



BSI Standards Publication

PUBLISHED DOCUMENT

Recommendations for the design of masonry structures to BS EN 1996-1-1 and BS EN 1996-2

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Foreword

Publishing information

This Published Document is published by BSI and came into effect on 30 November 2010. It was prepared by Subcommittee B/525/6, *Use of masonry*, under the authority of Technical Committee B/525, *Building and civil engineering structures*. A list of organizations represented on these committees can be obtained on request to their secretary.

Supersession

Together with BS EN 1996-1-1:2005, BS EN 1996-2:2006 and BS EN 1996-3:2006, this Published Document supersedes BS 5628-1:2005 and BS 5628-2:2005, and together with BS EN 1996-1-2:2005, BS EN 1996-2:2006 and BS EN 1996-3:2006, it supersedes BS 5628-3:2005, all of which were withdrawn on 31 March 2010.

Information about this document

This Published Document is a background paper that gives non-contradictory complementary information for use in the UK with the following parts of BS EN 1996 *Design of masonry structures*, and their UK National Annexes:

- *Part 1-1: General rules for reinforced and unreinforced masonry structures;*
- *Part 2: Design considerations, selection of materials and execution of masonry.*

Presentational conventions

The word “should” is used to express recommendations of this Published Document. The word “may” is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the clause. The word “can” is used to express possibility, e.g. a consequence of an action or an event.

Notes and commentaries are provided throughout the text of this standard. Notes give references and additional information that are important but do not form part of the recommendations. Commentaries give background information.

Contractual and legal considerations

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

Compliance with a Published Document cannot confer immunity from legal obligations.

Introduction

When there is a need for guidance on a subject that is not covered by the Eurocode, a country can choose to publish documents that contain non-contradictory complementary information that supports the Eurocode. This Published Document provides just such information and has been cited as a reference in the UK National Annex to BS EN 1996-1-1.

1 Scope

This Published Document contains non-contradictory complementary information and additional guidance for use in the UK with BS EN 1996-1-1 and BS EN 1996-2.

BS EN 1996-1-2 and BS EN 1996-3 are not specifically dealt with, but this Published Document may be relevant.

Most of the material in this Published Document is taken from those parts of BS 5628-1, BS 5628-2, BS 5628-3 and BS 5977-2 that were not contradictory to the new BS EN 1996 series, but had to be withdrawn when those British Standards were withdrawn.

This Published Document does not cover the detailing of components for seismic design.

2 Normative references

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

BS 493, *Specification for air bricks and gratings for wall ventilation*

BS 1186-2, *Timber and workmanship in joinery – Part 2: Specification for workmanship*

BS 1186-3, *Timber and workmanship in joinery – Part 3: Specification for wood trim and its fixing*

BS 4486, *Specification for hot rolled and hot rolled and processed high tensile alloy steel bars for the prestressing of concrete*

BS 4729, *Clay and calcium silicate bricks of special shapes and sizes – Recommendations*

BS 5440-1, *Fluing and ventilation for gas appliances of rated input not exceeding 70 kW net (1st, 2nd and 3rd family gases) – Part 1: Specification for installation of gas appliances to chimneys and for maintenance of chimneys*

BS 5606:1990, *Guide to accuracy in building*

BS 5617, *Specification for urea-formaldehyde (UF) foam systems suitable for thermal insulation of cavity walls with masonry or concrete inner and outer leaves*

BS 5618, *Code of practice for thermal insulation of cavity walls (with masonry or concrete inner and outer leaves) by filling with urea-formaldehyde (UF) foam systems*

BS 5642-1, *Sills and copings – Part 1: Specification for window sills of precast concrete, cast stone, clayware, slate and natural stone*

- BS 5642-2, *Sills and copings – Part 2: Specification for copings of precast concrete, cast stone, clayware, slate and natural stone*
- BS 5896, *Specification for high tensile steel wire and strand for the prestressing of concrete*
- BS 6213, *Selection of construction sealants – Guide*
- BS 6510, *Steel framed windows and glazed doors*
- BS 7456, *Code of practice for stabilization and thermal insulation of cavity walls (with masonry or concrete inner and outer leaves) by filling with polyurethane (PUR) foam systems*
- BS 7457, *Specification for polyurethane (PUR) foam systems suitable for stabilization and thermal insulation of cavity walls with masonry or concrete inner and outer leaves*
- BS 8000-3, *Workmanship on building sites – Part 3: Code of practice for masonry*
- BS 8000-8, *Workmanship on building sites – Part 8: Code of practice for plasterboard partitions and dry linings*
- BS 8000-16, *Workmanship on building sites – Part 16: Code of practice for sealing joints in buildings using sealants*
- BS EN 206-1, *Concrete – Part 1: Specification, performance, production and conformity*
- BS EN 459-1, *Building lime – Part 1: Definitions, specifications and conformity criteria*
- BS EN 485-1, *Aluminium and aluminium alloys – Sheet, strip and plate – Part 1: Technical conditions for inspection and delivery*
- BS EN 485-2, *Aluminium and aluminium alloys – Sheet, strip and plate – Part 2: Mechanical properties*
- BS EN 490, *Concrete roofing tiles and fittings for roof covering and wall cladding – Product specifications*
- BS EN 515, *Aluminium and aluminium alloys – Wrought products – Temper designations*
- BS EN 573-3, *Aluminium and aluminium alloys – Chemical composition and form of wrought products – Part 3: Chemical composition and form of products*
- BS EN 771-1:2003, *Specification for masonry units – Part 1: Clay masonry units*
- BS EN 771-2, *Specification for masonry units – Part 2: Calcium silicate masonry units*
- BS EN 771-3, *Specification for masonry units – Part 3: Aggregate concrete masonry units (dense and light-weight aggregates)*
- BS EN 771-5, *Specification for masonry units – Part 5: Manufactured stone masonry units*
- BS EN 771-6, *Specification for masonry units – Part 6: Natural stone masonry units*
- BS EN 845-1, *Specification for ancillary components for masonry – Part 1: Ties, tension straps, hangers and brackets*
- BS EN 845-2, *Specification for ancillary components for masonry – Part 2: Lintels*

