemed not to conform, and rejected.

NOTE 2 Repair of a rejected batch may be acceptable in principle by the purchaser provided that:

1) the cause of failure in respect of a) has been established;

2) the manufacturer puts forward a detailed method for repair which the purchaser deems to be practicable;

3) all posts in the batch are repaired to this method;

4) three test posts, selected by the representative of the purchaser after the whole batch has been repaired, are tested and conform with a) and b).

5) Welds in aluminium alloys are not repaired more than once.

9.4.4 ***Remedial work***

Weld repairs, if allowed, shall conform to an approved procedure, as described in **9.4.2.2**. Welds in aluminium alloys shall not be repaired more than once.

9.5 Tolerances

9.5.1 ***General***

9.5.1.1 *Components fabricated in aluminium or steel*

Fabricated components in either aluminium alloy or steel shall be assembled so that they are not twisted or otherwise damaged and shall be so prepared that the specified inclinations, if any, are provided. Shims and packings shall not be used except under the post base plate (see **9.8.3**).

9.5.1.2 *Fit of mating components*

The fit of mating components shall be such as to allow practical site assembly without inducing stress or distortion in the components whilst meeting the design strength requirements (see **9.8.2**).

9.5.1.3 *Rail fixings*

The tolerance on the position of rail fixings on posts shall be within ±3 mm of the specified dimension.

9.5.2 ***Sections, plate and sheet***

Tolerances on sections, plate and sheet shall be in accordance with Clause **7**.

9.6 Fastenings

Structural fastenings shall conform to the relevant British Standards (see Clause **7** and Note to Table 3).

9.7 Storage and transportation

9.7.1 *Handling and stacking*

Parapets shall be handled and stacked in such a manner that permanent damage to components and to any temporary or permanent protective treatment is avoided. Any damage sustained shall be made good.

Where cranage is required, fabric slings shall be used.

Parapet components shall be stored clear of the ground in such a way that contact with standing water, soil, cement or ash, or any other deleterious substance, is prevented. Parapet components shall not be stored in contact with other materials. Suitable packings shall be placed between the components to prevent contact, to allow the free circulation of air and to allow the dispersion of any water. Means shall be provided to prevent the accumulation of water on any surface.

NOTE Particular care in this respect should be taken to prevent wet storage stain forming on galvanized sections or those painted with zinc-rich priming paints and exposed to weathering before the surface is sealed with a finishing paint coating.

9.7.2 *Packing and transportation*

Parapets shall be protected from damage during transportation. Means shall be provided to prevent distortion of the fabrications and any machined or unprotected surface shall be coated with a suitable temporary protective system.

All bolts, screws, nuts and washers and any small loose components shall be suitably packed, protected and identified.

9.8 Installation and site workmanship

9.8.1 The manufacturer of the parapet shall produce a statement of method of erection and site work to completion, including layout drawings detailing anchorage positions.

Particular attention shall be given to bolt torque, weld gaps, the gap setting at expansion or bridge movement joints, protection of the underside of aluminium post base plates (see **6.6.3**) and holding-down bolt engagement (see **6.6.4**).

9.8.2 Parapets shall be set true to line and level, within the tolerances set for bedding, (see **6.6.6**) throughout their length to give a smooth flowing line to the finished parapet.

NOTE Infill panels when fitted should present a uniform and smooth appearance after fixing.

9.8.3 Parapets shall be securely held in their correct final position until the anchorages and bedding have attained the required strength.

Permanent packers shall be of an inert material.

The bedding shall completely fill the space between the base plate and the plinth. It shall not project above the underside of the base plate and it shall be resistant to penetration by water.

9.8.4 Damaged areas of protective coatings shall be made good after completion of the erection.

NOTE 1 Where extra bedding thickness is allowed (see **6.6.6**), it may be necessary to increase the length of the holding-down bolts to satisfy **6.6.4**.

NOTE 2 Where parapets are erected directly on to steelwork, bedding may not be necessary.

NOTE 3 The completed parapet may need protection from damage or contamination by the activities of other trades.

9.9 Identification marking of parapet system

An easily legible and durable plate or marking shall be applied and located near to the top of the first post at each approach end in an easily visible position.

Markings shall have lettering not less than 5 mm high and shall include the following information.

a) The names and trade marks of the designer and manufacturer.

b) The design serial number.

c) The designation of the parapet.

d) The year of manufacture.

9.10 Inspection

The promoter of the parapet shall produce a statement of method of inspection, detailing the time interval at which this shall be carried out.

Inspection shall give particular attention to:

— the occurrence of any damage to the parapet and infill panels;

— the torque and condition of bolts and condition of other fixings;

— the condition of protective coatings;

— the condition of bedding beneath base plates.

9.11 Repair

The promoter of the parapet shall produce a statement of method of repair.

Particular attention shall be given to bolt torque, weld gaps, the gap setting at expansion or bridge movement joints, protection of the underside of aluminium post base plates (see **6.6.3**) and holding-down bolt engagement (see **6.6.4**).

10 Performance

10.1 Type tests for parapet design

10.1.1 *General*

The parapet design shall conform to **10.1.2**, **10.1.3** or **10.1.4**, as appropriate, when subjected to full scale impact testing in accordance with Annex D. The promoter shall have available for inspection by the purchaser complete records of the tests together with full design calculations and details in accordance with the requirements of this standard. Currently approved systems as listed in Annex F are exempt from this requirement.

NOTE 1 This British Standard cannot call for product certification by third parties. It is strongly advised, however, that when a promoter or manufacturer wishes to prove that a new parapet design conforms to this standard, he ensures that an independent, recognized, expert third party is involved to:

a) check and verify the design calculations;

b) witness and validate that the test procedures conform to Annex D;

c) assess, verify and report that the appropriate acceptance criteria of this clause are met;

d) check and verify the records of the test as required by Annex D.

NOTE 2 Most prospective purchasers are unlikely to require to examine the full record of testing, particularly if independent assessment and verification are available, and it will probably be helpful if promoters also have a summarized version available.

NOTE 3 A parapet that is over-designed for the selected containment level could produce undue forces on the anchorage and main structure. It is particularly important to avoid this at high containment levels. Evidence of plastic yield would demonstrate that the full post strength has been required in containing the test vehicle.

10.1.2 *Normal level of containment parapet acceptance criteria*

10.1.2.1 *General*

When tested as described in Annex D the parapet shall conform to **10.1.2.2**, **10.1.2.3**, **10.1.2.4**, **10.1.2.5** and **10.1.2.6**.

10.1.2.2 *Containment*

The following criteria shall apply.

a) The vehicle shall not penetrate or overtop the parapet.

b) The maximum wheel penetration of the vehicle as measured under **D.8.1**i) during impact shall not exceed 500 mm.

10.1.2.3 *Integrity of the test parapet*

No part of the test parapet shall become detached nor any principal longitudinal element of the system completely fail. Failure shall be defined as a reduction in the perimeter of cross-section of more than 80 % measured in the plane of failure. All main bolts connecting posts to rails and rail joints shall remain in position.

Portions of metal gouged from components by wheel nuts or other hard projections on the vehicle shall not be considered parts for this purpose.

Post to rail connections will be judged satisfactory provided that at least one post to rail joint on any one post remains attached.

10.1.2.4 *Integrity of the anchorage and attachment system*

The following criteria shall apply.

a) No failure of the anchorage shall take place.

b) There shall be no damage to the attachment system if such damage would make it difficult to replace the damaged parts of the parapet, unless the damage is part of the designed failure mode.

NOTE The anchorage is not considered to be a part of the parapet so far as these tests are concerned and its strength is dealt with in **6.6.5**. Failure of the anchorage used will, however, invalidate a test, as the response of the parapet would be modified.

10.1.2.5 *Vehicle movement after impact*

The vehicle shall be redirected so that no part of it crosses the line drawn parallel with and at a distance of 2.2 m plus the width of the vehicle (2*b* in Figure A.1) plus 0.16 times the vehicle length from the face of the parapet, within a distance of 10 m from the break point of vehicle contact with the parapet. The test vehicle shall neither turn onto its side nor roll over within the paved parapet test area.

10.1.2.6 *Integrity of the vehicle*

No major component of the vehicle shall become detached.

NOTE It has to be a matter of judgement by the assessors of the test as to what is major and what is not reasonably avoidable because of the vehicle design. Detached pieces of parapets or vehicles could cause danger to other persons, vehicles or property in the vicinity and therefore no detachment of parts is allowed for the parapet. It would be unreasonable to be so specific for the vehicle, and the detachment of items of trim, glass and wing mirrors etc., is inevitable. The parapet should not, however, act upon the vehicles so as to detach any major component such as wheels, doors, wings etc.

10.1.3 ***Low level of containment parapet acceptance criteria***

10.1.3.1 *General*

When tested as described in Annex D the parapet shall conform to **10.1.3.2**, **10.1.3.3**, **10.1.3.4**, **10.1.3.5** and **10.1.3.6**.

10.1.3.2 *Containment*

The following criteria shall apply.

a) The vehicle shall not penetrate or overtop the parapet.

b) For a parapet intended to redirect the vehicle, the maximum wheel penetration of the vehicle as measured under **D.8.1**i) during impact shall not exceed 500 mm.

10.1.3.3 *Integrity of the test parapet*

No part of the test parapet shall become detached nor any principal longitudinal element of the system completely fail. Failure shall be defined as a reduction in the perimeter of cross-section of more than 80 % measured in the plane of failure. All main bolts connecting posts to rails and rail joints shall remain in position.

Portions of metal gouged from components by wheel nuts or other hard projections on the vehicle shall not be considered parts for this purpose.

Post to rail connections will be judged satisfactory provided that at least one post to rail joint on any one post remains attached.

10.1.3.4 *Integrity of the anchorage and attachment system*

The following criteria shall apply.

a) No failure of the anchorage shall take place.

b) There shall be no damage to the attachment system if such damage would make it difficult to replace the damaged parts of the parapet, unless the damage is part of the designed failure mode.

10.1.3.5 *Vehicle movement after impact*

The vehicle shall either be redirected onto a path as close as possible to the line of the parapet or shall be arrested by the parapet. If redirection takes place the vehicle shall be redirected so that no part of it crosses the line drawn parallel with and at a distance of 2.2 m plus the width of the vehicle (2*b* in Figure A.1) plus 0.16 times the vehicle length from the face of the parapet, within a distance of 10 m from the break point of vehicle contact with the parapet. The test vehicle shall neither turn onto its side nor roll over within the paved parapet test area.

10.1.3.6 *Integrity of the vehicle*

No major component (see Note to **10.1.2.6**) of the vehicle shall become detached.

10.1.4 ***High level of containment parapet acceptance criteria***

10.1.4.1 *General*

When tested as described in Annex D the parapet shall conform to **10.1.4.2**, **10.1.4.3**, **10.1.4.4**, **10.1.4.5** and **10.1.4.6**.

10.1.4.2 *Containment*

The following criteria shall apply.

a) The vehicle shall not penetrate or overtop the parapet.

b) The maximum wheel penetration of the vehicle as measured under item i) of **D.8.1** during impact shall not exceed 500 mm.

10.1.4.3 *Integrity of the test parapet*

No part of the test parapet shall become detached nor any principal longitudinal element of the system completely fail. Failure shall be defined as a reduction in the perimeter of cross-section of more than 80 % measured in the plane of failure. All main bolts connecting posts to rails and rail joints shall remain in position.

Portions of metal gouged from components by wheel nuts or other hard projections on the vehicle shall not be considered parts for this purpose.

Post to rail connections will be judged satisfactory provided that at least one post to rail joint on any one post remains attached.

10.1.4.4 *Integrity of the anchorage and attachment system*

The following criteria shall apply.

a) No failure of the anchorage shall take place.

b) There shall be no damage to the attachment system if such damage would make it difficult to replace the damaged parts of the parapet, except for damage that is part of the designed failure mode.

10.1.4.5 *Vehicle movement after impact*

The vehicle shall be redirected so that no part of it crosses the line drawn parallel with 4.4 m plus the width of the vehicle (2*b* of Figure A.1) plus 0.16 times the vehicle length from the face of the parapet, within a distance of 20 m from the break point of vehicle contact with the parapet. The test vehicle shall neither turn onto its side nor roll over within the paved parapet test area.

10.1.4.6 *Integrity of vehicle and load*

The vehicle and its load shall remain substantially intact in that not more than 5 % of the combined mass shall become detached or be split during the test up to the time when contact with the parapet ceases.

NOTE Testing has demonstrated that it is not practical to call for complete integrity of the vehicle and load when testing for high containment. The limit set is considered to be sufficient to prevent significant modification of the impact effect on the parapet. The use of a loaded tanker as the test vehicle (see **6.1.3**) reduces the risk of a load loss. The possible hazards of heavy vehicle containment are referred to in **A.3**, **A.8** and **A.9**.

