

Highway parapets for bridges and other structures —

Part 4: Specification for parapets of reinforced and unreinforced masonry construction

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

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Foreword

This part of BS 6779 has been prepared under the direction of Subcommittee B/509/1, Road restraint systems.

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

Annex A, Annex B, Annex C, Annex D, Annex F and Annex G are informative. Annex E is normative.

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

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 48, an inside back cover and a back cover.

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Introduction

Reinforced or unreinforced masonry parapets are often used for economic reasons or where a masonry finish is required on the exposed surfaces of parapets. Reinforced masonry parapets contain steel reinforcement which is adequately anchored into the supporting structure. Unreinforced masonry parapets are built directly onto the supporting structure without any special provision for anchorage.

As masonry parapets are of solid construction they provide effective pedestrian protection without modification, subject to satisfying the minimum height requirements specified in **6.3**.

The requirements in this standard, for both the reinforced and unreinforced masonry parapets, are based on the results of tests. The requirements for unreinforced masonry parapets are additionally based on mathematical modelling of vehicle impacts by computer which has been subsequently verified by full scale vehicle impact tests.

In the case of unreinforced masonry parapets, individual blocks or sections of the masonry may be dislodged and mobilized by a vehicle impact. The tests and computer modelling have shown that most of this masonry will be propelled away from the highway, but some can come to rest on the highway in the immediate vicinity of the parapet. An assessment of the possible injury or damage risk from mobilized masonry can be used to determine the acceptability of the use of an unreinforced masonry parapet at a particular site. A suitable method of risk assessment is described in Annex A.

Vehicle containment levels are related to defined vehicle impacts. Only normal and high containment levels are specified for reinforced masonry parapets. The low containment level described in part 1 of this standard, for the design of metal parapets in certain circumstances, is not considered appropriate for reinforced masonry constructions. For unreinforced masonry parapets only low and normal containment levels are specified since the use of unreinforced masonry at the high risk sites associated with high level containment is not appropriate due to the possibility of masonry becoming detached as a result of an impact. Advice is included for alternative levels of containment where the vehicle speed or angle of impact with the parapet may be restricted (see Annex B).

The main objectives of the types of parapet 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 either redirecting vehicles on to a path close to the line of the parapet, or arresting the vehicle motion with acceptable deceleration forces;
- c) to reduce the risk of errant vehicles overtopping the parapet or overturning.

It is possible in the case of both reinforced and unreinforced masonry parapets to give design criteria to produce satisfactory designs. In consequence full scale acceptance testing, as required for metal parapets in part 1 of this standard, is not necessary. The criteria for reinforced masonry parapets include equivalent static loads for the design of the parapet. In unreinforced masonry parapets a significant proportion of the kinetic energy of an impacting vehicle is absorbed by momentum transfer into the masonry, in addition to that absorbed by structural deformation. The criteria for unreinforced masonry parapets are, therefore, based on the materials of construction and dimensions of the parapets.

NOTE Composite action with the main structure can be minimized by the sub-division of parapets into panels.

1 Scope

This part of BS 6779 specifies requirements for the design and construction of a specific form of reinforced, and various forms of unreinforced, masonry parapets which are designed to provide specified levels of containment for vehicles on highways. This part of BS 6779 also specifies requirements for the assessment of existing unreinforced masonry parapets.

This part of BS 6779 is applicable to unreinforced masonry parapets of 10 m or greater in length or, if the parapet contains movement joints, with a minimum panel length between joints of 10 m and to reinforced masonry parapets with panels 2 m, or greater, in length.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 1449-2:1983, *Specification for stainless and heat-resisting steel plate, sheet and strip*.

BS 3921:1985, *Specification for clay bricks*.

BS 4449:1997, *Specification for carbon steel bars for the reinforcement of concrete*.

BS 5328-2:1997, *Concrete — Part 2: Methods for specifying concrete mixes*.

BS 5328-3:1990, *Concrete — Part 3: Specification for the procedures to be used in producing and transporting concrete*.

BS 5328-4:1990, *Concrete — Part 4: Specification for the procedures to be used in sampling, testing and assessing compliance of concrete*.

BS 5390:1976, *Code of practice for stone masonry*.

BS 5400-2:1978, *Steel, concrete and composite bridges — Part 2: Specification for loads*.

BS 5400-3:1982, *Steel, concrete and composite bridges — Part 3: Code of practice for design of steel bridges*.