- BS EN 845-3, *Specification for ancillary components for masonry – Part 3: Bed joint reinforcement of steel meshwork*
- BS EN 934-3, *Admixtures for concrete mortar and grout – Part 3: Admixtures for masonry mortar – Definitions, requirements, conformity and marking and labelling*
- BS EN 942, *Timber in joinery – General requirements*
- BS EN 988, *Zinc and zinc alloys – Specification for flat rolled products for building*
- BS EN 998-2, *Specification for mortar for masonry – Part 2: Masonry mortar*
- BS EN 1052-1, *Methods of test for masonry – Part 1: Determination of compressive strength*
- BS EN 1052-4, *Methods of test for masonry – Part 4: Determination of shear strength including damp proof course*
- BS EN 1304, *Clay roofing tiles and fittings – Product definitions and specifications*
- BS EN 1652:1998, *Copper and copper alloys – Plate, sheet, strip and circles for general purposes*
- BS EN 1990:2002+A1:2005, *Eurocode – Basis of structural design*
- BS EN 1992-1-1, *Eurocode 2 – Design of concrete structures – Part 1-1: General rules and rules for buildings*
- BS EN 1995, *Eurocode 5 – Design of timber structures*
- BS EN 1996-1-1:2005, *Eurocode 6 – Design of masonry structures – Part 1-1: General rules for reinforced and unreinforced masonry structures*
- BS EN 1996-2:2006, *Eurocode 6 – Design of masonry structures – Part 2: Design considerations, selection of materials and execution of masonry*
- BS EN 12588, *Lead and lead alloys – Rolled lead sheet for building purposes*
- BS EN 13162, *Thermal insulating products for buildings – Factory made mineral wool (MW) products – Specification*
- BS EN 13163, *Thermal insulating products for buildings – Factory made products of expanded polystyrene (EPS) – Specification*
- BS EN 13164, *Thermal insulating products for buildings – Factory made products of extruded polystyrene foam (XPS) – Specification*
- BS EN 13165, *Thermal insulating products for buildings – Factory made rigid polyurethane foam (PUR) products – Specification*
- BS EN 13166, *Thermal insulating products for buildings – Factory made products of phenolic foam (PF) – Specification*
- BS EN 13167, *Thermal insulating products for buildings – Factory made cellular glass (CG) products – Specification*
- BS EN 13914-1, *Design, preparation and application of external rendering and internal plastering – Part 1: External rendering*
- BS EN 14411, *Ceramic tiles – Definitions, classification, characterisation and marking*
- BS EN 15287-1, *Chimneys – Design, installation and commissioning of chimneys – Part 1: Chimneys for non-roomsealed appliances*

BS EN ISO 11600, *Building construction – Jointing products – Classification and requirements for sealants*

DD 86-1, *Damp-proof courses – Part 1: Methods of test for flexural bond strength and short term shear strength*

DD 86-2, *Damp-proof courses – Part 2: Methods of test for creep deformation*

NA to BS EN 1990:2002+A1:2005, *UK National Annex to Eurocode – Basis of structural design*

NA to BS EN 1996-1-1:2005, *UK National Annex to Eurocode 6 – Design of masonry structures – Part 1-1: General rules for reinforced and unreinforced masonry structures*

prEN 10138 (all parts), *Prestressing steels*

3 Terms and definitions

For the purposes of this Published Document the terms and definitions given in BS EN 1996-1-1 and BS EN 1996-2 and the following apply.

3.1 actual dimension

either work size of the unit

or, where applicable for solid walls sum of the work size of the units together with the work size of the joints between them

3.2 consequence classes

3.2.1 consequence (building) class 1

- single occupancy houses not exceeding four storeys;
- agricultural buildings;
- buildings into which people rarely go, provided no part of the building is closer to another building, or area where people do go, than a distance 1.5 times the building height

3.2.2 consequence (building) class 2A

- five-storey single occupancy houses;
- hotels not exceeding four storeys;
- flats, apartments and other residential buildings not exceeding four storeys;
- offices not exceeding four storeys;
- industrial buildings not exceeding three storeys;
- retailing premises not exceeding three storeys of less than 1 000 m² floor area in each storey;
- single-storey educational buildings;
- all buildings not exceeding two storeys to which members of the public are admitted and which contain floor areas not exceeding 2 000 m² at each storey

3.2.3 consequence (building) class 2B

- hotels, flats, apartments and other residential buildings greater than four storeys but not exceeding 15 storeys;
- educational buildings greater than one storey but not exceeding 15 storeys;

- retailing premises greater than three storeys but not exceeding 15 storeys;
- hospitals not exceeding three storeys;
- offices greater than four storeys but not exceeding 15 storeys;
- all buildings to which members of the public are admitted which contain floor areas exceeding 2 000 m² but less than 5 000 m² at each storey;
- car parking not exceeding six storeys

3.2.4 consequence class 3

- all buildings defined above as class 2A and 2B that exceed the limits on area and number of storeys;
- all buildings to which members of the public are admitted in significant numbers;
- grandstands accommodating more than 5 000 spectators;
- buildings containing hazardous substances and/or processes

3.3 capping

construction that protects the top of a wall, but does not shed rainwater clear of the surfaces of the wall beneath

3.4 cavity tray

damp-proof course that bridges a wall cavity to lead moisture to the external face of a wall

3.5 closer

portion of a masonry unit used to maintain bond

3.6 coping

construction that protects the top of a wall, balustrade or parapet and sheds rainwater clear of the surfaces beneath

3.7 course

single layer of masonry units of uniform height, including the bed joint

3.8 diaphragm wall

wall of two leaves of masonry, separated by a wide cavity, having vertical webs of masonry to improve structural performance

3.9 effective depth

depth, in members in bending, from the compression face to the centroid of the longitudinal tensile reinforcement or prestressing tendons

3.10 efflorescence

crystalline deposit of salts on a surface as a result of the evaporation of water from a salt solution

3.11 fair faced

surface built neatly and evenly without applied finish

3.12 fin wall

wall with extended piers (fins) at frequent intervals constructed of masonry

3.13 free-standing wall

wall or part of a wall, exposed on both faces, that stands above any horizontal lateral support

