

Highway parapets for bridges and other structures —

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

ICS 93.040

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee B/509, Road equipment, to Subcommittee B/509/13, Bridge parapets, upon which the following bodies were represented:

- Aluminium Federation
- Association of Consulting Engineers
- British Railways Board
- British Steel Industry
- County Surveyors' Society
- Department of Transport (Transport Research Laboratory)
- Institution of Civil Engineers
- Institution of Highways and Transportation

This British Standard, having been prepared under the direction of the Technical Committee B/509, was published under the authority of the Standards Board and comes into effect on 15 May 1994

© BSI 03-1999

The following BSI references relate to the work on this standard:
Committee reference B/509/13
Draft for comment 92/13171 DC

ISBN 0 580 67164 7

Amendments issued since publication

Amd. No.	Date	Comments
Corr. 1	30 April 2009	12.2.1 Correction of spelling of "parapet"

Contents

	Page
Committees responsible	Inside front cover
Foreword	iii
Introduction	1
Section 1. General	
1 Scope	1
2 References	2
3 Definitions	2
4 Symbols	3
5 Designation of combined metal and concrete parapets	3
Section 2. Design	
6 Levels of containment	4
7 Vehicle impact loading	4
8 Wind loading	8
9 Parapet heights	8
10 Front face, profile, freedom from projections and joint treatment	9
11 Durability	11
12 Design method	12
13 Prevention of composite action between the parapet and main structure	17
14 Ends of parapets and movement joints	17
15 Protection at ends of parapets	19
Section 3. Concrete construction	
16 Materials and workmanship	21
17 Surface finish	21
Section 4. Metal construction	
18 Materials	22
19 Workmanship, inspection and testing	24
20 Tolerances in metal construction	28
21 Fastenings	28
22 Storage and transportation, handling and stacking	28
23 Packing and transportation	28
24 Installation and site workmanship	28
25 Identification marking of parapets	29
Section 5. Additional design requirements for parapets for particular applications	
26 General requirements for infilling and additional members	30
27 Requirements for particular types of infilling	30
28 Applications not over or adjacent to railways	31
29 Applications over or adjacent to railways	31
Annex A (informative) Information to be provided by the supplier/purchaser	32
Annex B (informative) Parapet post and rail systems exempted from design requirements	33
Figure 1 — Dimensional parameters for combined metal and concrete parapets	10
Figure 2 — Alternative joint details in concrete panel	11
Figure 3 — Diagrammatic arrangement of a possible precast reinforced concrete panel installation	16

	Page
Figure 4 — Shear transfer arrangement used in the tested high containment parapet	18
Table 1 — Designation of combined vehicle parapets	3
Table 2 — Nominal loads for parapets	5
Table 3 — Nominal loads for attachment systems and anchorages	6
Table 4 — Minimum thickness of members, infill panels and other components	13
Table 5 — Values of γ_{fL} : ultimate limit state	13
Table 6 — Values of f_k and γ_m	14
Table 7 — Materials of construction for steel parapets	23
Table 8 — Materials of construction for aluminium alloys parapets	25
Table 9 — Minimum requirements for construction of parapets over or adjacent to railways	31
List of references	35

Foreword

This Part of BS 6779 is one of a series prepared under the direction of Technical Committee B/509 “Road equipment”. The other Parts already published in the series are:

- *Part 1: Specification for vehicle containment parapets of metal construction;*
- *Part 2: Specification for vehicle containment parapets of concrete construction;*

The other Part so far planned in the series is:

- *Part 4: Specification for vehicle containment parapets of composite masonry and concrete construction;*

Parapets are multi-purpose in that they have to serve the safety of errant vehicles and their occupants, pedestrians and other road users, and may be used to guard against possible initiation of a major incident in areas adjoining highways such as high-speed rail lines.

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 of advantage and safety then has to be made.

The range of vehicles using the roads is vast and constantly developing as changes take place in design, axle loadings and other characteristics, and errant vehicles will produce impacts of differing severity over a range of angles, speeds and disposition of loaded weight. Open frame parapets may be required to have mesh, bar or solid infill for additional safety and protection of pedestrians, animals and rail users, hence the range of variables and their combinations is virtually infinite.