BS 5400-4:1990, *Steel, concrete and composite bridges — Part 4: Code of practice for design of concrete bridges*.

BS 5628-1:1992, *Code of practice for use of masonry — Part 1: Structural use of unreinforced masonry*.

BS 5628-2:1995, *Code of practice for use of masonry — Part 2: Structural use of reinforced and prestressed masonry*.

BS 5628-3:1985, *Code of practice for use of masonry — Part 3: Materials and components, design and workmanship*.

BS 6073-1:1981, *Precast concrete masonry units — Part 1: Specification for precast concrete masonry units*.

BS 6073-2:1981, *Precast concrete masonry units — Part 2: Method for specifying precast concrete masonry units*.

BS 6457:1984, *Specification for reconstructed stone masonry units*.

BS 6744:1986, *Specification for austenitic stainless steel bars for the reinforcement of concrete*.

BS 6779-1:1998, *Highway parapets for bridges and other structures — Part 1: Specification for vehicle containment parapets of metal construction*.

BS 8000-3:1989, *Workmanship on building sites — Part 3: Code of practice for masonry*.

BS EN 10088-1:1995, *Stainless steels — Part 1: List of stainless steels*.

BS EN ISO 3506-1:1998, *Mechanical properties of corrosion resistant stainless steel fasteners — Part 1: Bolts, screws and studs*.

BS EN ISO 3506-2:1998, *Mechanical properties of corrosion resistant stainless steel fasteners — Part 2: Nuts*.

3 Terms and definitions

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

3.1

vehicle restraint system

installation to provide a level of containment for errant vehicles to limit damage or injury to users of the highway

3.2

highway parapet

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

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

3.4

front face

face nearest to the traffic

3.5

outer face

face furthest from traffic

3.6

supporting structure

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

3.7

adjoining paved surface

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

3.8

datum for height considerations

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.

3.9

datum for design considerations

transverse plane through the parapet, or at the intersection with the main structure, which is critical for design purposes

3.10

top of parapet

top of coping for determining parapet height with respect to the datum for height considerations or top of front face of parapet for determining height for impact considerations

3.11

anchorage

arrangement within the supporting structure to which the parapet is directly fixed by means of the attachment system

NOTE Examples of these are drilled-in or cast-in sockets for bolt attachments or cast in anchorage cradles etc.

3.12

attachment system

system of attachment of the parapet to the anchorage or the continuation of reinforcement from within the core of a reinforced masonry parapet into the supporting structure

3.13

non-effective longitudinal member

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

3.14

masonry

assemblage of structural units which are bonded together with mortar so as to act compositely

3.15

reinforced masonry highway parapet

masonry parapet consisting of two parallel single leaf masonry walls, effectively tied together, either side of a cavity containing steel reinforcement which attaches the parapet to an integral base or continues as attachment to the main structure

NOTE The cavity is infilled with concrete so as to result in composite action with the masonry under load.

3.16

unreinforced masonry highway parapet

parapet constructed of masonry structural units bonded together with mortar with no reinforcement incorporated into the construction other than bed joint reinforcement

NOTE 1 Bed joint reinforcement may be incorporated to control cracking arising from longitudinal thermal or shrinkage movement.

NOTE 2 Specific types of unreinforced masonry parapets are defined in 3.17, 3.18, 3.19 and 3.20.

3.17

brick masonry highway parapet

parapet consisting of brick units with mortared joints

3.18

ashlar stone masonry highway parapet

stone parapet of finely dressed stone blocks, laid in courses with mortared joints

NOTE 1 The stone blocks are solid between the faces of the parapet, i.e. there is no mortared core.

NOTE 2 The facing may be plain or tooled.

3.19

coursed/uncoursed rubble stone masonry highway parapet

parapet consisting of multi-sized natural stone blocks of random rubble, squared rubble or miscellaneous rubble as defined in BS 5390 which have been coursed, brought to courses or are uncoursed and which have thick mortared joints

NOTE The parapet shall have a well filled mortared core and may have through stones passing through the core.

3.20

drystone highway parapet

parapet without mortar consisting of multi-sized natural stone blocks, which may be coursed or uncoursed, with or without through stones (stones extending through to both faces)

NOTE Drystone construction is not included in the definition of masonry (see 3.14) but it is nevertheless covered by the scope and requirements of this standard.