- 3.14 header**
shorter face of a masonry unit showing on the face of a wall
- 3.15 insulation slab**
resilient, semi-rigid, rectangular unit of thermal insulation material of uniform thickness, usually of mineral wool
- 3.16 jamb**
vertical part of a wall at an opening
- 3.17 key element**
structural member capable of resisting a specified load and upon which the stability of the remainder of the structure depends
- 3.18 pocket-type**
masonry reinforced primarily to resist lateral loading where the main reinforcement is concentrated in vertical pockets formed in the tension face of the masonry and is surrounded by in situ concrete
- 3.19 Quetta bond**
masonry at least one and a half masonry units thick in which vertical pockets containing reinforcement and mortar or concrete infill occur at intervals along its length
- 3.20 reinforced hollow masonry units**
hollow masonry units that may be reinforced horizontally or vertically and subsequently wholly or partly filled with concrete
- 3.21 retaining wall**
wall designed to resist lateral pressure from retained material
- 3.22 rubble**
stone of irregular shape and size
- 3.23 shear span**
ratio of maximum design bending moment to maximum design shear force
- 3.24 shear tie**
bed joint connector used to bond masonry units together in a cross-section in lieu of masonry bonding
- 3.25 sleeper wall**
low loadbearing wall to provide intermediate support to a suspended ground floor
- 3.26 slip tie (general purpose)**
wall tie fitted across a movement joint in masonry to transmit shear forces, but with one end debonded to allow the joint to close or open
- 3.27 special shaped brick**
brick with shape or size other than a standard parallel faced rectangular prism
- 3.28 stretcher**
longer face of a masonry unit showing on the face of a wall
- 3.29 string course**
moulded course, that may be one of a number of courses, that projects from a wall

3.30 weathered/weathering

having an upper surface sloped to throw off water

3.31 weephole

hole through a wall that drains water to its outer face

4 Symbols

For the purposes of this Published Document the symbols given in BS EN 1996-1-1 and BS EN 1996-2 and the following apply.

A_{ps}	area of prestressing tendons (mm^2)
A_{s1}	area of compression reinforcement in the most compressed face (mm^2)
A_{s2}	area of reinforcement in the least compressed face (mm^2)
a	shear span (mm)
a_v	distance from face of support to the nearest edge of a principal load (mm)
b_t	width of section at level of the tension reinforcement (mm)
c	lever arm factor
d_d	depth of masonry in compression (mm)
d_o	overall depth of section (mm)
d_1	the depth from the surface to the reinforcement in the more highly compressed face (mm)
d_2	the depth of the centroid of the reinforcement from the least compressed face (mm)
E_{cm}	modulus of elasticity of concrete (kN/mm^2)
E_s	modulus of elasticity of steel (kN/mm^2)
e_x	resultant eccentricity in plane of bending (mm)
f_{ci}	strength of concrete at transfer (N/mm^2)
f_p	stress due to prestress at the centroid of the section (N/mm^2)
f_{pb}	stress in tendon at the design moment of resistance of the section (N/mm^2)
f_{pe}	effective prestress in tendon after all losses have occurred (N/mm^2)
f_{pu}	characteristic tensile strength of prestressing tendons (N/mm^2)
f_s	stress in the reinforcement (N/mm^2)
f_{s1}	stress in the reinforcement in the most compressed face (N/mm^2)
f_{s2}	stress in the reinforcement in the least compressed face (N/mm^2)
f_t	diagonal tensile strength of masonry (N/mm^2)
f_{yt}	characteristic tensile strength of flat metal section (shear connector) (N/mm^2)
F_t	tie force (kN)
G_k	characteristic dead load (kN)
H	clear distance between lateral supports (mm)
h	clear height of wall between concrete surfaces or other construction capable of providing adequate resistance to rotation across the full thickness of a wall (mm)

j	coefficient derived from Table 17
K_L	factor for use in assessment of loads on lintels
K_t	coefficient to allow for type of prestressing tendon
L	distance between end anchorages (mm)
L_a	span in accidental damage calculation (m)
l_t	transmission length (mm)
M_{Rd}	design moment of resistance (Nmm)
M_x	design moment about the x axis (Nmm)
M'_x	effective uniaxial design moment about the x axis (Nmm)
M_y	design moment about the y axis (Nmm)
M'_y	effective uniaxial design moment about the y axis (Nmm)
p	overall section dimension in a direction perpendicular to the x axis (mm)
p_{lim}	acceptance limit for compressive strength of units (N/mm ²)
p_o	specified compressive strength of units (N/mm ²)
p_u	mean compressive strength of units (N/mm ²)
Q	moment of resistance factor (N/mm ²)
Q_k	characteristic imposed load (kN)
q	overall section dimension in a direction perpendicular to the y axis (mm)
r	width of shear connector (mm)
s	spacing of shear connectors (mm)
t_p	thickness of a pier (mm)
t_1	thickness of leaf 1 of a cavity wall (mm)
t_2	thickness of leaf 2 of a cavity wall (mm)
t_w	width of masonry section in vertical shear (mm)
u	thickness of shear connector (mm)
v_{Ed}	shear stress due to design loads (N/mm ²)
v_d	design shear stress (N/mm ²)
W	assessed load on lintel (kN)
W_e	equivalent uniformly distributed load on lintel (kN/m)
W_k	characteristic wind load (kN/m ²)
γ_F	partial factor for loads
ρ	ratio of area of tension reinforcement to the effective area of the section
ϕ_t	nominal diameter of tendon (mm)
ϕ_v	angle of inclination to the vertical (degrees)

5 Materials and components

5.1 General

The following clauses contain complementary and non-contradictory information relating to materials and components for use in masonry designed in accordance with the BS EN 1996 series of Eurocodes.

5.2 Damp-proof courses

Damp-proof course (DPC) materials should conform to the relevant British Standard referenced in Table 1.

Designers should pay particular attention to the characteristics of the materials chosen for DPCs. Materials that squeeze out are undesirable in highly stressed walls, and the effect of sliding at the DPC should be considered especially in relation to lateral loading.

Guidance on structural considerations affecting the selection of DPCs is given in BS 8215 and characteristic strengths for some DPC materials are given in DD 86-3. In general, advice on the resistance to compression, tension, sliding and shear should be sought from the manufacturers of the DPC.