Thus, specifying desirable characteristics for parapets, deciding upon levels of containment to be achieved, and specifying designs and/or tests to produce parapets which perform accordingly is fraught with difficulty. There are inevitably areas of imprecision: for example, for practical reasons ordinary production vehicles have to be used in testing parapets, and while these will conform to the specified parameters, they all may not have precisely the same effect upon a particular parapet.

A programme of full scale dynamic testing of prototype parapets was carried out for Part 1 of BS 6779 and is continuing for subsequent Parts of the standard. The results from these tests have been used to supplement and extend what was considered to be the best of current practice. Unfortunately such tests are costly and resource consuming and the range is necessarily limited. Some references will be found in the text of the various Parts to such problems and to the inclusion of established parapet designs. Appendix A of BS 6779-1:1992 in particular provides some background to the consideration of impact from errant vehicles.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 36, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

Introduction

This Part of BS 6779 specifies requirements for the design and construction of parapets of combined metal and concrete construction, intended to provide specific levels of vehicle containment on highways. The parapets are for use on bridges, retaining walls or other structures.

The design requirements specified for normal containment parapets are based upon the results of tests on parapets having precast concrete panel lengths of 3.0 m. Although these tests were carried out some time ago the testing regime and criteria for successful performance were similar to those currently specified in BS 6779-1:1992 if somewhat less well defined. It is considered reasonable to extrapolate to include panel lengths from 2.6 m to 3.1 m for parapets conforming to the dimensional requirements of Figure 1.

The design requirements specified for high containment are based upon the results of more recent tests on parapets having precast concrete panel lengths of 2.1 m. It is considered reasonable to extrapolate to include panel lengths from 1.8 m to 2.4 m for parapets conforming to the dimensional requirements of Figure 1.

As combined metal and concrete parapets are comparatively rigid structures the dynamic response is more predictable than for metal parapets covered in Part 1. Therefore, within the above ranges of panel lengths and outline configurations it is possible to give theoretical design criteria to produce satisfactory designs.

For parapets outside these ranges of panel lengths or having dimensions that do not conform to Figure 1, to be deemed to conform to this specification, designs may be produced making such extrapolations or modifications from those set out herein as are considered reasonable but any such design needs to be validated by full scale dynamic testing to the requirements of Appendix E of BS 6779-1:1992. The performance criteria to be met for such a test are to be those required in **26.2** of BS 6779-1:1992, for normal containment and **26.4** for high containment, with the addition of “or concrete” after “metal” in the **26.2.3** and **26.4.3**.

The design of parapets having free-standing panels and of parapets with panels having adequate shear transfer arrangements are covered.

Containment levels are related to defined vehicle impacts and a “normal level of containment” and a “high level of containment” are specified. A low level of containment, used in Part 1 of this series for the design of metal parapets in certain circumstances, is not considered appropriate to combined construction. Appendix A to BS 6779-1:1992 outlines the derivation of design forces in relation to containment levels. Under all but the most exceptional cases the normal level of containment specified in BS 6779 is considered to offer the best overall compromise between the safety of impacting vehicles and their occupants, the safety of other vehicles on the highway and their occupants and the prevention of penetration by the impacting vehicle into adjoining areas.

The main objectives of the forms of parapet defined in this Part 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 errant vehicles with minimum deceleration forces on to a path as close as possible to the line of the parapet and to reduce the risk to the vehicle both of overturning and of overtopping the parapet.

Prototype, high level containment combined parapets using both aluminium and steel have been successfully tested and details are given in Annex B.

1 Scope

This Part of BS 6779 specifies requirements for the design and construction of combined concrete and metal parapets to provide specified levels of containment for vehicles on highways. Normal containment parapets have concrete panel heights of 0.4 m to 0.8 m with one, two or three effective longitudinal metal members. High containment parapets have a panel height of 0.9 m and a single metal, effective, longitudinal member. The metal members are carried on metal posts attached to the concrete panels which may be in situ or precast, with or without shear transfer. Prestressed concrete and parapets designed to act compositely with the main structure are not covered in this Part of BS 6779.