3.21

masonry structural unit

bricks or blocks of fired clay, concrete, natural, or reconstructed stones

3.22

road speed limit

statutory speed limit applicable to the length of highway at the site of the highway parapet

3.23

impact speed

vehicle speed at impact corresponding with a particular level of containment which, for the purposes of assessing the adequacy of existing parapets, may be a site specific level of containment

3.24**hazard zone**

area of highway or adjacent land where occupiers could be at risk of injury following a vehicle impact with a parapet

3.25**divergent width**

distance, measured at right angles to the direction of travel, through which a vehicle could diverge on an errant course, prior to striking the parapet

4 Symbols

H	is the vertical distance from the top of the front face of the parapet to the datum for design considerations (m).
γ_m	is the partial factor for material strength.
γ_{mb}	is the partial safety factor for bond strength between concrete infill and steel.
γ_{mm}	is the partial safety factor for compressive strength of masonry.
γ_{ms}	is the partial safety factor for strength of steel.
γ_{mv}	is the partial safety factor for shear strength of masonry.
f_k	is the characteristic compressive strength of masonry.
f_{cu}	is the characteristic compressive strength of concrete.
f_y	is the characteristic tensile strength of steel reinforcement.
L	is the length of parapet panel in metres (m).
Q^*	is the applied design load in kilonewtons (kN).
Q_k	is the nominal load in kilonewtons (kN).
γ_{fl}	is the partial safety factor for load.
S^*	is the applied design load effects (kN).
γ_{f3}	is the partial safety factor for load effect.
R^*	is the member design load resistance (kN).

5 Designation of masonry vehicle parapets

For the purpose of an abbreviated description, masonry parapets shall be designated, in accordance with Table 1, by three characters indicating:

- a) level of containment;
- b) height of parapet above the adjoining paved surface;
- c) type of parapet.

Table 1 — Designation of masonry vehicle parapets

Item	Designation	Clause reference number
a)	<i>Level of containment</i> L = Low N = Normal H = High	6.1
b)	<i>Height above datum</i> 1.00 = 1 m height 1.25 = 1.25 m height etc.	6.3
c)	<i>Type</i> RMB = reinforced brick masonry RMS = reinforced stone masonry UMA = unreinforced ashlar stone masonry UMB = unreinforced brick masonry UMR = unreinforced random rubble stone masonry UMD = unreinforced drystone	3
NOTE Examples of designation. N/1.00/RMB indicates a parapet of 1 m height above the datum of normal containment in reinforced brick masonry construction. L/1.2/UMD indicates a parapet of 1.2 m height above the datum of low containment in unreinforced drystone construction.		

6 Design

6.1 Levels of containment

6.1.1 Low and normal levels of containment

The low and normal levels of containment shall be those 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) for low level of containment 113 km/h (70 mile/h) for normal level of containment

NOTE For the assessment of the adequacy of existing parapets, a site specific level of containment may be adopted. The vehicle impact characteristics for the site specific containment should be the same as those for the low and normal levels, except that the speed should be the lowest value from the following:

- a) the statutory road speed limit appropriate to the class of road;
- b) the maximum speed attained by 85 % of vehicles using that section of highway within any 16 hour week day period;
- c) the theoretical speed based on highway geometrical constraints determined in accordance with the method suggested in Annex B.

6.1.2 High level of containment

A high level of containment shall be that required to resist penetration from the following vehicle impact characteristics.

Vehicle	Four axle rigid tanker or equivalent
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 extremely high risk situations.

NOTE 2 Some authorities, notably Railtrack and other bodies undertaking railway operations authorized by the Railway Inspectorate, have specific requirements which should be determined for parapets on structures over their property. For applications over or adjacent to railways, reference should be made to Railtrack or other appropriate railway authority.

6.2 Wind loading

Wind loading shall be in accordance with BS 5400-2. Wind loading and vehicle impact shall not be considered coexistent.

6.3 Parapet heights

The minimum height of 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, 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 1 The minimum heights are to be provided in masonry construction. If additional height is required only for the protection of animals this may be provided by the addition of a non-effective longitudinal member, excepting that for applications over railways or in other high risk situations non-effective members may not be used where such members may become detached if struck by an errant vehicle.

NOTE 2 Many existing unreinforced masonry parapets may be less than 1.00 m high hence for assessment purposes containment charts (see Figure 2, Figure 3, Figure 4 and Figure 5) are provided for parapets down to 0.8 m high. The 0.8 m lower limit has been chosen to restrict the risk of cars riding over the top of the parapet. This risk is increased where kerbs are present on the approach to the parapet which could give an upward momentum to the impacting vehicle.