Tests to determine the shear strength of DPC materials should be in accordance with BS EN 1052-4. Tests to determine the flexural strength should be in accordance with DD 86-1, and tests to determine the deformation due to creep should be in accordance with DD 86-2.

Bituminous materials for DPCs in masonry built of some natural stones should be carefully selected to avoid the risk of staining.

The physical properties and performance of materials for DPCs are set out in Table 1.

Table 1 Physical properties and performance of materials for DPCs

Material	Minimum mass kg/m ²	Minimum thickness mm	Joint treatment to prevent water moving		Liability to extrusion	Durability	Other considerations
			Upward	Downward			
(A) Flexible							
Lead sheet	A)	1.8	Lapped at least 100 mm	100 mm passing lap and interlocking upstand	Not under pressure met in normal construction	Corrodes in contact with mortars. Protect with bitumen or bitumen paint of heavy consistency applied to both surfaces of the lead.	Easily worked to required shape but this is a slow process. Limit lengths to 1.5 m.
Copper conforming to BS EN 1172:1997, 2.28 grades C104 or C106 in the O condition	Approximately 2.28	0.25	Lapped at least 100 mm	Welded or weltd	Not under pressure met in normal construction	Highly resistant to corrosion. If soluble salts are present, protect as for lead.	Can stain masonry. Not easy to work on site, so not suitable for cavity trays. Avoid contact with aluminium.
Bitumen Hessian base (class A of BS 6398:1983)	3.8	—	Lapped at least 100 mm	Lapped at least 100 mm and sealed	Likely to extrude under heat and moderate pressure but this is unlikely to affect resistance to moisture penetration	The hessian or fibre can decay but this does not affect efficiency if the bitumen remains undisturbed. Classes D and E are most suitable for buildings that are intended to have a very long life or where there is risk of movement.	Materials should be unrolled with care. In cold weather warm before use. When used as a cavity tray, the DPC should be fully supported. For further guidance see BS 6398:1983, Annex B.
Bitumen fibre base (class B of BS 6398:1983)	3.3	—					
Bitumen Hessian base and lead (class D of BS 6398:1983)	4.4	—					
Bitumen fibre base and lead (class E of BS 6398:1983)	4.4	—					

A) Code number 4 in BS 743:1970.

Table 1 Physical properties and performance of materials for DPCs (*continued*)

Material	Minimum mass kg/m ²	Minimum thickness mm	Joint treatment to prevent water moving		Liability to extrusion	Durability	Other considerations
			Upward	Downward			
(A) Flexible (continued)							
Polyethylene, low density (0.915 g/cm ³ to 0.925 g/cm ³) conforming to BS 6515	Approximately 0.5	0.46	Wetted and sealed with double-sided adhesive tape	Wetted	Not under pressure met in normal construction	No evidence of deterioration in contact with other building materials.	Accommodates considerable lateral movement. When used as a cavity tray, can be difficult to hold in place and may need bedding in mastic for the full thickness of the outer leaf, to prevent rain penetration. Not suitable for use where compressive stress is low, e.g. under copings.
Bitumen polymer and pitch polymer	Approximately 1.5	1.10	Lapped at least 100 mm	Lapped at least 100 mm and sealed	Not under pressure met in normal construction	Unlikely to be impaired by any construction movements normally occurring up to the point of failure of the wall.	Accommodates considerable lateral movement. When used as a cavity tray, preformed cloaks should be used, e.g. at changes of level and junctions.
(B) Semi-rigid							
Mastic asphalt conforming to BS 6925 of hardness appropriate to conditions	—	12	No joint problems	No joint problems	Liable to extrude under pressure above 0.65 N/mm ²	No deterioration.	To provide a key for mortar below next course of brick masonry, up to 35% grit should be beaten into asphalt immediately after application and left proud of surface. Alternatively, the surface should be scored whilst still warm.

Table 1 Physical properties and performance of materials for DPCs (continued)

Material	Minimum mass kg/m ²	Minimum thickness mm	Joint treatment to prevent water moving		Liability to extrusion	Durability	Other considerations
			Upward	Downward			
(C) Rigid							
DPC units of prescribed water absorption conforming to BS EN 771-1	—	Two courses, laid to break joint, bedded in M12 (1:3) Portland cement:sand mortar	No joint problems	Not suitable	—	No deterioration	Particularly appropriate where is required to transmit flexural tension, e.g. at base of a free-standing wall. DPC Designation 1 units are required for buildings. DPC Designation 1 or 2 may be used in external works (see BS EN 771-1:2003, NA.3.10).
Slate conforming to BS 743 and most granites	—	Two courses laid to break joint, bedded in M12 (1:3) Portland cement:sand mortar	No joint problems	Not suitable	—	No deterioration	—

5.3 Wall ties and ancillary components

5.3.1 Wall ties

Wall ties should conform to BS EN 845-1. For guidance on selection and use of wall ties see 5.3.3, 6.2.2, Table 2 and Table 9 to Table 12.

5.3.2 Ancillary components

Tension straps, joist hangers lintels, bed joint reinforcement, ties and brackets should conform to Table 2 in relation to material/coating specification and situation.

5.3.3 Wall ties for grouted cavity construction

Wall ties for low-lift grouted-cavity construction (see 6.2.2) should conform to BS EN 845-1 and have a declared tensile load capacity not less than 5 000 N.

Details of a tie for high-lift grouted cavity walls that is suitable for resisting the bursting forces which occur during the cavity filling and compaction operations are given in 8.2.2.3.

5.4 Special shaped brick masonry units

Special shaped clay and calcium silicate brick masonry units should conform to BS 4729.

5.5 Sealants

Sealants should conform to BS EN ISO 11600.

Sealant selection should be in accordance with the recommendations given in BS 6213.

Sealants should be installed in accordance with BS 8000-16.

For the selection of a sealant for use with a particular type of natural stone, the sealant manufacturer should be consulted to avoid problems such as migration staining. Some silicone sealants liberate acidic by-products during curing and are therefore unsuitable for use with calcareous stones.