2 References

2.1 Normative references

This Part of BS 6779 incorporates, by reference, provisions from specific editions of other publications. These normative references are cited at the appropriate points in the text and the publications are listed on page 35. Subsequent amendments to, or revisions of, any of these publications apply to this Part of BS 6779 only when incorporated in it by updating or revision.

2.2 Informative references

The Part of BS 6779 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

an installation to provide a level of containment for errant vehicles 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 combined parapet

a parapet having one, two or three metal effective longitudinal members, carried on metal posts, mounted on concrete panels of not less than 0.4 m height

3.4 safety fence

an installation provided for the protection of users of the highway consisting of horizontal beams or wire ropes mounted on posts

3.5 safety barrier

an installation provided for the protection of users of the highway that is continuously in contact with its supporting foundation

3.6 transition system

an arrangement for connecting dissimilar and/or different capacity vehicle restraint systems

3.7 front face

the face nearest to the traffic

3.8 outer face

the opposite face to the front face

3.9 traffic face of a combined parapet

the front face of the concrete base and a continuation vertically from the top of this, tangential to the front face of the rail(s)

3.10 main structure

any part of the bridge, retaining wall or other structure on which the parapet is mounted

3.11 adjoining paved surface

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

3.12 datum for height considerations

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

NOTE This will normally be the adjoining paved surface.

3.13 anchorage

that part contained within the main structure to which a precast parapet is directly fixed by means of the attachment system; for example, a cast-in anchorage cradle in a reinforced concrete deck beam

3.14 attachment system

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

3.15 shear transfer arrangement

an arrangement for transferring horizontal shear between adjacent panels across the vertical joint

3.16 infilling panel

a non-structural panel used to cover the spaces between rails and between the bottom rail and the panel or plinth on the front face of a parapet to safeguard pedestrians or meet other requirements

3.17**effective longitudinal member**

those longitudinal metal rails of a parapet which are intended and designed to become effective in restraining a vehicle in an impact

3.18**non-effective longitudinal member**

an additional longitudinal member above the effective longitudinal members provided to give additional height to the parapet for the protection of pedestrians or animals or to support noise or other environmental barriers

3.19**panel**

the section of the precast or in situ concrete part of a combined parapet between vertical joints

3.20**panel wall**

the vertical or near vertical wall of a panel

3.21**panel base**

the part of a panel below the panel wall (usually only present in precast parapets)

4 Symbols

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

d	Effective depth to tension reinforcement
D	Nominal bolt diameter (mm)
f_k	Characteristic (or nominal) strength of the material
h	Vertical distance from top of parapet to the applied impact (m)
H	Vertical distance from top of parapet to the horizontal section where bending moment is considered (m)
L	Length of parapet panel (m)
L_d	Distance from centre of reinforcement area to the extreme compression fibre
Q^*	Design loads
Q_k	Nominal loads
R^*	Design resistance
S^*	Design load effects
γ_{FL}	Partial load factor
γ_{f3}	Partial factor for load effects

γ_m Partial factor on material strength

σ_{vb} Minimum ultimate tensile strength of bolt material (N/mm²)

σ_{ya} Minimum yield strength of anchorage material (N/mm²)

n Number of effective longitudinal members

Table 1 — Designation of combined vehicle parapets

Item	Designation	Clause reference number
a)	Levels of containment N = Normal H = High	6
b)	Height above datum 1.00 = 1 m height 1.25 = 1.25 m height 1.50 = 1.50 m height, etc.	9
c)	Type Without shear transfer between the concrete panels F = In situ concrete and metal f = Precast concrete and metal With shear transfer between the concrete panels T = In situ concrete and metal t = Precast concrete and metal	12.3.8

NOTE 1 Examples of designation:
N/1.00/F indicates an in situ panel, combined parapet of 1 m height above the datum of normal level of containment, with no shear transfer arrangement.
H/1.50/t indicates a precast panel, combined parapet of 1.50 m height above the datum of high level of containment, with shear transfer arrangement.