10.1.5 ***Permitted modifications for* N/1.00/O *or* L/1.00/O *design***

For parapet designs of designation N/1.00/O or L/1.00/O, which have successfully withstood dynamic testing carried out in accordance with Annex D, the following modifications to the tested design shall be accepted, without further test, as conforming to this part of BS 6779.

a) An increase in height upto a total height of 1.8 m resulting from either:

1) the addition of one non-effective longitudinal member; or

2) in the case of a post and rail type parapet, the addition of one or more non-effective longitudinal member where the strength of the vertical members or components and of the attachment system and anchorages shall not be increased to resist any increased moments.

NOTE 1 The non-effective member may be the same section as the effective longitudinal members used in the dynamically tested 1 m high parapet. (See Table 5).

NOTE 2 The non-effective longitudinal members should be designed to withstand a horizontal ultimate load of 1.4 kN/m or wind loading where solid infill is used (see Annex B) whichever is greater, and the parapet posts should be checked to prove that they are capable of providing support for the consequential load effects. This loading should not be considered co-existent with the loading required for vehicle containment.

b) Provided no evidence exists of a lesser performance at closer post centres, a reduction in post spacings by up to 20 %. Closer post centres than those given above may be used for single bays where this cannot be avoided, at movement joints and at ends of parapet runs.

c) An addition of infilling (except vertical infill) which conforms to Clause **8**, provided that:

1) the span between effective supports/fixings to the longitudinal members, components or component remains unaltered, e.g. for post and rail type parapets, the post centres remain unaltered (except as allowed in b) above);

NOTE The disposition of the longitudinal members or components vertically may be varied slightly within the limits of Figure B.1.

2) the vehicle containment resistance of the longitudinal members, components, or component that formed the 1.0 m high tested parapet remains unaltered, e.g. for post and rail parapets of current design, the three basic rails of the 1 m high parapet remain unaltered.

NOTE It is considered that the additional height and closer post spacing afforded by the modifications permitted under **10.1.5**a) and **10.1.5**b) respectively may increase the containment capacity of the parapet and may cause a small increase in stiffness. Hence the angle at which an errant vehicle is redirected may increase slightly. However, these modifications are unlikely to alter significantly the general result of dynamic testing as the test vehicle would not impinge directly onto the additional rail or components.

10.1.6 ***Permitted modification for* H/1.5/0 *designs***

For parapet designs of designation H/1.5/0, which have successfully withstood dynamic testing carried out in accordance with Annex D, the following modifications to the design shall be accepted without further test, as conforming to this part of BS 6779.

a) An increase in height upto a total height of 2 m by the addition of one non-effective longitudinal member. (See Notes to Table 5.)

b) Provided no evidence exists of a lesser performance at closer post centres, a reduction in post spacings by upto 20 %. Closer post centres than those given above may be used for single bays where this cannot be avoided, at movement joints and at ends of parapet runs.

c) An addition of infilling (except vertical infill) which conforms to Clause **8**.

10.1.7 ***Certification of production parapet***

The production parapet shall be certified by the manufacturer as a low, normal or high level of containment parapet provided the following requirements have been met:

a) that it conforms in all respects with the design of parapet that successfully met the requirements of this standard; or

b) where modifications have been made to the tested design, these conform to **10.1.5** or **10.1.6**, as appropriate.

NOTE The purchaser may wish to incorporate other modifications into a parapet design which would prevent him obtaining the certification required in a) or b) of **10.1.7**. Modified designs outside the provision of **10.1** have to be regarded as non-standard. To avoid unnecessary cost it may be acceptable to the purchaser to agree such modifications to a tested design without further dynamic tests.

Annex A (informative) Guidance on levels of containment and derivation of theoretical design forces

A.1 In designing parapets to meet the objectives set out in the introduction, a balance has to be sought between overall risk, level of containment, ability to redirect the effect on the main structure and the consequent cost.

A.2 Accidents involving the penetration of parapets designed to provide containment are fortunately rare and those resulting in secondary accidents due to penetration extremely rare.

A.3 Parapets are normally expected to be found in situations where there is an obvious hazard and some protective barrier has to be provided.

There is a large release of energy when a heavy vehicle impacts a high containment parapet, and testing has demonstrated that detachment of the load may take place, adding to the hazard caused by redirection of the heavy vehicle which is itself unlikely to be controllable after the impact.

A.4 Since the early 1960s metal parapets have been designed to Department of Transport requirements using two levels of containment. These are the normal and low containment levels specified in this standard (see **6.1.1** and **6.1.2**). As indicated above, their performance in service has been very good and they have been found to provide a reasonable compromise between level of containment and ability to redirect without giving rise to undue practical problems of design, construction, anchorage or cost.

A.5 The low level of containment is specifically for use in urban situations where speed restrictions up to 80 km/h (50 mile/h) apply. Post and two horizontal rail systems with vertical bar infill are considered by many authorities to give a better appearance. This construction tends to arrest the impacting vehicle rather than redirect it.

A.6 The normal level of containment has generally been provided by post and three or four horizontal rail systems, with the addition of mesh or solid panel infilling where protection for animals and pedestrians is required. Such systems can produce good redirecting properties.

A.7 Designs in both steel and aluminium are available and are in general use at the time of issue of this standard. They have been designed and prototypes have been tested to resist the characteristic vehicle impacts specified herein and have a good record in service over a considerable span of years. This standard has been based on the development work on design and testing that went into the production of these designs.

A.8 In the early 1980s a high level of containment was introduced. This was largely as a requirement of British Rail in respect of certain lines where speeds, stopping distances and headways of trains are such as to make a multi-casualty disaster practically inevitable if a vehicle should fall into the track. The criteria for high containment parapets are now included in this standard, and a steel design, a prototype of which has been successfully dynamically tested, is accepted as conforming. Concrete high containment parapets will be dealt with in BS 6779-2. High containment parapets are necessarily strong and hence less yielding than the lighter parapets. Their effect upon vehicles is consequently more severe and the possibility of detachment and shedding of the load of an HGV under such high energy impacts is an additional hazard. The use of high containment parapets should, therefore, be subject to very careful consideration to ensure that the overall risk to life and property is not increased. Their use should largely be restricted to cases such as that outlined above. Guidance on situations requiring the use of high containment parapets may be obtained from the Department of Transport, or, for railways, from the railway authority.

A.9 If a high level of containment is chosen, there are consequent problems not only in designing a parapet of sufficient strength but also in providing sufficient anchorage restraint in the supporting structure, to the extent where restrictions may be imposed on its overall design and appearance. A parapet of sufficient strength to provide a high level of containment is also likely to be so stiff as to cause additional damage to light vehicles that strike it and may result in them being deflected from it at a greater angle than is desirable. This will increase the risk of injury of the vehicle occupants and of a secondary accident on the highway.

A.10 This standard has been written primarily in general terms, so as to allow new forms of parapet to be developed and also to give clearer and more detailed design guidance based on the configurations of parapets now in general use in the UK. Because of the dependence of the applied force on deflection and the complex interaction of the parts of the parapet under dynamic loading, it is not possible to depend upon analytical design alone, and dynamic testing of any new parapet design is a requirement of this standard (see **10.1.1**). The following clauses give background information on levels of containment and theoretical forces induced in parapets.

A.11 The mean lateral deceleration of the centre of gravity of the vehicle resulting from an angled impact [see Figure A.1a)] may be approximated by:

$$a = \frac{(v\sin\theta)^2}{2[c\sin\theta + b(\cos\theta - 1) + z]}$$

where

a	is the mean lateral deceleration (m/s^2);
b	is the distance of the centre of gravity of the vehicle from the side of the vehicle (m);
c	is the distance of the centre of gravity of the vehicle from the front of the vehicle (m);
v	is the approach velocity (m/s);
z	is the sum of barrier deflection and depth of vehicle crumpling measured perpendicularly to the face of the barrier (m), see Figure A.1b);
θ	is the angle between the path of the vehicle and the barrier at impact (degrees).

It follows that the mean impact force F (in kN) is obtained from the equation:

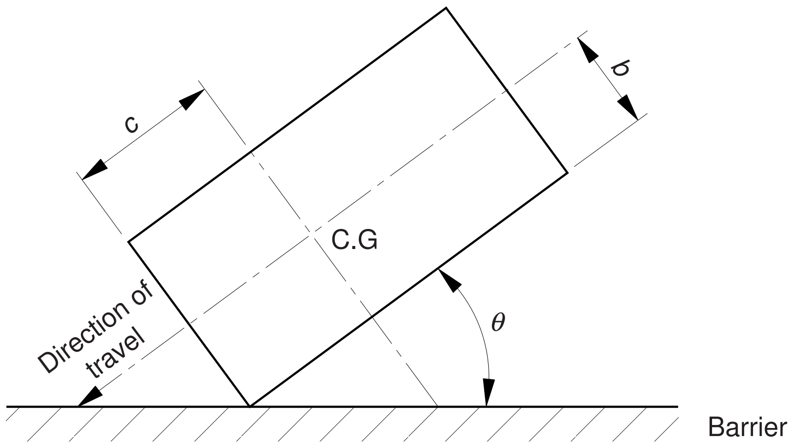
$$F = ma = \frac{m(v\sin\theta)^2}{2\,000[c\sin\theta + b(\cos\theta - 1) + z]}$$

where

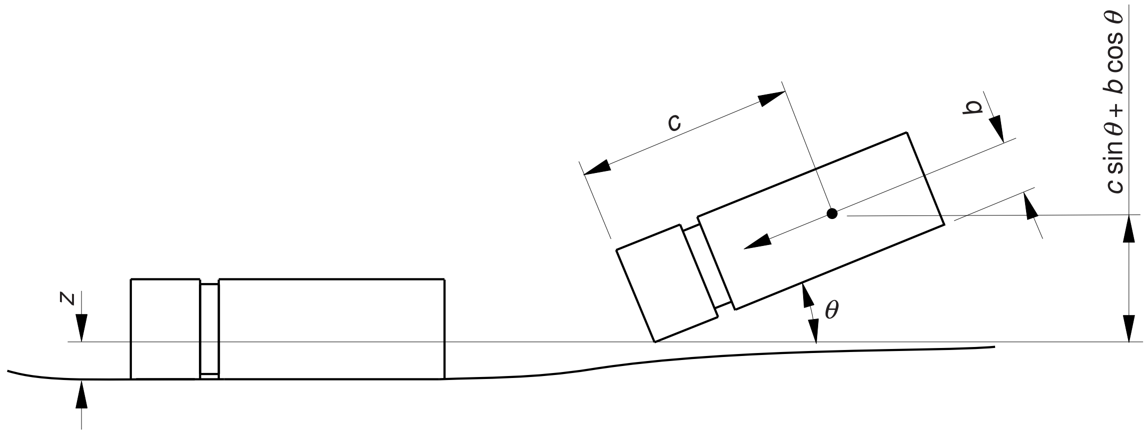
m is the vehicle mass (in kg).

A.12 The normal level of containment is that required for a 1 500 kg saloon car impacting at 20° at a speed of 113 km/h (70 mph) (see **6.1.1**). Local design forces are taken as 50 kN (see **B.2.1**) but on historical evidence the overall dynamic response will be at least 60 kN, hence this is the minimum average force required for dynamic testing (see **10.1.2.2**). Possible values representing a test vehicle and producing F = 60 kN response are:

m	= 1 500 kg;
v	= 31.3 m/s (70 mile/h);
c	= 2.44 m;
b	= 0.76 m;
z	= 0.64 m;
θ	= 20°.



a) Vehicle dimensions and angle of impact



b) Barrier deflection and vehicle crumpling

Figure A.1 — Dynamic testing

A.13 To give a better understanding of the effect of changes in these parameters, reference should be made to the graphs shown in Figure A.2, Figure A.3, Figure A.4, Figure A.5, Figure A.6 and Figure A.7 which illustrate how force varies if one term is varied whilst the others are kept constant.

Figure A.2 (force/mass) shows a straight line relationship as would be expected.

Figure A.3 (force/velocity) shows that the force rises steeply as the velocity is increased.

Figure A.4 (force/dimension *c*) shows that increasing *c* produces a comparatively small fall in force within the normal range of *c*.

Figure A.5 (force/dimension *b*) shows little effect within the normal range of *b*.