5.6 Airbricks, gratings and flues

Airbricks and gratings should conform to BS 493. Flues should follow the recommendations given in BS 5440-1 or BS EN 15287-1, as appropriate.

Unless satisfactory local experience exists, clay products should not be used in limestone masonry nor concrete products used in sandstone masonry. These restrictions avoid the risk of attack by run-off from limestone and concrete, respectively.

5.7 Sills

Sills can be purpose made components or can be constructed from suitably durable materials. Sill materials should conform to the British Standards listed in Table 3.

Table 2 Selection of ancillary components in relation to material/coating specification and situation

Material/ coating reference in accordance with BS EN 845-1	Material/ coating reference in accordance with BS EN 845-2	Material/ coating reference in accordance with BS EN 845-3	Material /coating specification (NOTE 1 See BS EN 845-1 to -3 for the full details of the specifications. The zinc coating masses are approximate values for one surface.)	Situation in buildings up to three storeys in a non-aggressive environment (For other buildings see Note 2 and Note 3)											
				In contact with or embedded in an internal wall or an inner leaf of an external cavity wall						In contact with or embedded in an outer leaf of an external cavity wall or a single leaf external wall					
				T	S	L	L+	R	C	T	S	L	L+	R	C
1		R1	Austenitic stainless steel (molybdenum chrome nickel alloys)	Y	Y			Y	Y	Y	Y			Y	Y
2			Plastic used for the body of ties	Y ^{A)}						Y ^{A)}					
3	L3	R3	Austenitic stainless steel (chrome nickel alloys)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4			Ferritic stainless steel	X	X				X	X	X				X
5, 6, 7			Aluminium bronze, phosphor bronze, copper	Y	Y				Y	Y	Y				Y
8, 9			Zinc coated (940 g/m ²) steel wire or component	Y	Y				Y	Y	Y				Y
10	L10		Zinc coated (710 g/m ²) steel component	X	Y	Y	Y		Y	X	X	Y	Y		X
11	L11		Zinc coated (460 g/m ²) steel component	X	Y	X	Y		Y	X	X	X	Y		X
	L11.1		Zinc coated (460 g/m ²) steel component with organic coating over all outer surfaces of finished component			Y	Y					Y	Y		
	L11.2					Y	Y					Y	Y		
12.1	L12.1		Zinc coated (300 g/m ²) steel strip or sheet with organic coating over all outer surfaces of finished component	X	Y	Y	Y		Y	X	X	Y	Y		X
12.2	L12.2			X	Y	Y	Y		Y	X	X	Y	Y		X
13		R13	Zinc coated (265 g/m ²) steel wire	X	Y			Y	Y	X	X			X	X
14	L14		Zinc coated (300 g/m ²) steel strip or sheet with all cut edges organic coated	X	Y	X	Y		Y	X	X	X	Y		X
15			Zinc pre-coated (300 g/m ²) steel strip or sheet	X	Y				Y	X	X				X
16.1	L16.1		Zinc coated (137 g/m ²) steel strip or sheet with organic coating over all outer surfaces of finished component	X	Y	X	Y		Y	X	X	X	Y		X
16.2	L16.2			X	Y	Y	Y		Y	X	X	Y	Y		X
17			Zinc pre-coated (137 g/m ²) steel strip with zinc coated edges	X	Y				Y	X	X				X
18		R18	Zinc coated (60 g/m ²) steel wire with organic coating over all surfaces of finished component	X	X			X	X	X	X			X	X
19		R19	Zinc coated (105 g/m ²) steel wire	X	X			X	X	X	X			X	X
20		R20	Zinc coated (60 g/m ²) steel wire	X	X			X	X	X	X			X	X
21		R21	Zinc pre-coated (137 g/m ²) steel sheet	X	X			Y	X	X	X			X	X

Table 2 Selection of ancillary components in relation to material/coating specification and situation (continued)

Key to product types	
T	Ties and brackets conforming to BS EN 845-1 with this material/coating reference.
S	Tension straps and hangers conforming to BS EN 845-1 with this material/coating reference.
L	Lintels conforming to BS EN 845-2 with this material/coating reference have integral damp-proof systems and may be used without the need to provide a separate damp-proof course.
L+	Lintels conforming to BS EN 845-2 with this material/coating reference may be used in these locations with a separate damp-proof course.
R	Bed joint reinforcement conforming to BS EN 845-3 with this material/coating reference.
C	Components outside the scope of EN 845-1 to 3 but meeting the specification requirements of EN 845-1 for the material/coating reference.
Key to Table	
Y	Components with this material/coating reference may be used in these locations.
(Blank)	Components with this material/coating reference are not specified.
X	The use of components with this material/coating reference is not recommended in these locations.
The recommendations given in the table may be used for the internal walls and inner leaves of all buildings in a non-aggressive environment.	
NOTE 2 <i>In contact with or embedded in an outer leaf of an external cavity wall or a single leaf external wall, in buildings exceeding three storeys in a non-aggressive environment, the material/coating specifications should be limited to austenitic stainless steels (references 1, R1, 3, L3 and R3) or aluminium bronze, phosphor bronze or copper (references 5, 6 or 7).</i>	
NOTE 3 <i>For buildings located in an aggressive environment (e.g. coastal sites) the material/coating specification for products in both leaves of an external wall should be austenitic stainless steel (molybdenum chrome nickel alloys – references 1 or R1).</i>	
A) Restricted to use for box-form residential buildings of up to two storeys (10 m max. height).	

Table 3 Sill materials

Material	Appropriate British Standards
Masonry units	BS EN 771-1, BS EN 771-2, BS EN 771-3, BS EN 771-5, BS EN 771-6 or BS 4729
Cast (manufactured) stone	BS 5642-1
Clay tile	BS EN 1304
Clayware	BS 5642-1
Concrete	BS 5642-1
Natural stone	BS 5642-1
Slate	BS 5642-1
Steel	BS 6510
Timber	BS 1186-2, BS 1186-3 and BS EN 942

5.8 Lintels

Lintels should conform to the appropriate British Standard listed in Table 4. For the assessment of loads on lintels, see Clause 7.