NOTE 2 Infill items are to be described separately in addition.

5 Designation of combined metal and concrete 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 above the datum;
- c) type of parapet.

Designation details are set out in Table 1.

Section 2. Design

6 Levels of containment

6.1 Normal level of containment

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

Vehicle type	Saloon car
Mass	1 500 kg
Height of centre of gravity	530 mm
Angle of impact	20°
Speed	113 km/h (70 mile/h)

NOTE 1 The normal level of containment is that suitable for general use.

NOTE 2 The choice of car is open but the Department of Transport choose a particular model for their tests only changing when necessary.

6.2 High level of containment

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

Vehicle type	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 1 The high level of containment is for use only in situations where penetration presents the probability of extreme high risk.

NOTE 2 Tankers are used by the Department of Transport for their tests.

7 Vehicle impact loading

NOTE The results of a series of impact tests carried out on combined parapets have been analysed to produce the equivalent static loads and design methods set out in clause 7 and 12.

7.1 General

The parapet shall be designed to resist loading appropriate to the designated level of containment with or without shear transfer provision using the equivalent static nominal loadings given in 7.2 and 7.3 which are applicable to panel lengths (L) 2.6 m to 3.1 m and 1.8 m to 2.4 m respectively.

The nominal loadings given in 7.2 and 7.3 are summarized in Table 2 and Table 3.

Q_k is the nominal value given in Table 2;

n is the number of effective longitudinal members including the concrete panel in the parapet (not exceeding 4 for normal containment and 2 for high containment);

For normal containment, the minimum height to the top of the concrete panel shall be 400 mm. Panels are counted as:

- 400 mm height up to and including 600 mm, $n = 1$;
- over 600 mm and up to and including 800 mm (maximum), $n = 2$.

For high containment the height is taken as 900 mm only, $n = 1$.

7.2 Normal containment: no shear provision between panels

NOTE Shear transfer provision between panels of normal containment parapets is not recommended because of the problem of joint formation in the thinner section.

7.2.1 Metal posts, rails and their interconnection

7.2.1.1 Posts, post to base plate connection and base plate

An individual horizontal nominal load of Q_k/n kN is applied transversely to the post, acting at the level of the centroid of each effective rail section.

An individual horizontal nominal load of $Q_k/8n$ kN is applied longitudinally to the post, acting at the level of the centroid of each effective rail section.

Concurrently, a horizontal nominal load of $(0.9 \times Q_k/n)$ kN is applied transversely and a horizontal nominal load of $(0.9 \times Q_k/8n)$ kN is applied longitudinally to the post, both acting at the level of the centroid of each effective rail section.

7.2.1.2 Rail

An individual horizontal nominal load of Q_k/n kN is applied transversely as a point load at mid-point between the centres of support, acting at the level of the centroid of each effective rail section.

An individual vertical load of $Q_k/2n$ kN is applied as a point load at mid-point between the centres of support, acting through the centroid of each effective rail section.

Concurrently, a horizontal nominal load of $(0.75 \times Q_k/n)$ kN applied transversely and a vertical nominal load of $(0.75 \times Q_k/2n)$ kN is applied as a point load at mid-point between the centres of support, both acting at the level of the centroid of each effective rail section.

NOTE The point load is nominal and rails do not require reinforcement against local damage.