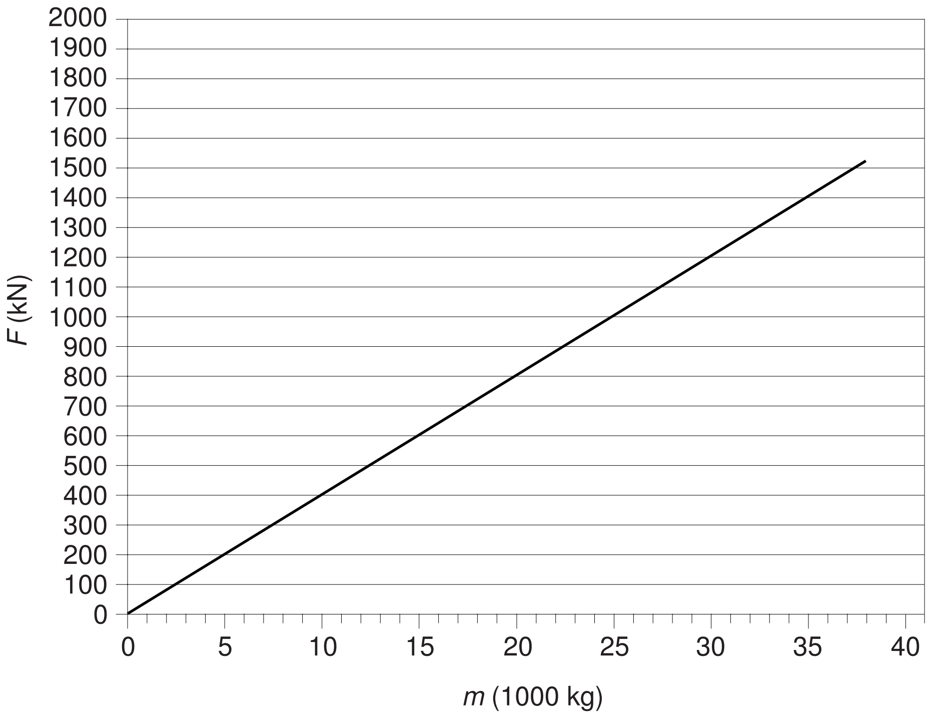
Figure A.6 (force/ *z*) shows that an increase in *z* initially causes considerable reduction in force. This demonstrates the advantage of the more flexible, light metal parapets in reducing the severity of impact as compared with a more rigid concrete parapet or even a stiffer, higher containment metal construction.

Figure A.7 (force/angle θ) shows a variable build up of force with θ to about $\theta = 12°$ developing into a straight line relationship.

A.14 In considering these results it is necessary to consider how they relate to a high containment vehicle as well as to the standard test vehicle. The standard vehicle is a fairly large well-loaded car travelling at the maximum permitted speed of 113 km/h (70 mile/h). Travelling along a narrow road, the alignment of which permits such speeds, the likelihood of an impact at an angle greater than 20° is fairly remote as in producing sufficient turning radius the car would probably overturn or skid. At slower speeds an angle of 20° is more readily produced. There is also the possibility that, on a wide road, a vehicle could veer across several traffic lanes or to the far side and thus produce a greater angle of impact, or that, on bridges close to junctions, the alignment of the parapet could be at an obtuse angle to some approaching traffic. Considering the other vehicle factors, c could be considerably greater and b somewhat greater for the larger vehicle, but the effect of variations in b is comparatively small.

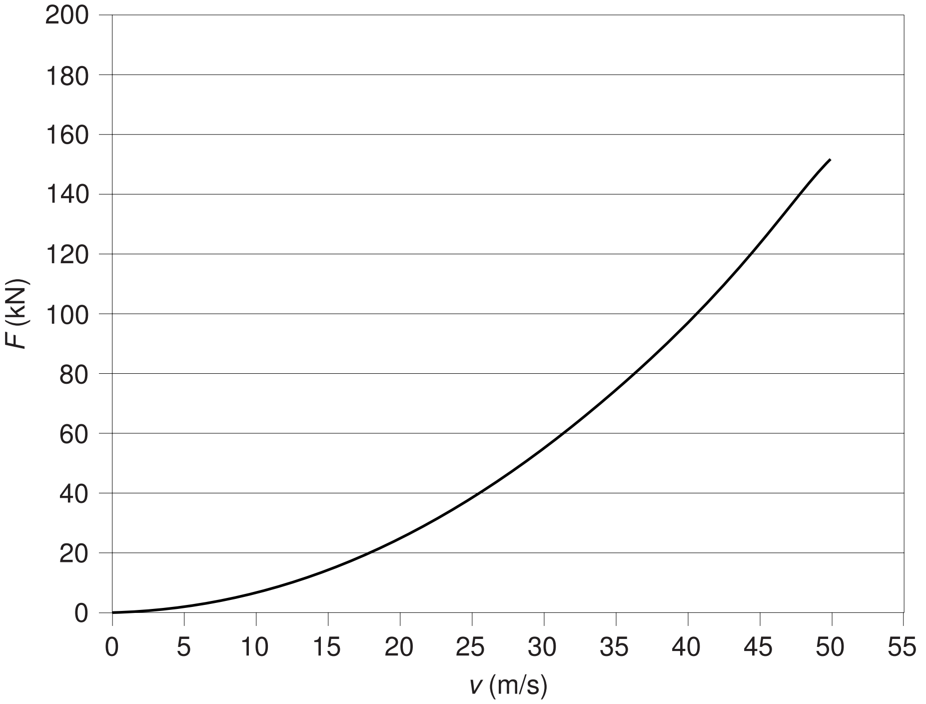
A.15 The remaining factor z is quite critical. The dynamic test for the parapets specified in this standard calls for the wheel penetration under standard impact to be not greater than 500 mm [see item b) of **10.1.2.2**]. Crumpling of the vehicle can vary considerably depending upon its size, construction and point of impact. The value of 0.64 m used in **A.12** does, with values of 2.44 m for c and 0.76 m for b, produce the 60 kN minimum response required in the dynamic test. Although this relationship is used for illustrative and comparative purposes in this annex, it should be realized that a variable force will be generated during the period of contact.

The impact of a larger, heavier vehicle is likely to produce a larger value for z.



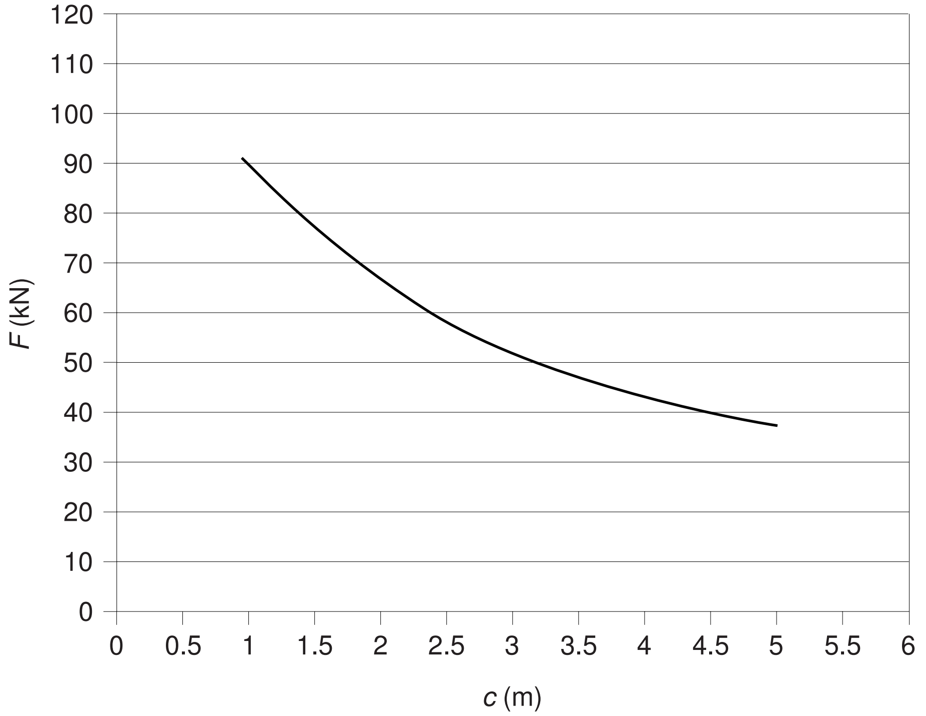
NOTE Force normal to the barrier.

Figure A.2 — Variation of lateral impact force F with mass of vehicle m



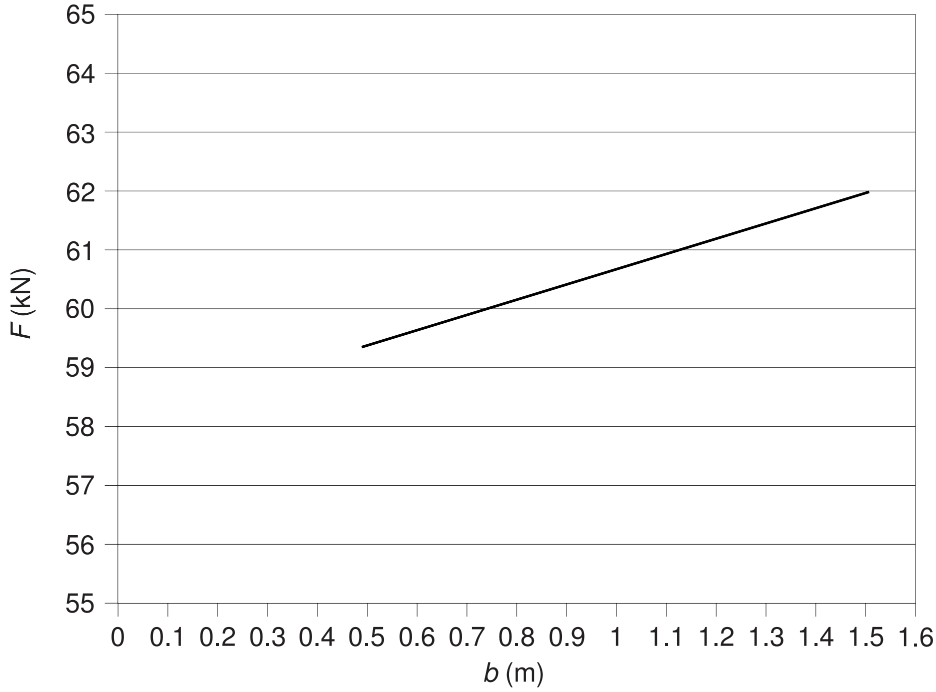
NOTE Force normal to the barrier.

Figure A.3 — Variation of lateral impact force *F* with speed of vehicle *v*



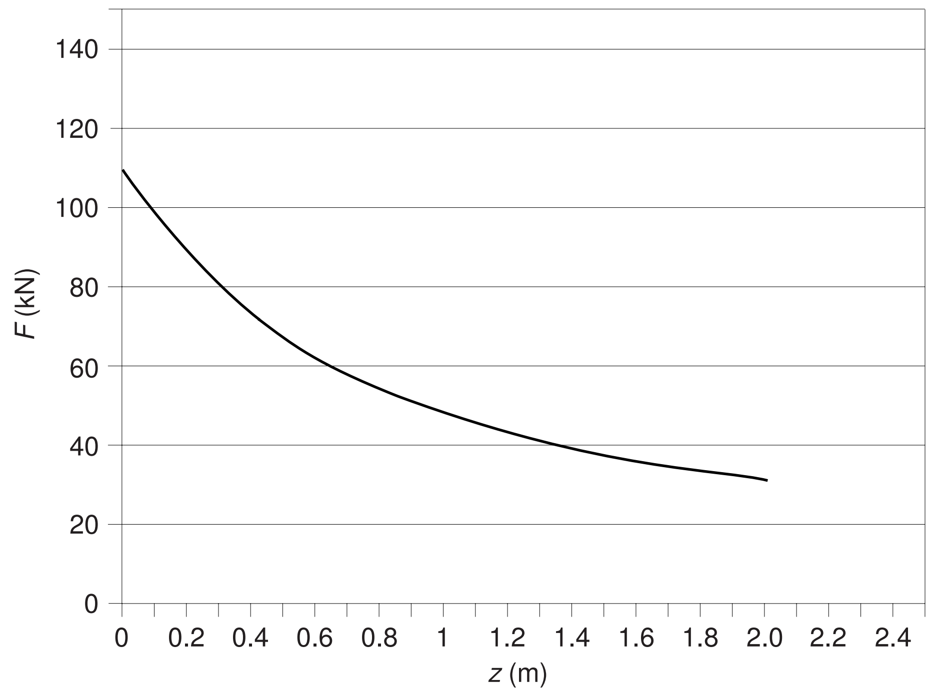
NOTE Force normal to the barrier.