6.4 Front face and top face profile

The front face profile shall be either vertical or uniformly inclined away from the traffic, from the base to the top of the parapet at an angle not exceeding 5°.

Where the masonry on the front face of the parapet has an irregular surface finish, the maximum amplitude of the steps and undulations in the surface shall be not more than 30 mm when measured with respect to a plane taken through the peaks. This plane shall be flat for straight parapets and curved to follow the nominal parapet curvature for parapets which are curved on plan.

Where pedestrians have access adjacent to the parapet, and there is a significant risk of injury due to people climbing on the parapet, a steep coping [see Figure 1c)], or other suitably shaped coping, shall be provided on the top face. Steep copings shall be provided on bridges over railways where there is access to pedestrians. (See also 6.6.14).

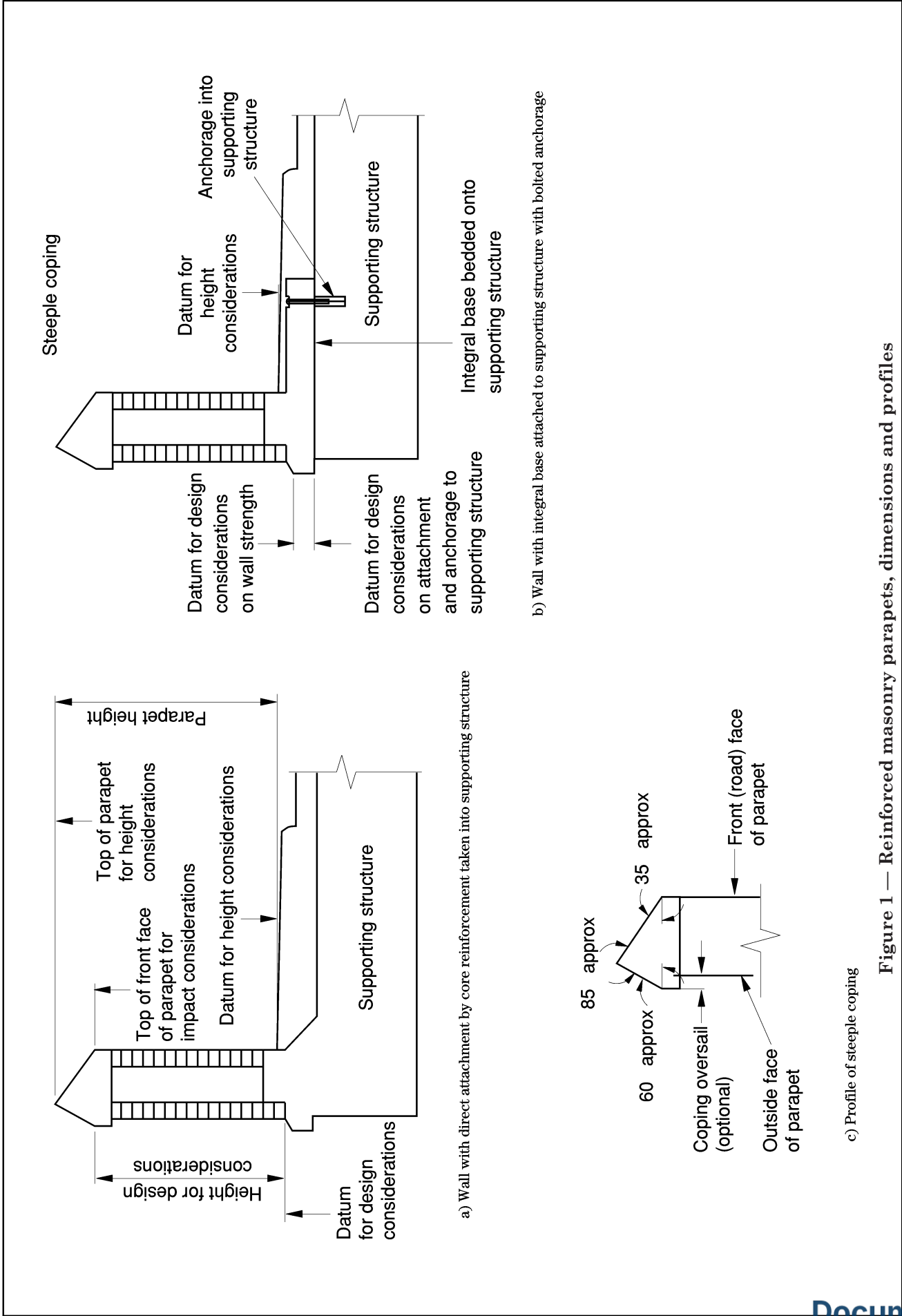


Figure 1 — Reinforced masonry parapets, dimensions and profiles

6.5 Pilasters

To minimize the risk of hook-up of a vehicle, the front face of the pilaster shall be flush with the front face of the parapet. However, where a projection of the pilaster to the front face of the parapet is essential, the projection shall be limited to a depth of 75 mm and be splayed at an angle of 45° or flatter relative to the front face.