Table 2 — Nominal loads for parapets

Level of containment	Nominal load Q_k	Post, post to base plate connection, base plate				Rail				Post to rail connection				Concrete panels			
		Loads considered individually		Loads considered concurrently		Loads considered individually		Loads considered concurrently		Horizontal transverse nominal load kN	Vertical nominal load kN	Horizontal longitudinal nominal load kN		Horizontal transverse nominal loads applied concurrently kN		Nominal shear in panel kN/panel	Nominal shear transfer across joint kN
		Horizontal transverse nominal load from each effective metal longitudinal member kN (see 7.1)	Horizontal longitudinal nominal load from each effective metal longitudinal member kN (see 7.1)	Horizontal transverse nominal load from each effective metal longitudinal member kN (see 7.1)	Horizontal longitudinal nominal load from each effective metal longitudinal member kN (see 7.1)	Horizontal transverse nominal load kN	Vertical nominal load kN	Horizontal transverse nominal load kN	Vertical nominal load kN			Intermediate posts	End posts (end bay)	Top of panel	Centroid of each effective longitudinal member (see 7.1)		
Normal	50	$\frac{Q_k}{n}$	$\frac{Q_k}{8n}$	$\frac{0.9 Q_k}{n}$	$\frac{0.9 Q_k}{8n}$	$\frac{Q_k}{n}$	$\frac{Q_k}{2n}$	$\frac{0.75 Q_k}{n}$	$\frac{0.75 Q_k}{2n}$	$\frac{Q_k}{n}$	$\frac{Q_k}{2n}$	$\frac{Q_k}{2n}$	$\frac{Q_k}{n}$	$\frac{Q_k}{n}$	$\frac{Q_k}{n}$	50	—
High with shear transfer	320	$\frac{Q_k}{n}$	$\frac{Q_k}{8n}$	$\frac{0.9 Q_k}{n}$	$\frac{0.9 Q_k}{8n}$	$\frac{Q_k}{n}$	$\frac{Q_k}{2n}$	$\frac{0.75 Q_k}{n}$	$\frac{0.75 Q_k}{2n}$	$\frac{Q_k}{n}$	$\frac{Q_k}{2n}$	$\frac{Q_k}{4n}$	$\frac{Q_k}{2n}$	$\frac{Q_k}{n}$	$\frac{Q_k}{n}$	380	70
High without shear transfer														$\frac{1.4 Q_k}{n}$	$\frac{Q_k}{n}$	440	—

NOTE For n see 7.1.

Table 3 — Nominal loads for attachment systems and anchorages

Level of containment	Attachment systems and anchorages for connection of metal posts to concrete panels			Attachment systems and anchorages for connection of precast concrete units to supporting structure				
	Horizontal transverse nominal load from each effective metal longitudinal member kN	Horizontal longitudinal nominal load from each effective metal longitudinal member kN	Vertical nominal load from each effective metal longitudinal member kN	Parapet collapse load kN	Horizontal longitudinal nominal load applied at		Vertical downward nominal load applied at	
					Centroid of post kN	Top of front face of concrete panel kN	Centroid of post kN	Top of front face of concrete panel kN
Normal	$\frac{Q_k}{n}$	$\frac{Q_k}{8n}$	$\frac{Q_k}{2n}$	As specified in 12.2.2	—	—	—	—
High with shear transfer	$\frac{Q_k}{n}$	$\frac{Q_k}{8n}$	$\frac{Q_k}{2n}$	As specified in 12.2.2	25	75	75	75
High without shear transfer								

NOTE For n see 7.1

7.2.1.3 Post to rail connections

Connections shall be designed to resist the following nominal loads acting individually.

a) A horizontal load acting at right angles to the traffic face, towards the post centreline, through the centroid of the effective rail section of value

$$\frac{Q_k}{n} \text{ kN.}$$

b) A vertical load, applied either upwards or downwards, acting through the centroid of the effective rail section of value $\frac{Q_k}{2n}$ kN.

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

- 1) for intermediate posts, $Q_k/2n$ kN;
- 2) for special end posts, Q_k/n kN;

NOTE 1 The strength of post to rail connections has not previously been specified and there is wide variation in the strengths of connections used in successful parapet designs. It is considered, however, that the minimum criteria suggested above will help to improve overall performance.

NOTE 2 Where the strength of a connection is not amenable to verification by analysis it may be justified by test.

7.2.2 Concrete panels

7.2.2.1 Nominal bending moment in panels where $n = 1$ (i.e. other than those for normal containment exceeding 600 mm in height)

NOTE The panel acts as an effective longitudinal member and carries the loads from the post.