Figure A.4 — Variation of lateral impact force *F* with position of centre of gravity *c*



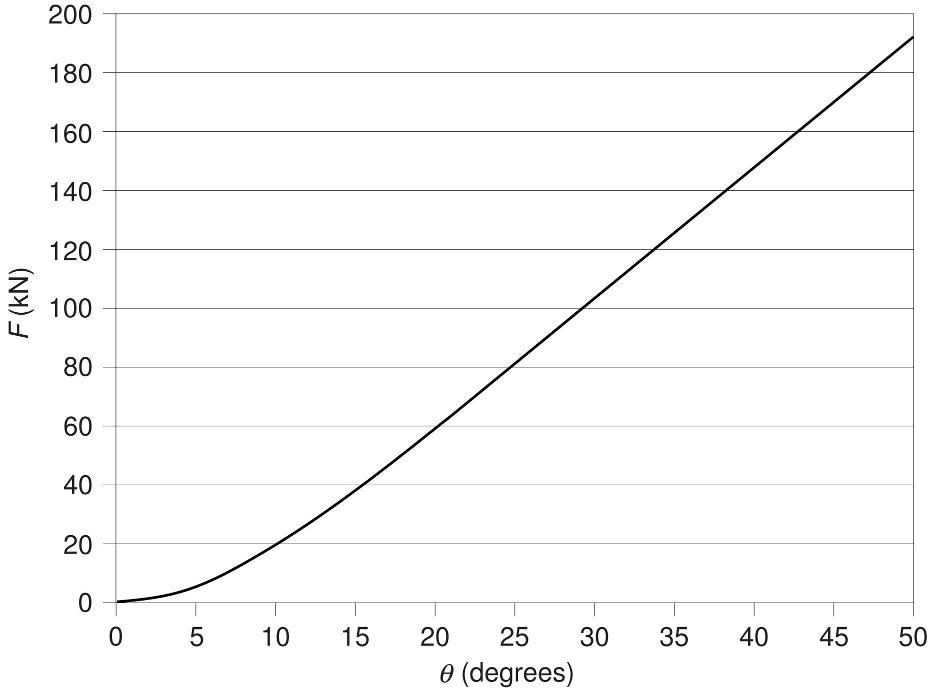
NOTE Force normal to the barrier.

Figure A.5 — Variation of lateral impact force *F* with position of centre of gravity *b*



NOTE Force normal to the barrier.

Figure A.6 — Variation of lateral impact force *F* with sum of barrier deflection and depth of vehicle crumpling *z*



NOTE Force normal to the barrier

Figure A.7 — Variation of lateral impact force F with angle of impact θ

A.16 In the limiting case of θ, where a vehicle impacts at right-angles to the parapet, the forces become enormous and there is no practical possibility of retaining a vehicle on the highway. Assuming the vehicle remains at right-angles throughout, the force F (in kN) is given by the equation:

$$F = \frac{mv^2}{2\,000z}$$

However, if it is assumed that, due to some imbalance of forces, the vehicle will still swing around and at the end of the impact will be parallel to the parapet, the force is generally:

$$F = \frac{mv^2}{2\,000(c - b + z)}$$

which gives forces that are much smaller but are still high.

This is illustrated in Table A.1 which is for a 30 t vehicle travelling at 17.78 m/s (40 mile/h) and where c = 6 m and b = 1.25 m.

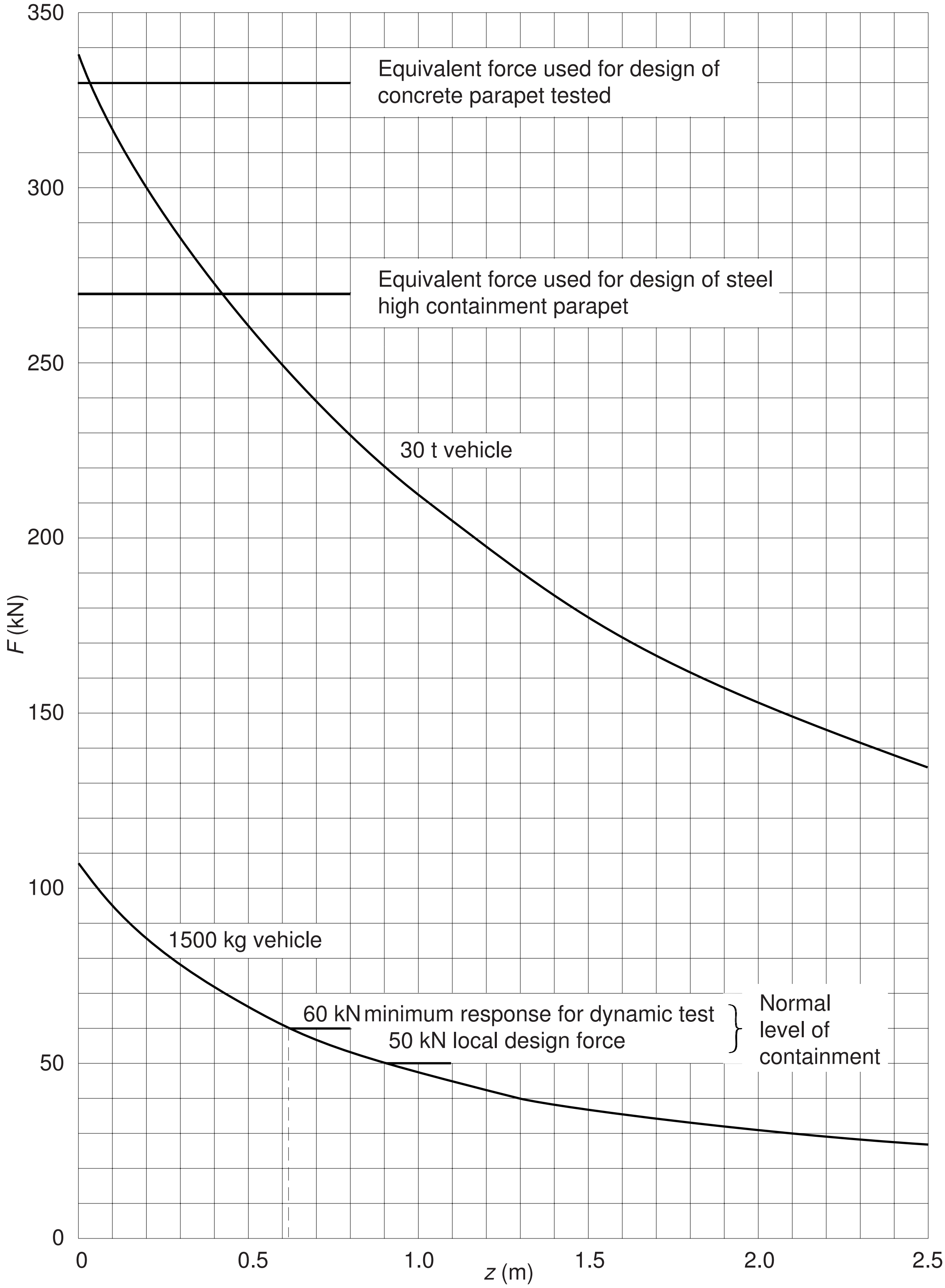
Table A.1 — Theoretical mean impact force for a 90° impact from a 30 t vehicle

z (m)	0	0.5	1.0	1.5	2.0
F (kN) $\left(\text{if } F = \frac{mv^2}{2\,000z}\right)$	—	9 505	4 753	3 168	2 376
F (kN) $\left[\text{if } F = \frac{mv^2}{2\,000(c - b + z)}\right]$	1 001	905	827	760	704

A.17 Comparison of these values with those of the graph in Figure A.7, and in particular the normal containment design force of 50 kN, shows the impracticability of retaining vehicles producing such levels of impact force.

A.18 Figure A.8 shows the theoretical mean impact forces produced for differing values of z by a 1 500 kg vehicle as detailed in **A.12**, and for a 30 t rigid vehicle having v = 17.78 m/s (40 mile/h), c = 5.1 m, b = 1.2 m and θ = 20°.

A.19 It has to be emphasized that all the values of F in this annex are theoretical mean impact forces and that the actual pattern of force is by no means constant but varies in intensity, tending to have initial and final peaks which can be very much higher than the average. So far as impacts on metal parapets are concerned there is a wealth of test data which confirms that a parapet, designed to the static forces recommended in Annex B and having a response to dynamic impact in the order of that of the present post and rail designs, will produce a satisfactory performance.



30 t vehicle: v = 17.78 m/s (40 mile/h), θ = 20°, c = 5.1m, b = 1.2 m
1500 kg vehicle: v = 31.3 m/s (70 mile/h), θ = 20°, c = 2.44 m, b = 0.76 m

Figure A.8 — Theoretical mean lateral impact forces for varying *z* values for two vehicles

Annex B (informative) Detailed design recommendations for new designs of post and rail configurations

B.1 Limiting dimensions for metal parapets

B.1.1 Metal parapets should conform to the general dimensional recommendations given in **B.1.2**, **B.1.3** and **B.1.4**, and to the particular recommendations of Figure B.1, Figure B.2, Figure B.3, Figure B.4 and Figure B.5 for the appropriate designation as given in Table B.1.

Table B.1 — Designations and limiting dimensions

Type of parapet	Designation (see Clause 5)	Limiting dimensions given in figure
Vehicle parapet	N/1.00/0	Figure B.1
Vehicle/pedestrian parapet	L/1.00/[a] N/1.00/[a] L/1.50/[a]	Figure B.2
Vehicle/pedestrian parapet	L/1.00/V	Figure B.3
Vehicle/pedestrian parapet over railway	N/1.25/[a] N/1.50/[a]	Figure B.4
Vehicle/pedestrian high containment parapet	H/1.50/[a]	Figure B.5

[a] Infilling in accordance with Clause **8** to be provided as required.

B.1.2 The distance between centrelines of supporting posts should not exceed the distance used in the design of the effective longitudinal members, up to a maximum of 3 800 mm for normal and low containment parapets and 3 000 mm for high containment parapets.

B.1.3 The minimum overall depth of longitudinal members projected on to the traffic face should be 50 mm for normal and low containment parapets and 100 mm for high containment parapets.

B.1.4 For minimum thickness of members, see Table 2.

B.2 Design criteria for components of metal parapets

B.2.1 *General*

Components of metal parapets may be designed by applying the simplified relationships given in **B.2.2** to **B.2.6** to conform with the nominal loads given in Table B.2. The simplified expressions are derived on the basis that $\gamma_{f3} = 1.0$ and $\gamma_m = 1.0$.

Table B.2 — Nominal loads for parapets of tested configuration

Parapet containment level	Effective longitudinal members	Supporting posts
	Nominal load Q_k applied horizontally to longitudinal members at mid-point between centres of supports kN	Nominal load Q_k applied transversely to the post according to the disposition of the effective longitudinal members kN
Low, L	25/*n*	25
Normal, N	50/*n*	50
High, H	270/*n*	270

NOTE *n* is the number of effective longitudinal members in the parapet.

B.2.2 ***Strength of supporting posts***

Posts should conform to the following recommendations a) to f) with regard to strength. Posts and longitudinal members supporting a parapet with solid infill, including acoustic barrier, should also satisfy wind loading.

a) *Transverse loading*. The product of the nominal yield stress, or 0.2 % proof stress (determined in accordance with Table 7), and the plastic modulus of any post about an axis parallel to the line of the parapet, should be not less than the moment induced by the transverse design load Q^*, acting on the post according to the disposition of the effective longitudinal members.

b) *Longitudinal loading*. The product of the nominal yield stress, or 0.2 % proof stress (determined in accordance with Table 7), and the plastic modulus of any intermediate posts about an axis at right angles to the line of the parapet, should be not less than 25 % of the requirement in the transverse direction.

c) *Strength of connection of post to base plate*. The connection between post and base plate should develop the theoretical full plastic moment of the actual post in transverse and longitudinal directions and the design load of the post in shear.

d) *Strength of the attachment system of the post base plate to plinth*. The post base plate and the attachment between the post base plate and the plinth should be capable of developing a moment of resistance about each axis, taken at the underside of the base plate, at least 50 % greater than the theoretical full plastic moment of the actual post. See Table 6.

e) *Bedding grout*. For design of bedding grout see **9.1.2.6**.

f) *Anchorages*. For design of anchorages refer to Table 6 and **6.6**.

B.2.3 ***Strength and continuity of effective longitudinal members***

Effective longitudinal members should conform to the following recommendations a) to d) regarding strength and continuity.

a) *Continuity in bending*. Longitudinal members should be structurally continuous in bending, and their design strength in bending should be maintained over the whole length of the parapet where practicable. When such continuity is not possible, such as at larger movement or complex movement joints, the parapet should be terminated on either side and the gap between the ends of longitudinal members should not exceed 25 mm when the joint is at its minimum opening [see item b) of **6.5.1.1**, item a)2) of **6.5.1.2** and **6.5.1.3**].

b) *Horizontal bending strength*. The product of the nominal yield stress, or 0.2 % proof stress, (determined in accordance with Table 7) and the plastic modulus about the vertical axis of each effective longitudinal member of a parapet, including all joints, should be not less than the maximum continuous moment, calculated elastically, induced by the design load Q^*, acting horizontally at the midpoint between centres of support of the longitudinal member.

c) *Vertical bending strength*. The bending strength of the member, including all joints, about the horizontal axis should be not less than 50 % of that required about the vertical axis.

d) *Continuity and strength in tension*. Longitudinal members should be structurally continuous in tension throughout the whole length of the parapet, except as allowed under item a) of **6.5.1.1**a)1) of **6.5.1.2** and **6.5.2.3**.