Where a recessed panel is required to the front face of a pilaster it shall be limited to 75 mm and the edges be splayed as required for projections.

Where a pilaster is located at a curved end on a parapet (see Figure 7) it shall not project or be recessed.

For unreinforced parapets if the interlocking bond pattern in the masonry units of the parapet is discontinued at the junction with the pilaster then shear connections shall be provided in accordance with 6.7.4.

6.6 Reinforced masonry parapets

6.6.1 General

Reinforced masonry parapets shall be designed generally in accordance with BS 5628-2, to resist loading appropriate to the designated level of containment using the equivalent static nominal loading from Table 2 for panel lengths up to and including 3.5 m. For parapets of greater panel length than 3.5 m, the forces and moments given in 6.6.3 shall apply. In all cases the design shall be checked against punching shear in accordance with 6.6.4.

NOTE 1 The difference between height for structural design considerations and parapet height is illustrated in Figure 1a) together with potential difference between top of parapet for height considerations and top of front face of parapet for impact considerations.

The parapet shall be attached to the supporting structure by appropriate attachments/anchorage such that all of the sustained loading is resisted by cantilever action. The attachment/anchorage system shall satisfy the design requirements of 6.6.9 with the partial safety factors of Table 3 and Table 4.

NOTE 2 Partial safety factors for attachments/anchorages are enhanced with respect to those for parapet design to prevent failure occurring within the attachment/anchorage system with consequential damage to the supporting structure.

NOTE 3 The equivalent static nominal loads for the design of reinforced masonry parapets to high containment level are derived from strain measurements on the vertical reinforcement. From the strain values and observations of damage caused under test, a reinforced masonry parapet designed to the specific requirements of this part of BS 6779 should not require emergency replacement. Different levels of damage may be sustained by parapet systems designed to the specified requirements of other parts of this standard.

NOTE 4 Details of a reinforced masonry parapet design developed from a test carried out to a high level containment for British Rail by MIRA (Motor Industry Research Association) are given in Annex C. This design performed very satisfactorily under test and the values from the instrumentation attached to the wall have been incorporated in this standard.

NOTE 5 A typical strain graph of a high level containment test showing the recorded values in the vertical reinforcement is shown in Annex D. This serves well to illustrate the time scale of peak strains and the way the impact force is impacted in particular stages.

NOTE 6 The profile of the coping for the parapet tested at MIRA as illustrated in Annex C has been subsequently revised in agreement with the Railway Inspectorate, see Figure 1c) for the revised profile.

6.6.2 Design loading for panel lengths (L) 2.0 m to 3.5 m

For parapet or panel lengths of 2.0 m to 3.5 m, the bending moments and shear forces to be resisted per unit length of parapet shall be in accordance with Table 2.

Table 2 — Equivalent static nominal loads (Q_k) for panel lengths (L) 2.0 m to 3.5 m inclusive

Parapet containment level	Q_k for deriving nominal bending moment ^a	Q_k for deriving nominal shear forces ^b
Normal	77 kN over 1 m length	110L kN/panel
High	(124 + 104L) kN/panel	(110 + 85H)L kN/panel
NOTE It is not considered practicable to provide for shear transfer between panels without inducing a concentrated load at the panel joints such that severe local damage may occur.		
^a The bending moment to be resisted at the datum for design considerations by applying the stipulated load as a transverse horizontal uniformly distributed load to the top of the front face of the parapet for impact considerations.		
^b The shear force to be resisted by any transverse section at distance H below top of front face of parapet for impact considerations. Also as the applied force to design copings and their attachment to the parapet wall.		

6.6.3 Parapet lengths greater than 3.5 m

For parapet lengths greater than 3.5 m the bending moments and shear forces to be resisted per unit length of parapet shall be derived from Table 2 assuming a panel length of 3.5 m.