Table 4 Lintels

Material	Appropriate British Standard
Autoclaved aerated concrete	BS EN 845-2
Cast concrete	
Reinforced concrete	
Prestressed concrete	
Manufactured stone	
Pressed steel	
Rolled low carbon steel	BS EN 1995
Prefabricated reinforced masonry	
Timber	
Natural stone	None applicable
In-situ reinforced concrete	BS EN 1992-1-1
In-situ reinforced masonry	BS EN 1996-1-1
Composite lintels	BS EN 1996-1-1

5.9 Copings

Copings can be purpose made components or can be constructed from suitably durable materials. Coping components and/or materials and the British Standards to which they should conform are listed in Table 5.

Table 5 Copings

Material	Appropriate British Standards	Recommended thickness mm
Aluminium	BS EN 515, BS EN 573-3, BS EN 485-1 and BS EN 485-2	0.6 to 0.9
Masonry units	BS EN 771-1, BS EN 771-2, BS EN 771-3, BS EN 771-5, BS EN 771-6 or BS 4729	—
Cast (manufactured) stone	BS 5642-2	—
Clay tile	BS EN 1304 or BS EN 14411	—
Concrete (cast)	BS 5642-2	—
Concrete tile	BS EN 490	—
Copper	BS EN 1652:1998, material designation Cu-FRTP CW006A or Cu-DHP CW024A in the O condition	—
Lead	BS EN 12588	Not less than 1.8
Natural stone	BS 5642-2	—
Zinc	BS EN 988	Not less than 0.8

5.10 Flashings and weatherings

Flashings and weatherings should conform to the relevant British Standards given in Table 6.

Table 6 Flashings and weatherings

Material	Appropriate British Standards	Recommended thickness mm
Aluminium alloy	BS EN 485-1, BS EN 485-2, BS EN 573-3, BS EN 515	0.6 to 0.9 (sheet or strip)
Copper	BS EN 1652:1998, material designation Cu-FRTP CW006A or Cu-DHP CW024A in the O condition	0.4 to 0.7
Lead	BS EN 12588	Not less than 1.8

5.11 Insulation products

The insulation products listed in Table 7 should conform to the relevant British Standard listed in Table 7.

Table 7 Insulation products

Insulation product	Product specification	Code of practice for installation
(A) For installation during construction of masonry		
Mineral wool boards or slabs (glass or rock fibre)	BS EN 13162	—
Expanded polystyrene bead boards	BS EN 13163	—
Extruded expanded polystyrene boards	BS EN 13164	—
Polyurethane (PUR) boards	BS EN 13165	—
Polyisocyanurate (PIR) boards	BS EN 13166	—
Cellular glass boards	BS EN 13167	—
(B) For installation by blowing or injection into cavity walling to fill the cavity fully		
Loose mineral wool (glass or rock fibre)	—	—
Expanded polystyrene beads or granules	—	—
Urea-formaldehyde (UF) foam	BS 5617	BS 5618
Polyurethane (PUR) foam	BS 7457	BS 7456
Polyurethane (PUR) cavity stabilization foam	BS 7457	BS 7456

6 Design

6.1 Objectives and general recommendations

6.1.1 General

The following clauses contain complementary, non-contradictory information and recommendations for the design of masonry carried out in accordance with the BS EN 1996 series of Eurocodes.

6.1.2 Stability – General considerations

The designer responsible for the overall stability of the structure should ensure the compatibility of the design and details of parts and components. There should be no doubt of this responsibility for overall stability when some or all of the design and details are not made by the same designer.

To ensure a robust and stable design it will be necessary to consider the layout of the structure on plan, returns at the ends of walls, interaction between intersecting walls and the interaction between masonry walls and the other parts of the structure.

The design recommendations in BS EN 1996-1-1 assume that all the lateral forces acting on the whole structure are resisted by walls in planes parallel to these forces, or by suitable bracing. The Eurocodes on loading do not specifically require a check that a minimum horizontal load can be resisted, but it is recommended that a check is carried out to show that a building is capable of resisting a uniformly distributed horizontal load equal to 1.5% of the total characteristic dead load (permanent action) (i.e. $0.015G_k$) above any level.

As well as the above general considerations, attention should be given to the following recommendations.

- a) Stability and robustness of masonry construction, particularly housing, relies on the use of straps and ties. This structural interaction of walls, floors and roofs depends upon detailing.
- b) Robust connections should be provided between elements of the structure, particularly at floors and roofs. For guidance, see Figure 1 to Figure 13.
- c) Consideration should be given to connections between elements of different materials to ensure that any differences in their material or structural behaviour do not adversely affect the stability and/or performance of the elements.

The bearing on walls of timber joists and joist hangers should be not less than 75 mm. Frogs of bricks should be filled to provide an even bearing. It may be desirable to provide a wall plate in certain cases.

Figure 1 to Figure 13 illustrate connections that may be used to provide horizontal restraint in accordance with the recommendations for Consequence class 2A buildings (see 6.5.4).