B.2.4 ***Strength of non-effective longitudinal members***

Non-effective longitudinal members should be designed to resist a horizontal nominal load Q_k of 1.4 kN/m with a load factor of 1.2.

B.2.5 ***Connections between longitudinal members and supporting posts***

Connections should be designed to resist the following.

a) A horizontal force, acting at right angles to the traffic face, both towards and away from the post centreline, through the centroid of the rail section of value Q_k/n.

b) A vertical force, applied either upwards or downwards, acting through the centroid of the rail section of value $Q_k/2n$.

c) A force acting parallel to the rail at its centroid of section of value:

1) for intermediate posts, $Q_k/2n$;

2) for special end posts, Q_k/n

where

Q_k is the nominal load from Table B.2;

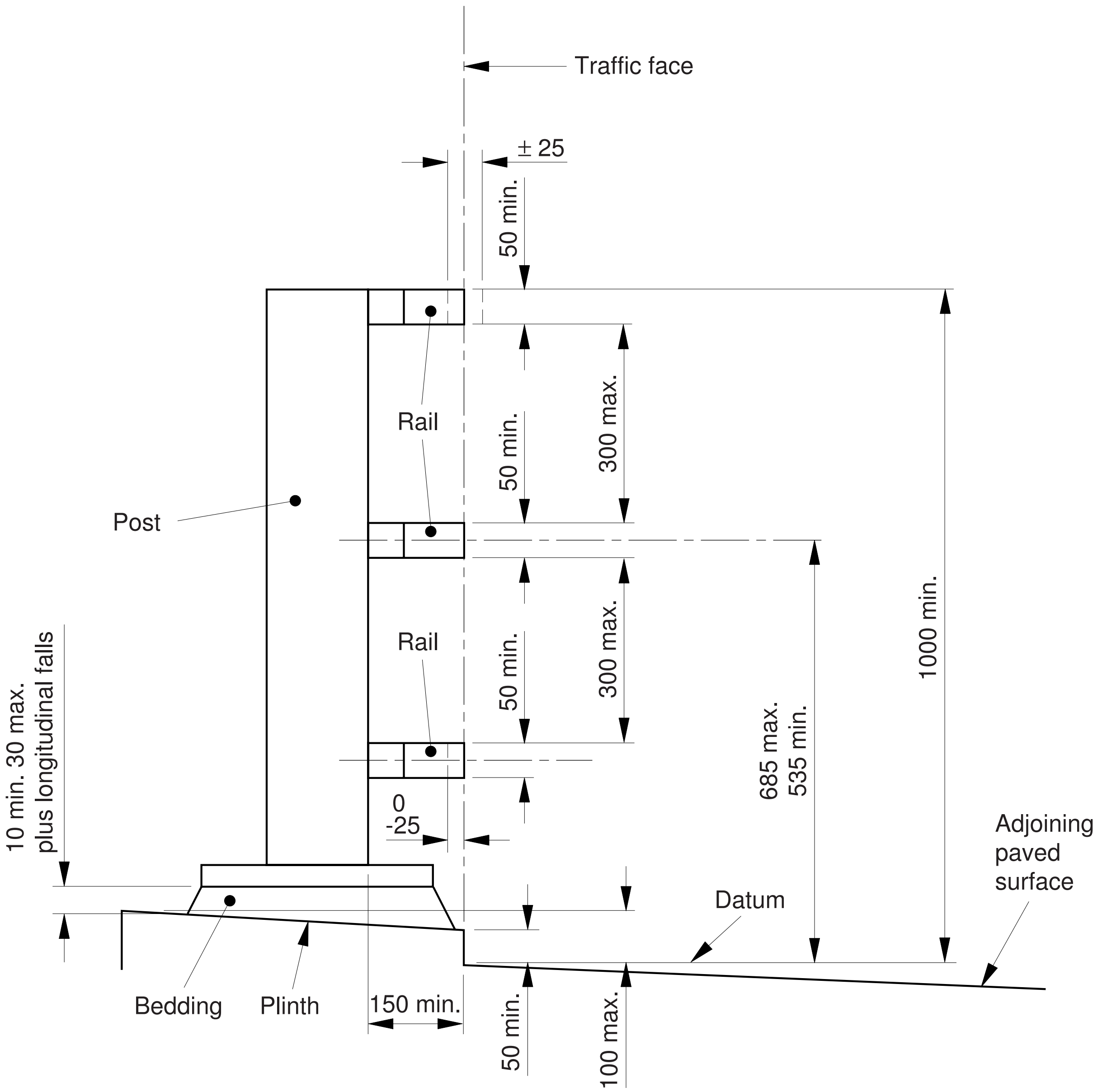
n is the number of effective longitudinal members;

3) for high containment end bays where no transition or shock transmission unit is used, see **6.5.1.7**.

B.2.6 ***Vertical bar infilling***

Vertical bar infilling should conform with **8.2**a).

All dimensions are in millimetres



NOTE 1 The post may slope towards the traffic face.

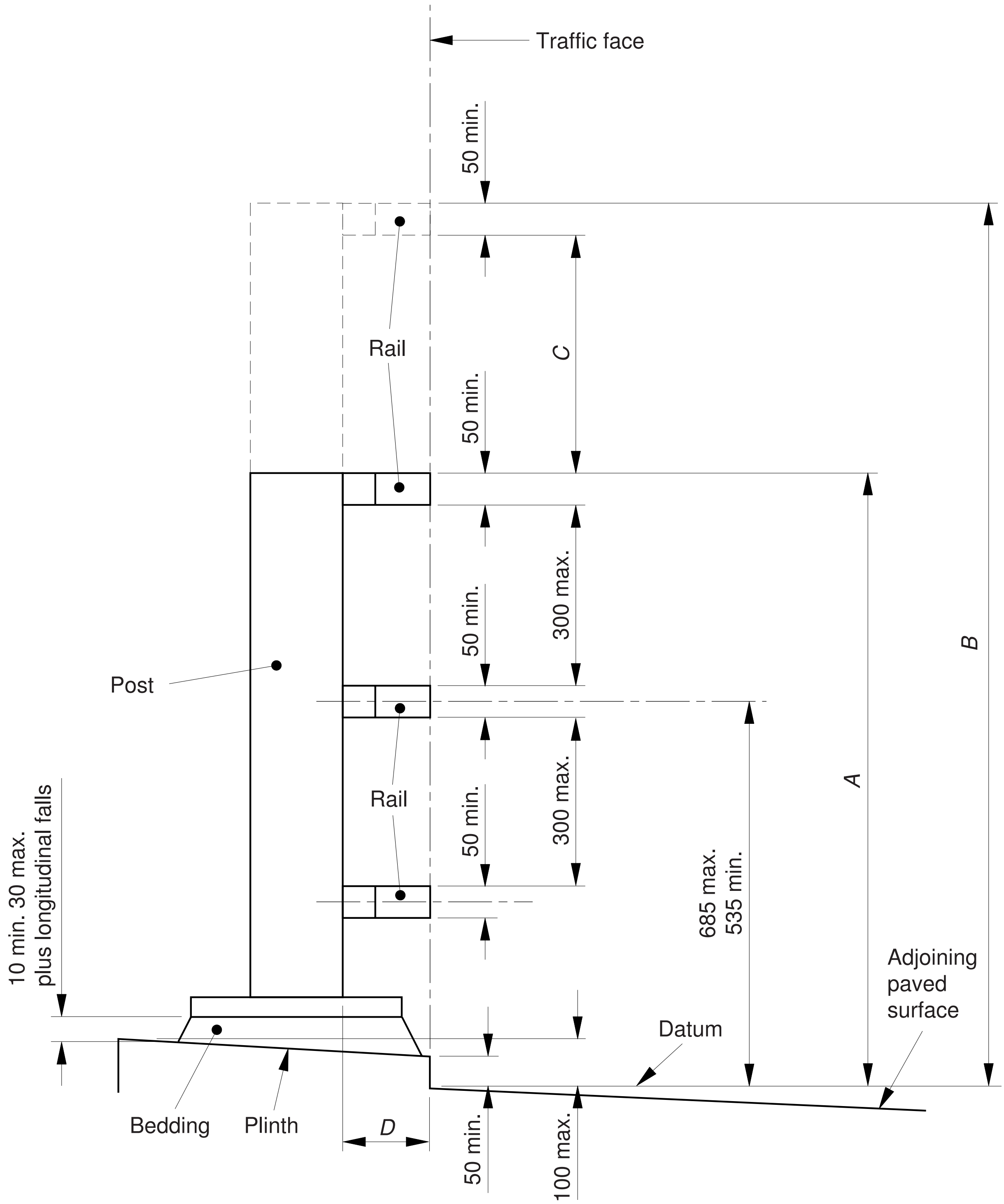
NOTE 2 Dimensions relative to the height datum assume there is no longitudinal fall on the plinth. Additional tolerances to take account of any such fall are permissible.

Figure B.1 — Vehicle parapet N/1.00/0: limiting dimensions for parapets of tested configuration

All dimensions are in millimetres

Designation	*A*	*B*	*C*	*D*
	mm	mm	mm	mm
L/1.00/[a]	1 000 min.	—	—	100 min.
N/1.00/[a]	1 000 min.	—	—	150 min.
L/1.50/[a]	—	1 500 min.	450 max.	100 min.

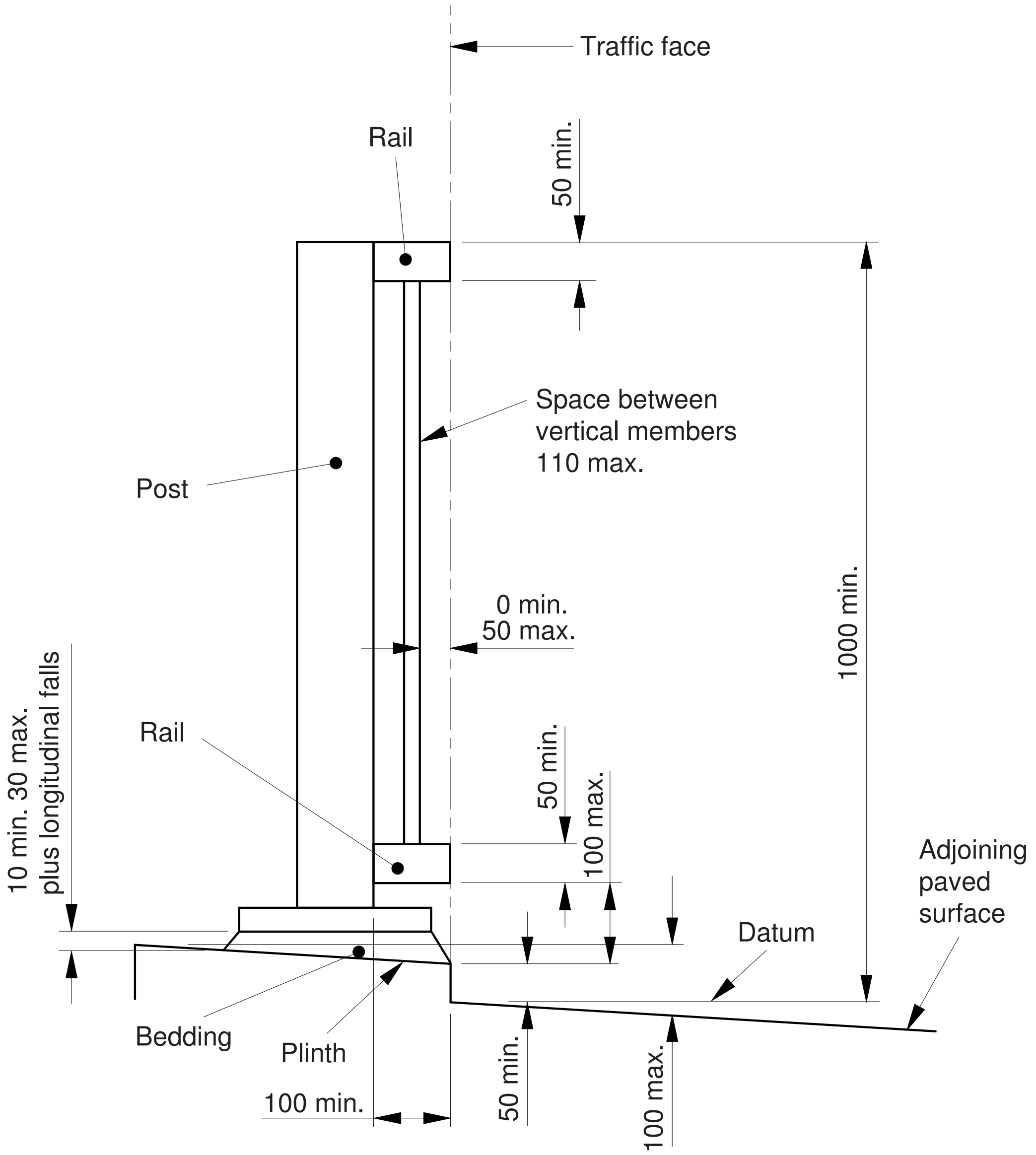
[a] Infilling in accordance with Clause **8** to be provided as required.