NOTE The requirement to resist a minimum force of 110 kN/m for shear considerations for normal as well as high containment is to ensure that wall elements, such as coping units, are not detached under a severe impact at top of parapet level.

6.6.4 Punching shear

In order to prevent masonry becoming displaced from the outer face under punching shear, the shear on a defined perimeter throughout the wall thickness shall not exceed the allowable characteristic shear strength of masonry in accordance with BS 5628-2:1978, providing that f_v is not taken to be greater than 0.7 N/mm².

For high containment the nominal punching shear force shall be a patch load of 255 kN applied over a circular area of 0.6 m diameter at any position on the front face of the wall.

For normal containment the nominal punching shear force shall be a patch load of 150 kN applied over a circular area of 0.6 m diameter at any position on the front face of the wall.

NOTE It may be assumed that the plane in which punching shear acts will be the circumference of the patch load spreading at 45° to the wall face for the thickness of the wall.

6.6.5 Design method

The parapet and attachments/anchorages shall be designed by the application of limit state principles, as specified in 6.6.6, 6.6.7, 6.6.8 and 6.6.9, using appropriate partial safety factors, γ_{fl} , in accordance with Table 3.

Table 3 — Values of γ_{fl}

Element	Loading	Partial safety factor, γ_{fl}	
		Normal containment	High containment
Parapet	Vehicle impact	1	1
	Wind loading	1.4	1.4
Attachment reinforcement	Displacement of coping	1.25	1.25
	Parapet collapse with reinforcement bonded to supporting structure	1.3	1.2
Bolts	Parapet collapse with parapet bolted to supporting structure	1.4	1.25
Anchorage	Parapet collapse	1.5	1.3

NOTE The partial safety factors specified are intended to control damage at the designated level of containment such that displacement of material from the parapet is not a hazard to highway users or to the space usage beyond the outer face of the parapet.

Characteristic (or nominal) material strengths, f , and partial factors on material strength, γ_m , shall be used in accordance with Table 4.

Table 4 — Values of f_{cu} , f_y , f_k and γ_m , ultimate limit state

Component	Material	Characteristic material strengths	γ_m
Parapet and coping	concrete	f_{cu} in accordance with BS 5400-4	1.0
	reinforcement	f_y in accordance with BS 5400-4	0.8
	masonry	f_k in accordance with BS 5628-2	1.0
Parapet integral base	concrete	f_{cu} in accordance with BS 5400-4	1.2
	reinforcement	f_y in accordance with BS 5400-4	1.0
Anchorage	steel	f_y in accordance with BS 5400-3	1.2
	stainless steel nuts bolts and washers	f_y in accordance with BS EN ISO 3506-1 and -2 or BS 1499-2 as appropriate	1.2
NOTE γ_m may be read as γ_{mm} , γ_{mv} and γ_{ms} as appropriate (see clause 4).			

6.6.6 Applied design load values

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

$$Q^* = \gamma_{fl} Q_k$$

where

γ_{fl} is the partial safety factor for load, as specified in Table 3;

Q_k is the nominal load in kilonewtons (kN).

6.6.7 Applied design load effects

The design load effects S^* in kilonewtons (kN) shall be obtained from the following:

$$S^* = \gamma_{f3} Q^*$$

where

γ_{f3} is the partial load factor for load effect. This shall be taken as:

1.0 for impact loading and parapet collapse;

1.1 for wind loading;

Q^* is the design load (in kN).

6.6.8 Design load resistance values

The design load resistance R^* in kilonewtons (kN) shall be obtained from the equation:

$$R^* = \frac{f}{\gamma_m} ; \frac{f_y}{\gamma_{ms}} ; \frac{f_{cu}}{\gamma_m} ; \frac{f_v}{\gamma_{mv}} \text{ as appropriate}$$

NOTE $R^* \geq S^*$ for all aspects of design.

6.6.9 Attachment systems and anchorages

Attachment systems and anchorages shall be designed to resist the loadings given in 6.6.2 and 6.6.3 as appropriate.

In addition, attachment systems and anchorages for high containment parapets shall be designed to withstand the following coexistent nominal loads, Q_k :

a) a nominal horizontal longitudinal load of 72 kN applied at the top of the front face of the parapet uniformly distributed over a length of 3.0 m, or for panel lengths less than 3.0 m, distributed over the length of the panel;

b) a nominal downwards vertical load of 175 kN uniformly distributed over a horizontal length of 3.0 m at the top of front face of the parapet or, for panel lengths less than 3.0 m, distributed over the length of the panel.