The bending moment to be resisted shall be that produced by applying the following combined nominal loads acting concurrently:

a) a horizontal, continuous, uniformly distributed load of $\frac{Q_k}{n}$ kN/panel applied transversely to the top of the front face of the panel;

b) a horizontal load of $\frac{Q_k}{n}$ applied transversely, acting at the level of the centroid of each effective metal rail section applied at the centreline of the post.

7.2.2.2 Nominal bending moment in panels where $n = 2$ (i.e. for normal containment exceeding 600 mm in height)

NOTE The panel acts as an effective longitudinal member and carries the loads from the post.

The bending moment to be resisted shall be that produced by applying the following combined nominal loads acting concurrently:

a) a horizontal, continuous, uniformly distributed load of $\frac{2Q_k}{n}$ kN/panel applied transversely to the top of the front face of the panel;

b) a horizontal load of $\frac{Q_k}{n}$ applied transversely, acting at the level of the centroid of each effective metal rail section applied at the centreline of the post.

7.2.2.3 Nominal shear in panel

The nominal shear force to be resisted by any transverse horizontal section of a panel shall be 50 kN/panel.

7.2.3 Attachment systems and anchorages for connection of metal posts to concrete panels

Attachment systems and anchorages for connection of metal posts to concrete panels shall be designed to resist:

- a horizontal load acting at right angles to the traffic face, towards the post centreline, through the centroid of each effective rail section of value Q_k/n kN;
- a vertical load, applied either upwards or downwards, acting through the centroid of each effective rail section at midway between centres of support of value $Q_k/2n$ kN;
- a load acting parallel to each effective rail at its centroid of section of value $Q_k/8n$ kN;
- the most severe combination of the above individual nominal loads multiplied by a factor of 0.65.

7.2.4 Attachment systems and anchorages for connection of precast concrete units to bridge decks

Attachment systems and anchorages shall be designed to resist the loadings given in 12.2.2.

7.3 High containment: applicable to both no shear provision and with shear provision between panels

7.3.1 Metal components (except anchorages and attachment systems for precast units to deck connections)

7.3.1.1 Posts, post to base plate connection and base plate

An individual horizontal nominal load of Q_k/n kN is applied transversely to the post, acting at the level of the centroid of each effective rail section.

An individual horizontal nominal load of $Q_k/8n$ kN is applied longitudinally to the post, acting at the level of the centroid of each effective rail section.

Concurrently, a horizontal nominal load of $(0.9 \times Q_k/n)$ kN is applied transversely and a horizontal nominal load of $(0.9 \times Q_k/8n)$ kN is applied longitudinally to the post, both acting at the level of the centroid of each effective rail section.

7.3.1.2 Rail

An individual horizontal nominal load of Q_k/n kN is applied transversely as a point load at mid-point between the centres of support, acting at the level of the centroid of each effective rail section.

An individual horizontal vertical load of $Q_k/2n$ kN is applied as a point load at mid-point between the centres of support, acting through the centroid of each effective rail section.

Concurrently, a horizontal nominal load of $(0.75 \times Q_k/n)$ kN applied transversely and a vertical nominal load of $(0.75 \times Q_k/2n)$ kN is applied as a point load at mid-point between the centres of support, both acting at the level of the centroid of each effective rail section.

NOTE The point load is nominal and rails do not require reinforcement against local damage.

7.3.1.3 Post to rail connections

Connections shall be designed to resist the following individual nominal loads:

- a horizontal load acting at right angles to the traffic face, towards the post centreline, through the centroid of the rail section of value $\frac{Q_k}{n}$ kN;
- a vertical load, applied either upwards or downwards, acting through the centroid of the rail section of value $\frac{Q_k}{2n}$ kN;
- a load acting parallel to the rail at its centroid of section of value:

- 1) for intermediate posts, $\frac{Q_k}{4n}$ kN;
- 2) for special end posts, $\frac{Q_k}{2n}$ kN;

NOTE 1 The strength of post to rail connections has not previously been specified and there is wide variation in the strengths of connections used in successful parapet designs. It is considered, however, that the minimum criteria suggested above will help to improve overall performance.