NOTE Dimensions relative to the height datum assume there is no longitudinal fall on the plinth. Additional tolerances to take account of any such fall are permissible.

Figure B.2 — Vehicle/pedestrian parapet L/1.00/, N/1.00/ and L/1.50/: limiting dimensions for parapets of tested configuration

All dimensions are in millimetres

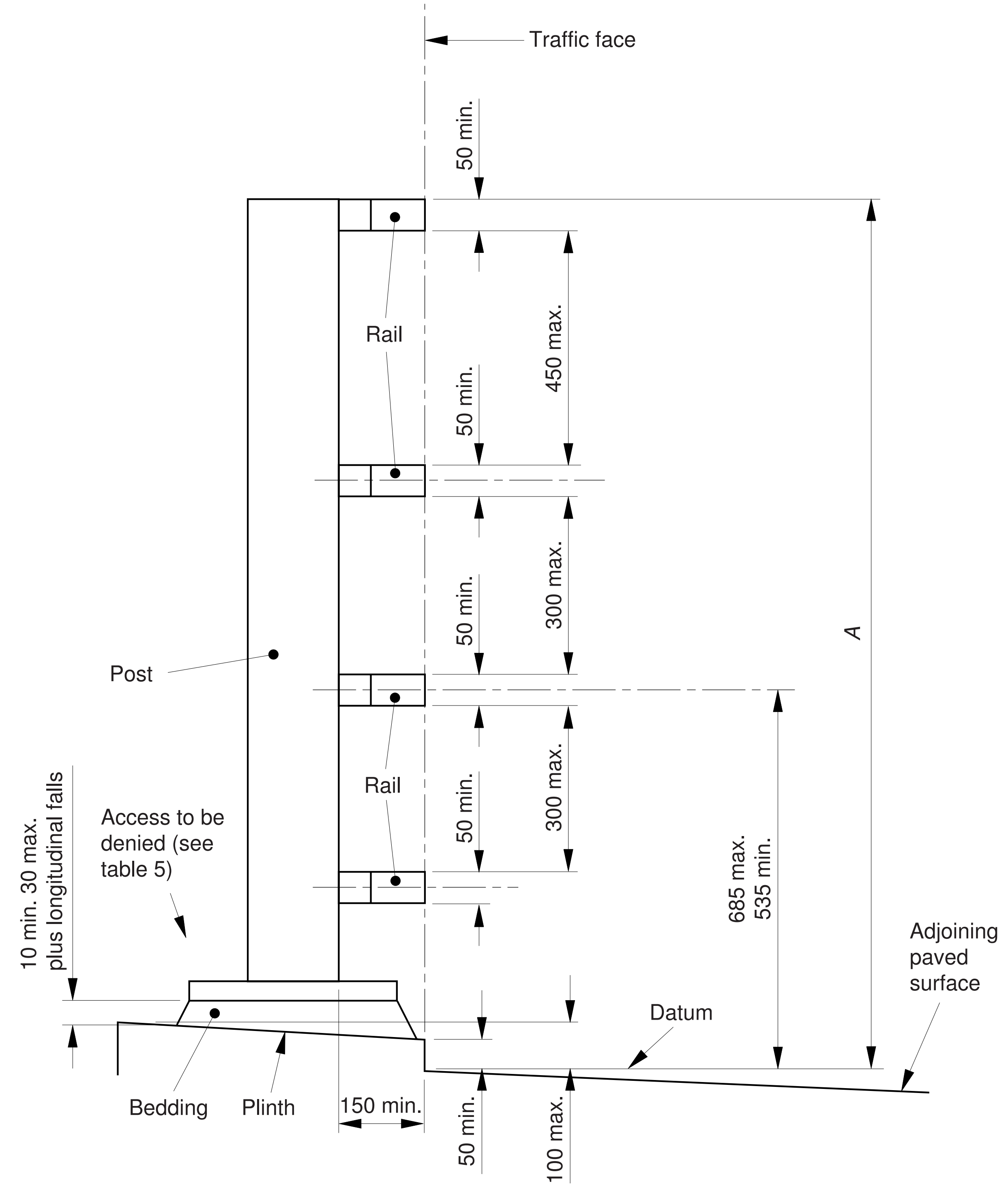


NOTE Dimensions relative to the height datum assume there is no longitudinal fall on the plinth. Additional tolerances to take account of any such fall are permissible.

Figure B.3 — Vehicle/pedestrian parapet L/1.00/V: limiting dimensions for parapets of tested configuration

All dimensions are in millimetres

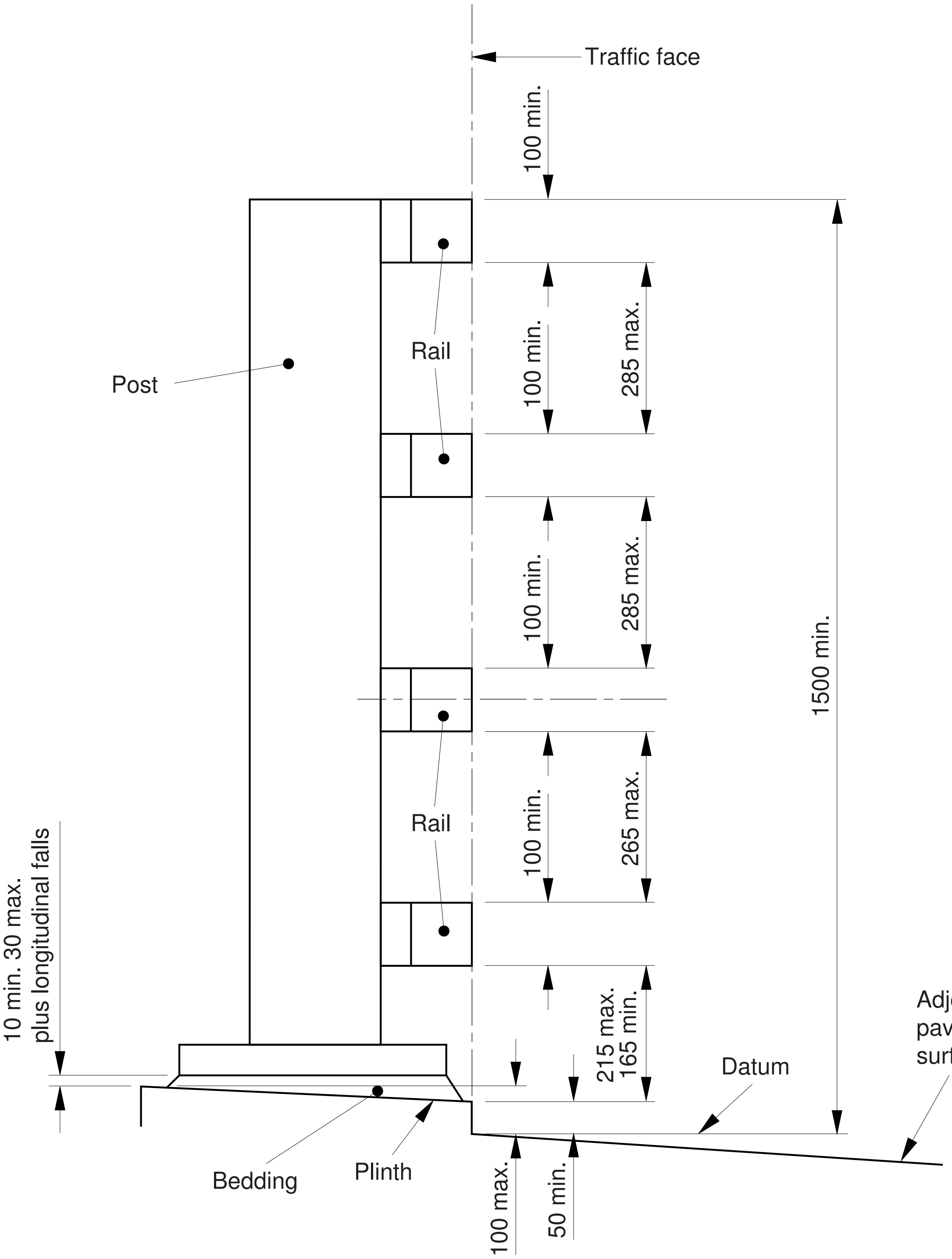
Designation	*A*
	mm
N/1.25[a]	1 250 min.
N/1.50/[a]	1 500 min.
[a] Infilling in accordance with Clause 8 to be provided as required.	



NOTE Dimensions relative to the height datum assume there is no longitudinal fall on the plinth. Additional tolerances to take account of any such fall are permissible.

Figure B.4 — Vehicle/pedestrian parapet over railways N/1.25/ and N/1.50: limiting dimensions for parapets of tested configuration

All dimensions are in millimetres



NOTE Dimensions relative to the height datum assume there is no longitudinal fall on the plinth. Additional tolerances to take account of any such fall are permissible.

Figure B.5 — Vehicle/pedestrian parapet H/1.5/[a]: limiting dimensions for parapets of tested configuration

[a] Infilling in accordance with Section 4 to be provided as required.

Annex C (informative)
Information to be provided by the supplier/purchaser

The following information should be provided by the purchaser.

Where the purchaser indicates alternatives or does not specify, the supplier should state what he intends to provide.

Table C.1 — Information to be supplied by the supplier/purchaser

Information to be supplied	Example of information required
a) Parapet material	Steel or aluminium alloy.
b) Surface protection	For a steel parapet, the preparation and protective system.
c) Designation	The designation of parapet (see Clause **5**).
d) Infill material and protection (if infill required)	Steel or aluminium alloy; expanded metal, welded mesh or solid; whether galvanized etc.; fixing method, non-effective member. Special requirements, such as acoustic barrier, anti-access barrier etc.
Attachment method	
e) Anchorage type and protection	Cast-in cradle, drilled holes galvanized, static testing etc.
f) Type of holding-down bolts	Normal; expanding; cast-in resin etc. Any torque or static testing requirements. Passive filler (see Note 3 to **6.6.5**).
g) Detailed layout	Relevant details including the following information: 1) horizontal and vertical dimensions and alignment; 2) joints required, giving details of position and movement and any special features such as vertical movements etc.
h) Details of connection to any safety fence/transition	
i) Availability of storage at site etc.	Position; area; type of surface.
j) Erection requirements	Relevant details including the following information: 1) dates required; 2) access to site and availability; 3) availability to cranage; 4) other operations in progress; 5) special conditions, e.g. proximity of traffic, site welding hazards.
k) Method of securing attachments against vandalism	High torque, spot welding, punch locking.
l) Production testing requirements	End posts and intermediate posts; number per order.
m) Weld defect levels for acceptance	A quality regime, production testing of posts and visual inspection are envisaged. Levels of visual defects allowed, such as porosity or changes of cross-section etc., may need to be given.
NOTE BS 5135 does not cover precise defect levels allowed.	

Annex D (normative) Method for dynamic testing

D.1 Dynamic testing

Parapets shall be tested dynamically as specified in **10.1**. The criteria for acceptance are given in that clause.

The test procedure shall cover the following:

a) examination of the test parapet to ensure that it conforms to the design and specification details;

b) determination of the properties of certain key components;

c) static test on vertical members;

d) a full-scale dynamic test;

e) examination of test data and preparation of a report, including a conclusion on performance in relation to the stated criteria.

D.2 Test parapet

D.2.1 The parapet to be tested shall be fully and clearly described by drawings and specifications including any details of fabrication or fixing. Supporting design calculations shall also be made available. The length of the test parapet shall be not less than 30 m or consist of not less than 10 standard panels, where appropriate. Rail joints shall be incorporated to meet the requirements of **D.6**. Infilling shall be omitted from the test parapet unless it forms a structural part of the parapet.

D.2.2 The parapet to be used in the test shall be examined in detail by the test authority for conformity with drawings and specifications. In particular, the dimensions of the erected parapet shall be recorded and the materials shall be certified in respect of quality. Cross-sectional dimensions of vertical members or components and horizontal members shall be determined to enable the critical cross-section properties to be calculated at two intermediate positions in the length of parapet. Where it is possible to isolate vertical members, such as the posts in post and rail configurations, two such members shall be statically tested in accordance with Annex E.