Figure 1 Timber floor bearing directly on to a wall

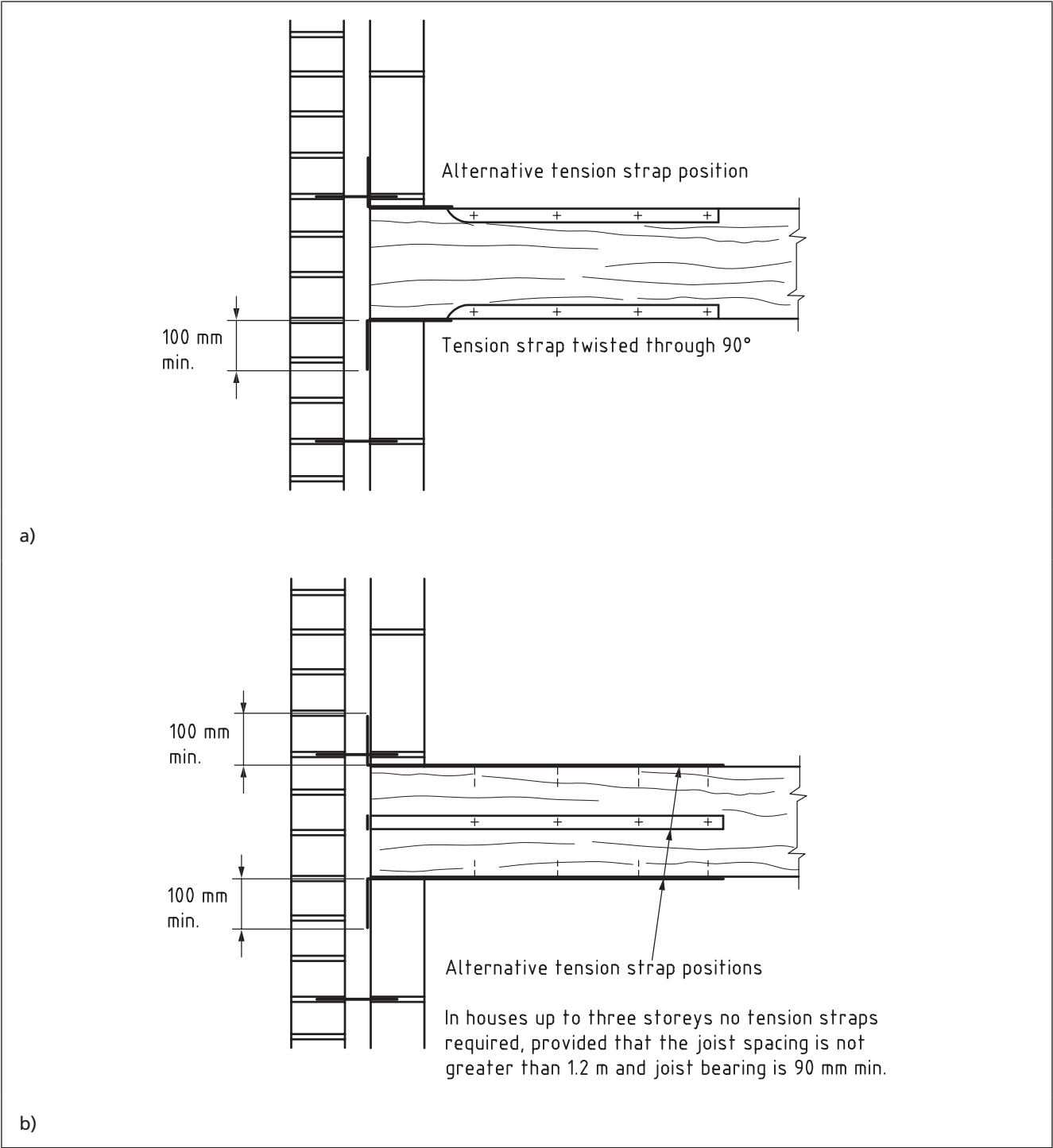


Figure 2 Timber floor using typical joist hanger

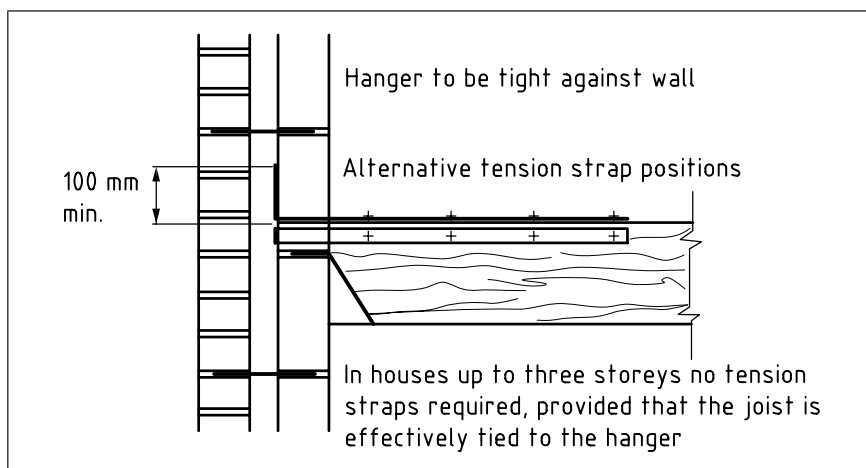


Figure 3 Timber floor using nailed or bolted joist hangers acting as tie

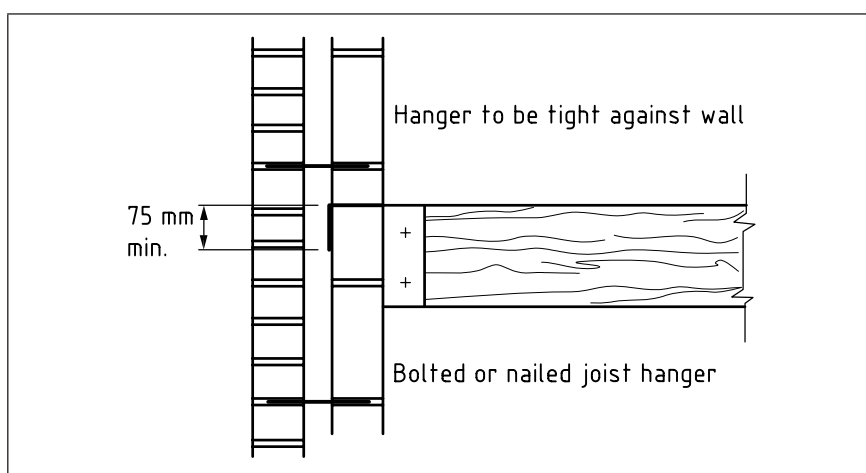