NOTE 2 Where the strength of a connection is not amenable to verification by analysis it may be justified by static test.

7.3.2 Concrete panels (no shear provision between panels)

7.3.2.1 Nominal bending moment in panel

NOTE The panel acts as an effective longitudinal member and carries the loads from the post.

The bending moment to be resisted shall be that produced by applying the following combined nominal loads acting concurrently:

- a horizontal, continuous, uniformly distributed load of $1.4 \frac{Q_k}{n}$ kN/panel applied transversely to the top of the front face of the panel;

- b) a horizontal load of $\frac{Q_k}{n}$ applied transversely, acting at the level of the centroid of each effective metal rail section applied at the centreline of the post.

7.3.2.2 Nominal shear in panel

The nominal shear force to be resisted by any transverse horizontal section of a panel shall be 440 kN/panel.

7.3.3 Concrete panels (with shear provision between panels)

7.3.3.1 Nominal bending moment in panel

The bending moment to be resisted shall be that produced by applying the following combined nominal loads acting concurrently:

- a) a horizontal, continuous, uniformly distributed load of $\frac{Q_k}{n}$ kN/panel applied transversely to the top of the front face of the panel;
- b) a horizontal load of $\frac{Q_k}{n}$ kN applied transversely, acting at the level of the centroid of each effective metal rail section.

7.3.3.2 Nominal shear in panel

The nominal shear force to be resisted by any transverse section of a panel shall be 380 kN/panel.

7.3.3.3 Nominal shear transfer at panel joints

The minimum ultimate transverse shear resistance to be provided in the panel wall shall be 70 kN.

7.3.4 Attachment systems and anchorages for connection of metal posts to concrete panels

Attachment systems and anchorages for connection of metal posts to concrete panels shall be designed to resist:

- a) a horizontal load acting at right angles to the traffic face, towards the post centreline, through the centroid of each effective rail section of value Q_k/n kN;
- b) a vertical load, applied either upwards or downwards, acting through the centroid of each effective rail section at midway between centres of support of value $Q_k/2n$ kN;
- c) a load acting parallel to each effective rail at its centroid of section of value $Q_k/8n$ kN;
- d) the most severe combination of the above individual nominal loads multiplied by a factor of 0.65.

7.3.5 Attachment systems and anchorages for connection of precast concrete units to bridge decks

7.3.5.1 Attachment systems and anchorages shall be designed to resist the loadings given in 12.2.2.

7.3.5.2 In addition, the following nominal loads shall be considered in combination with the loadings from 7.3.5.1.

- a) A horizontal longitudinal load of 25 kN applied to the metal post and acting at the level of the centroid of each effective metal rail section.
- b) A horizontal longitudinal load of 75 kN applied at the top of the front face of the concrete panel and uniformly distributed over the panel length.
- c) A downward vertical load of 75 kN acting through the centroid of the metal post.
- d) A downward vertical load of 75 kN applied at the top of the front face of the concrete panel and uniformly distributed over the panel length.

7.4 Main structure

The loads due to vehicle collision with parapets, and which are considered locally in the design of the elements of the parapet supporting structure and globally on main structures including bridge superstructures, bearings and substructures shall be as specified in Department of Transport Standard BD 37/88 [1].

8 Wind loading

Wind loading shall be derived from BS 5400-2:1978. Wind loading and vehicle impact shall not be considered coexistent.

9 Parapet heights

The minimum height of combined parapets shall be measured above the datum for height considerations and for particular applications shall be as listed below:

- 1.00 m — for vehicle and vehicle pedestrian parapets except as otherwise specified below;
- 1.25 m — with agreement (see clause 29) for bridges carrying motorways over railways, or other situations where pedestrians are excluded;
- 1.50 m — for all other bridges over railways:
- for high containment applications;
 - for protection of animals.

NOTE If additional height is required only for the protection of animals this may be provided by the addition of a non-effective member. (See 28.2).