D.2.3 The drawings, specification and the results of the detailed examination, material certification, dimensional check and static tests shall form part of the records of the test.

D.3 Test area

D.3.1 The test area (see Figure D.1 and Figure D.2) shall be generally flat with a gradient not exceeding 1 in 40, shall be surfaced to normal highway standard and shall be clean and free from water, ice or snow at the time of test. It shall be of sufficient size to enable the test vehicle to be accelerated upto the required speed and controlled so that its approach to the parapet is stable.

To enable characteristics after impact to be evaluated, the paved area shall extend to at least 50 m beyond the point of impact, covering the likely path of the vehicle.

NOTE In some cases it is helpful if the area in front of the parapet is marked with square grid lines at 1 m centres emanating from the traffic face.

D.3.2 A rigid plinth not less than 800 mm wide in cross-section and 50^{+10}_{0} mm high shall be provided, on which the test parapet shall be mounted with its traffic face in line with the forward edge of the plinth. The top of the plinth shall be treated to enable wheel tracks to be recorded.

D.3.3 Suitable anchorages shall be provided for the fixing of the parapet.

D.3.4 Details of test area, plinth and anchorages shall form part of the records of the test.

D.4 Vehicle

D.4.1 The vehicle to be used in the test shall be a complete four-wheeled passenger production saloon car, representative of the current vehicle population, for low and normal containment parapets and a four-axle rigid tanker or equivalent for high containment parapet. The tyres shall be inflated to the manufacturer's recommended pressures. The condition of the vehicle at the time of the test shall be such as to satisfy the requirements for the issue of a certificate of roadworthiness[1)] in respect of tyres, suspension, wheel alignment and bodywork. No repairs or modifications shall be made that would alter the characteristics of the vehicle or invalidate such a certification. The vehicle shall be clean and mud or deposits which may cause dust on impact shall be removed prior to testing.

D.4.2 The mass of the vehicle shall be (1 500 ± 5) kg and the height of its centre of gravity shall be (530 ± 50) mm for low and normal containment parapets and (30 000 ± 300) kg and 1.65 m ± 100 mm respectively for high containment parapets. If the mass of the car includes ballast and equipment this shall not exceed the manufacturer's recommended loading capacity, and it shall be distributed within the passenger and/or luggage compartment and securely attached to the structure of the vehicle. All loads shall be deployed so that the total mass is distributed evenly transversely and axle loads are within the manufacturer's recommended levels.

D.4.3 The vehicle shall be marked externally on the top and on the side away from the parapet with the position of the centre of gravity. A scale line of not less than 1 m shall also be marked through these points.

D.4.4 Details of vehicle and ballasting shall form part of the test records.

D.4.5 The vehicle shall be fitted with transducers, as near as practicable to its centre of gravity, capable of measuring accelerations in the three major axes.

[1)] In the United Kingdom a Department of Transport certificate is required.

Dimensions are in millimetres unless otherwise shown

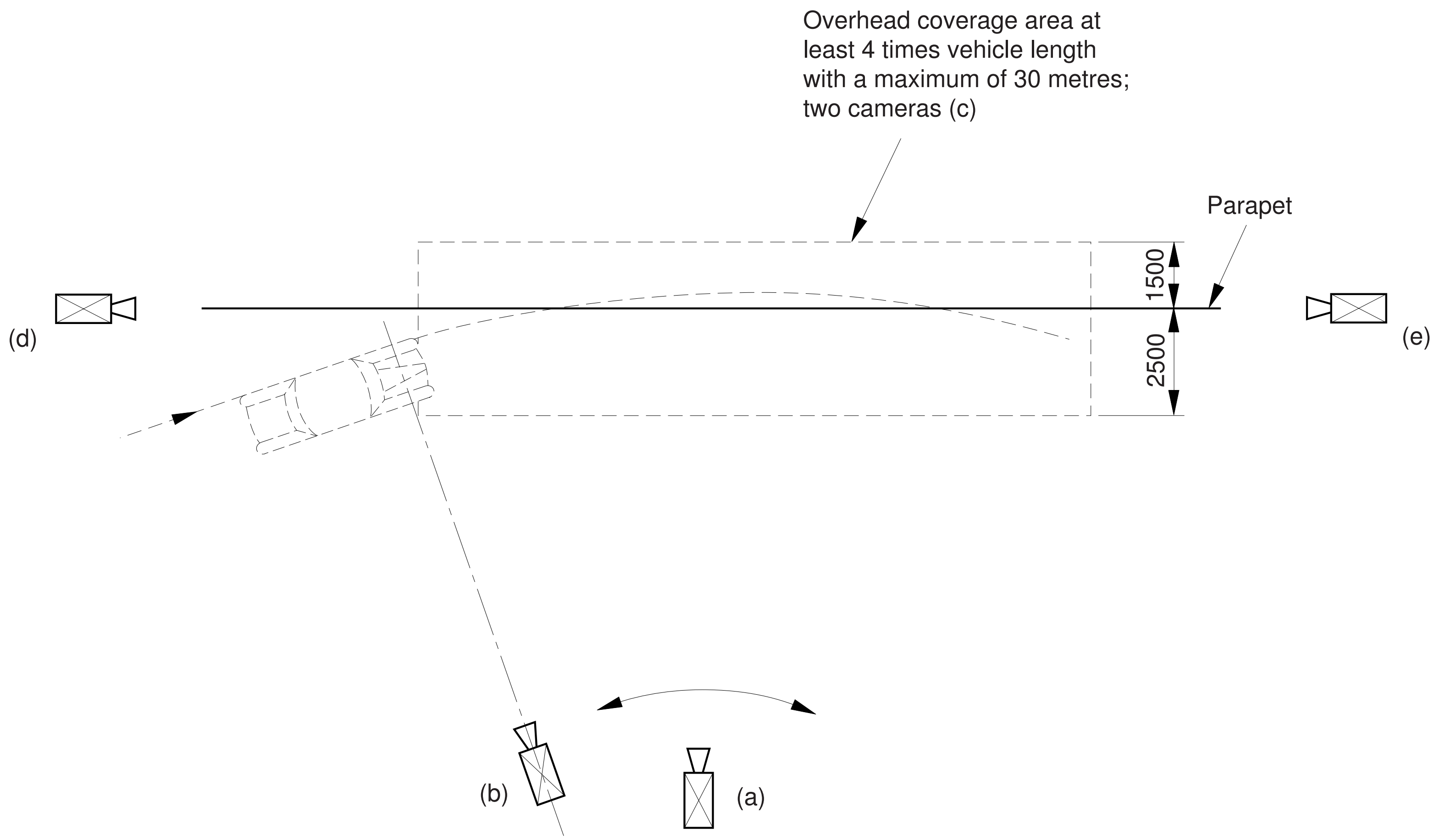


Figure D.1 — Typical layout of cameras for recording tests

SAFETY PARAPET: NORMAL CONTAINMENT 3 RAIL STEEL PARAPET

Length: 30 m

Maximum wheel penetration: 0.33 m, 0.90 m upstream of post 4

Maximum deflection: Dynamic: 0.35 mm, 1.5 m upstream of post 4 Static: 0.21 m, 1.25 m upstream of post 4

Damage:
Bottom rail pushed 0.21 m rearwards of traffic.
Centre rail pushed 0.175 m rearwards, centrally between posts 3 and 4.
Top rail pushed 0.10 m rearwards at post 4.
Post 4 rotated 5° rearwards from the traffic face.

VEHICLE

Type: Rover SDI 3500 Mass: 1498 kg Damage: Front LH corner pushed in 0.30 m.
Assessment difficult due to impact into concrete barriers.

VEHICLE BARRIER RESPONSE Impact velocities: Lateral: 10.9 m/s Longitudinal: 29.9 m/s

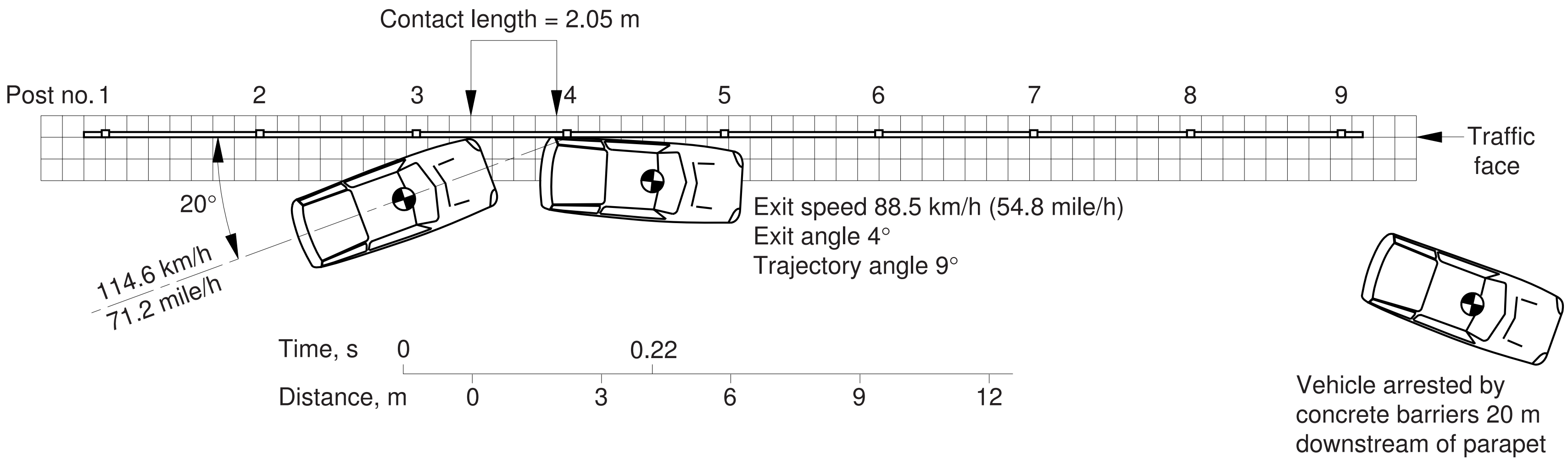


Figure D.2 — Typical details to be included in the test report

	Time after impact, s	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32
Vehicle acceleration, *g* **from accelerometers Filter: 10 Hz, 48 dB/oct.**	Lateral, *g*	−1.61	−3.73	−6.23	−8.36	−10.32	−12.15	12.43	−10.31	−6.33	−2.66	−0.74	−0.31	−0.29	−0.06	0.24	0.21
	Longitudinal, *g*	−1.21	−2.42	−3.81	−4.98	−5.62	−4.97	−3.02	−1.11	−0.48	−0.85	−1.14	−0.98	−0.79	−0.83	−0.84	−0.62
	Vertical, *g*	0.28	0.20	−0.16	−0.65	−1.09	−1.14	−0.99	−0.84	−0.02	1.38	1.89	0.95	−0.30	−0.82	−0.55	−0.06
	Resultant, *g*	2.03	4.45	7.30	9.77	11.80	13.18	12.83	10.41	6.35	3.12	2.32	1.39	0.89	1.17	1.03	0.66
Vehicle forces derived from accel. relative to undeflected barrier	Lateral, kN	−32.0	−68.5	−109.7	−142.4	−167.3	−185.7	−183.3	−152.6	−96.2	−40.0	−6.5	3.9	4.3	5.2	8.3	9.6
	Longitudinal, kN	−7.0	−13.5	−23.1	−35.8	−47.8	−47.3	−31.8	−14.1	−8.2	−13.0	−16.8	−14.4	−11.6	−12.2	−12.6	−9.5

MEAN DECELERATION of vehicle for duration of 0.22 s

Lateral: 6.92*g* Longitudinal: 2.65*g*

REMARKS The vehicle was contained and redirected by the parapet.

Figure D.2 — Typical details to be included in the test report (*continued*)

D.5 Propulsion of the vehicle

D.5.1 The test vehicle shall be accelerated by any method suitable for the site.

D.5.2 The vehicle shall impact with the parapet at the specified velocity and angle (see **D.6.1.2**, **D.6.2.2** and **D.6.3.2**) and shall approach the point of impact in a stable manner. The vehicle shall not be damaged by the means of propulsion. The means of propulsion shall be disconnected before impact or, where the vehicle is self-propelled, the ignition shall be cut out before the impact.

D.5.3 The vehicle shall not be restrained by the control of the steering or any other means during and after impact.

D.5.4 A description of the method of propulsion shall form part of the test record.

D.6 Test parameters for post and rail type parapets

D.6.1 ***Normal level of containment parapet***

D.6.1.1 One test shall be carried out on each parapet design.

D.6.1.2 The vehicle shall, at impact, have a velocity of (113 ± 5) km/h [(70 ± 3.5) mile/h] and be travelling at an angle of (20 ± 1)° to the line of the parapet.

D.6.1.3 For the test, the longitudinal centreline of the vehicle shall be aligned to within ±200 mm with the centroid of the intermediate post nearest to the point one-third along the length of the test parapet from the direction of approach of the vehicle. There shall be at least one rail joint vertically aligned in every rail in the panel adjacent to this post on the side from which the vehicle is approaching.

D.6.2 ***Low level of containment parapet***

D.6.2.1 One test shall be carried out on each parapet design.

D.6.2.2 The test vehicle shall, at impact, have a velocity of (80 ± 4) km/h [(50 ± 2.5) mile/h] and be travelling at an angle of (20 ± 1)° to the line of the parapet.

D.6.2.3 For the test, the longitudinal centreline of the vehicle shall be aligned to within ±200 mm with the mid-point between intermediate posts on the traffic face of the panel nearest to the point one-third along the length of the parapet from the direction of approach of the vehicle. There shall be at least one rail joint vertically aligned in every rail in this panel.

D.6.3 ***High level of containment parapet***

D.6.3.1 One test shall be carried out on each parapet design.

D.6.3.2 The vehicle shall, at impact, have a velocity of 64^{+3}_{0} km/h (40^{+2}_{0} mile/h) and be travelling at an angle of (20 ± 1)° to the line of the parapet.

D.6.3.3 For the test, the centreline of the near side wheel track shall be within ±300 mm of the vertical centreline of a post. The impact post shall be that nearest to the point one-third along the length of the parapet from the direction of approach of the vehicle. There shall be a vertically aligned rail joint in each rail in the impact panel.

D.7 Test parameters for other types of parapet

The number of tests, vehicle velocity and angle of impact shall be as specified in **D.6**. The position of impact shall be chosen to demonstrate the overall behaviour of the parapet.

D.8 Recording of test data

D.8.1 The test data to be measured and recorded shall include the following:

a) vehicle speed at impact;

b) vehicle approach angle;

c) vehicle path after impact;

d) maximum penetration of the vehicle during impact;

e) mean lateral deceleration into the parapet, from impact to maximum deflection, by recording lateral movement of the centre of gravity of the test vehicle;

f) mean longitudinal deceleration during vehicle contact with the parapet;

g) description of damage to the test vehicle;

h) description of damage to the test parapet;

i) maximum wheel penetration;

j) description of damage to the attachment system and anchorage;

k) maximum deformation of the parapet during impact;

l) for high containment tests only, any loss, spillage or movement of load, in particular, to confirm the requirements of **10.1.4.6**;

m) ASI, THIV and PHD (to be recorded for information only);

n) Average force imparted by the test vehicle to the parapet (to be recorded for information only).

Following the test, material samples adjacent to the impact zone shall be taken for testing. The results of these tests shall be included in the report and shall include:

1) 0.2 % proof stress;

2) average tensile strength;

3) average percentage elongation and associated method of measurement;

4) average section thickness at recorded positions.

D.8.2 The methods of obtaining the data listed in **D.8.1** shall include:

a) for items a) to d) inclusive, i) and k), cine-cameras operating at 200 frames per second, deployed in such a way as to give a complete record of the vehicle response and parapet behaviour (see Figure D.1);

b) additionally, for item a), an electronic timing system for recording the vehicle speed just prior to impact;

c) for items e) and f), transducers located as near as possible to the vehicle centre of gravity capable of measuring decelerations in the three major axes;

d) for items g), h), j) and l), still photographs and written descriptions detailing the damage and spillage;

e) for item i), in addition to the cameras, site measurement of the marks on the plinth;

f) for item m), vehicle instrumentation (transducers).

D.8.3 Diagrams setting out the path of the test vehicle and providing a summary of the damage to the vehicle and the parapet shall be produced and form part of the records of the tests.

NOTE A typical example is shown in Figure D.2.

D.8.4 The test data, cine-films, photographs, written descriptions, diagrams and analysis shall form part of the records of the tests.

NOTE 1 The following instrumentation facilities have been found to give satisfactory results for low and normal containment parapets.

a) One panned camera at normal speed sited at right angles to the path of the vehicle.

b) One fixed high-speed cine-camera similarly sited to the camera in item a).

c) Two overhead high-speed cine-cameras mounted approximately 12 m above the surface to record the change in direction and speed. These cameras, in conjunction with the grid of 1 m squares painted on the surface, enable the longitudinal and lateral decelerations to be plotted.

d) One high-speed cine-camera looking along the barrier from a point behind impact in order to record the vehicle roll, penetration and sequence of action as the parapet is struck. Information on the parallax for the overhead cameras is also derived from this position.

e) One high-speed cine-camera looking along the barrier from the opposite end to the camera in d).

NOTE 2 Extra cameras may be deployed to provide additional information.

f) An independent electro-mechanical device for recording the speed of the vehicle should be used at a point not further than 10 m from the impact position, measured along the direction of the vehicle approach, for providing comparison with the values obtained from the cameras.

g) Still cameras to provide photographs of the parapet and vehicle before and after the test.

h) Facilities to enable accurate analysis of the cine-films to be made.

NOTE 3 See figure D.1 for a diagram of typical layout of cameras for a test.

D.9 Test report

A written appraisal including the data in Figure D.2 shall be made of the results of each test, based upon the assessment criteria, together with conclusions upon the performance of the parapet in relation to the acceptance criteria.

D.10 Record of dynamic testing

A full record shall be made and preserved of each test, containing the details specified in **D.2.3**, **D.3.4**, **D.4.4**, **D.5.4**, **D.8.1**, **D.8.4** and **D.9**.

Annex E (normative) Static testing of posts

E.1 Test facility

A suitable form and general dimensions for a typical test rig for the static testing of parapet posts is shown in Figure E.1. The following requirements shall apply.

a) The stiffness of the rig shall be such that the horizontal deflection at the reaction plate shall be not greater than 10 % of the elastic deflection at the loading point of the post under test.

b) The test rig shall be capable of applying up to 1.75 times the theoretical moment of resistance, R^*, of the post at the critical section, i.e. $1.75R^*$.

c) The load shall be applied by hydraulic jack (see Figure E.1) in such a way as not to induce eccentricity of loading or local failure at the point of application.

d) The loading applied shall be measured by a sealed unit consisting of a load cell with a digital display. The load cell shall be calibrated to an accuracy of ±0.5 kN at intervals not exceeding 12 months by a test house accredited by the United Kingdom Accreditation Service (UKAS).

e) The dimensions in Figure E.1 from the plane of the base to the loading axis are typical only and may be adjusted to suit the available test rig. The loading axis height should however be such that the post fails primarily in bending (see **E.3**).

f) A suitable method of measuring the deflection of the post relative to the perpendicular from the plane of the base at the loading point and in the direction of application of the load, unaffected by any deflection of the rig, to an accuracy of 0.5 mm, shall be provided.

E.2 Load test procedures

E.2.1 Secure the post to the rig base by bolts, nuts and washers of the same strength and dimension as are to be used on site.

NOTE Plastics washers or sleeves need not be used.

E.2.2 Zero the load cell read-out just prior to loading.

E.2.3 Apply the load to produce a consistent average rate of deflection until the post has failed or the load has passed its maximum and fallen by 20 % of that value.

E.2.4 Record the full load deflection history at increments of deflection not exceeding 2 mm.

E.2.5 Note the following details:

a) the specific identification of the post;

b) the maximum load;

c) the deflection at maximum load;

d) any signs of fracture, and load at which fracture initiates;

e) the mode of failure.

E.3 Mode of failure

For steel parapet systems, failure of the post shall be by local buckling of its compression flange. There shall be no fracture of the post and no failure of the post to base plate weld.

E.4 Destructive examination

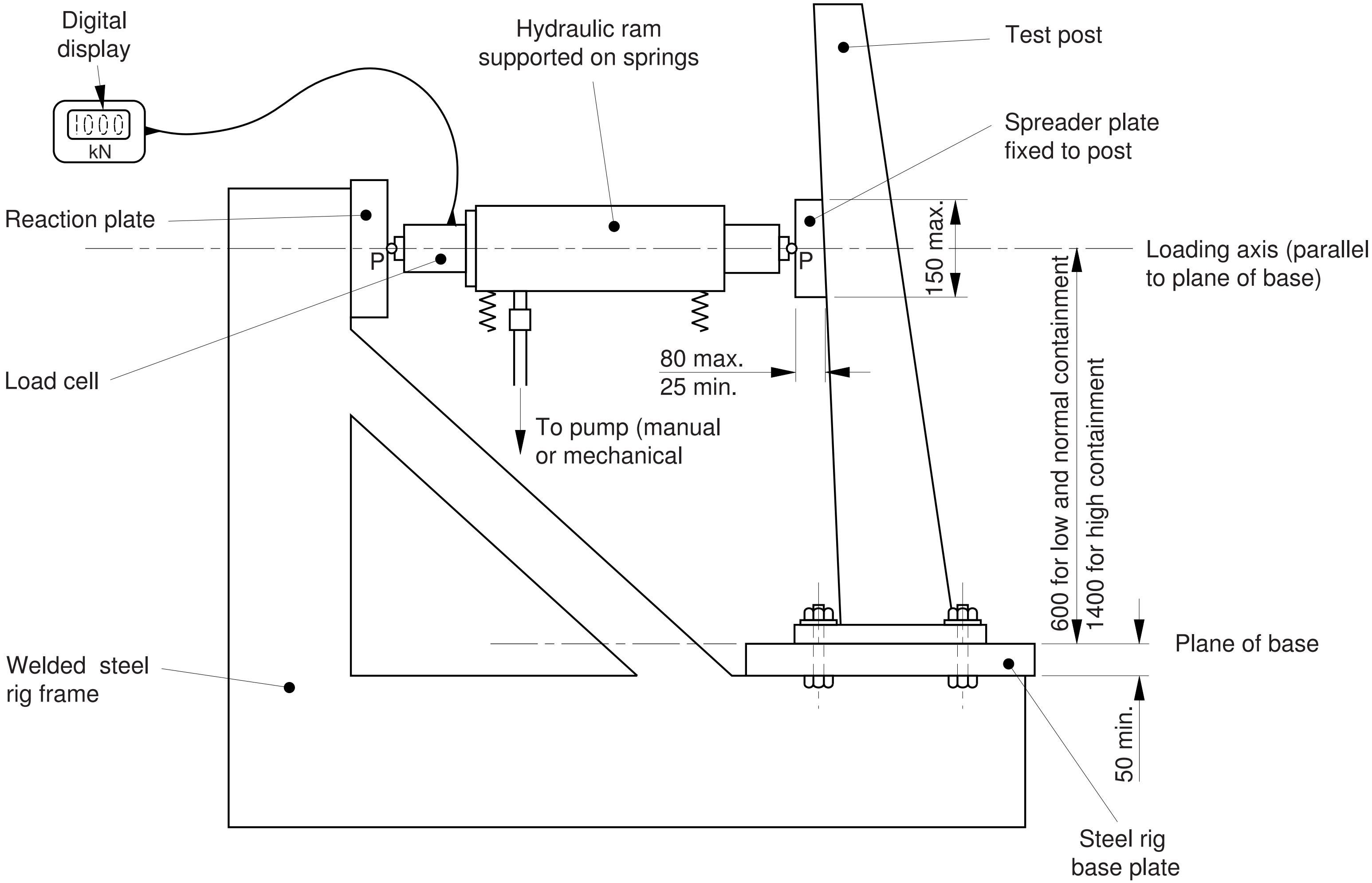
After completion of the test, the post shall be cut up by sawing, at the direction of the representative of the purchaser, to determine weld sizes (leg length and/or throat thickness) at up to four points in the critical section. Sectioned welds shall be smoothed by file and emery sufficiently to enable the weld size to be determined.

If defects such as porosity, lack of fusion or other discontinuities are found in the section of the weld, rendering the above measurement ineffective, the supplier shall be required to isolate, by further sawing, a length not greater than 50 mm of the weld and to break this open about the longitudinal axis of the weld. The effective throat thickness shall then be determined by dividing the net area of weld by the length of weld.

E.5 Recording of test results

The supplier or manufacturer shall keep a post test register in which he shall record the results of the load test, destructive examination and non-destructive inspection of all posts selected for testing. These shall be certified by the purchaser's representative who shall be supplied with a copy of the relevant information.

All dimensions are in millimetres.



The diagram is based on apparatus for normal containment tests and may need adapting to be suitable for high containment tests. There may also be other systems whereby the test load can be applied to the post.

Pivot point P is made of 12 mm minimum diameter hardened steel balls permitting rotation about all axes.

NOTE Drawing is not to scale.

Figure E.1 — Typical apparatus for static testing of parapet posts

Annex F *Annex deleted*

List of references (see Clause 2)

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[2)] Available by post from Department of Transport, Publications Sales Unit, Room 1, Spur 2, Block 3, Government Buildings, Lime Grove, Eastcote, Middlesex, HA4 8SE.

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