Figure 4 In-situ concrete floor bearing directly on to wall

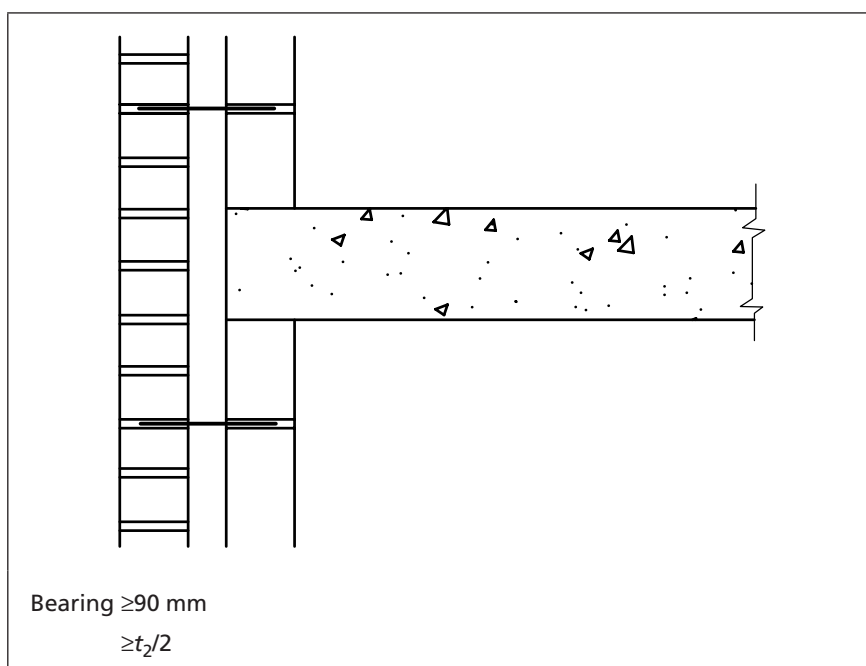


Figure 5 In-situ concrete floor abutting external cavity wall

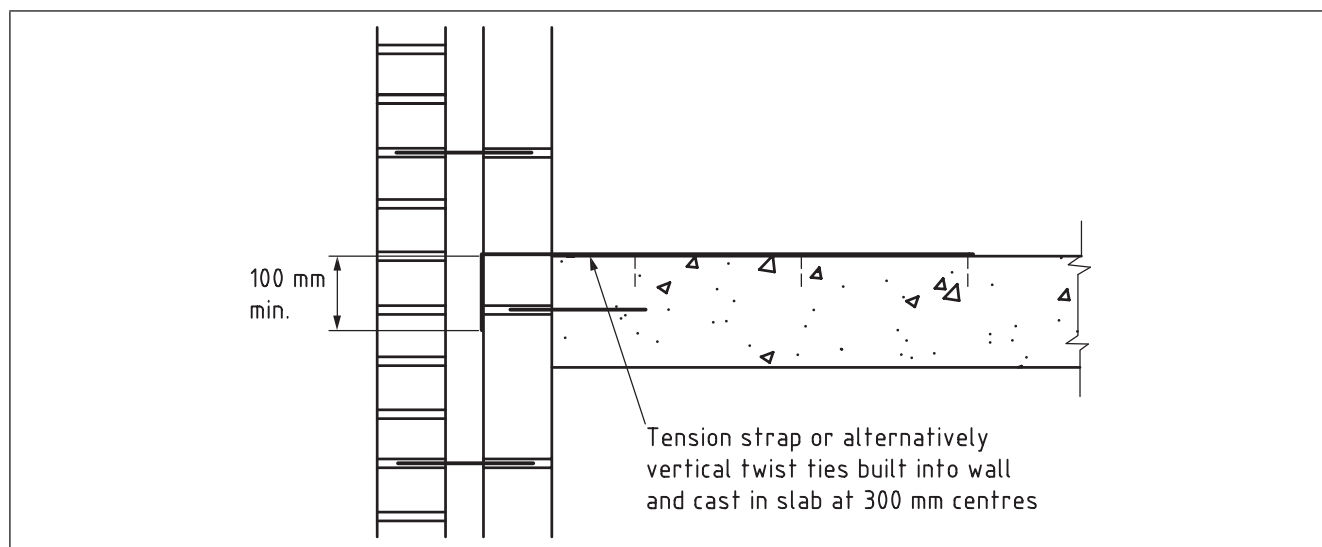


Figure 6 Beam and block floor abutting external cavity wall

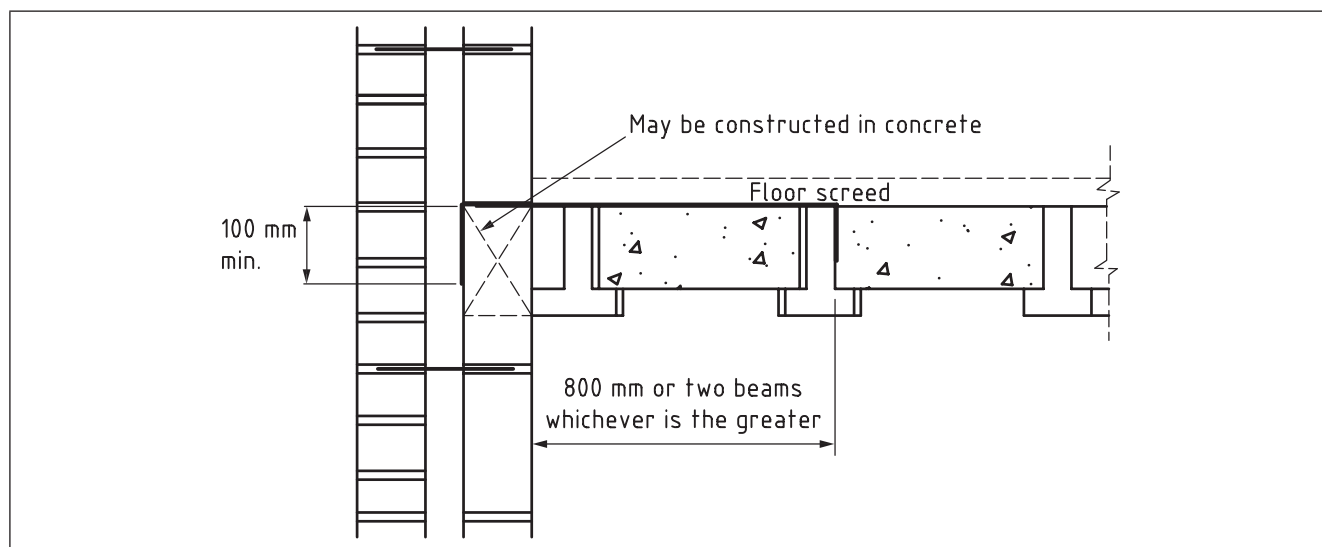


Figure 7 Timber floor abutting external cavity wall

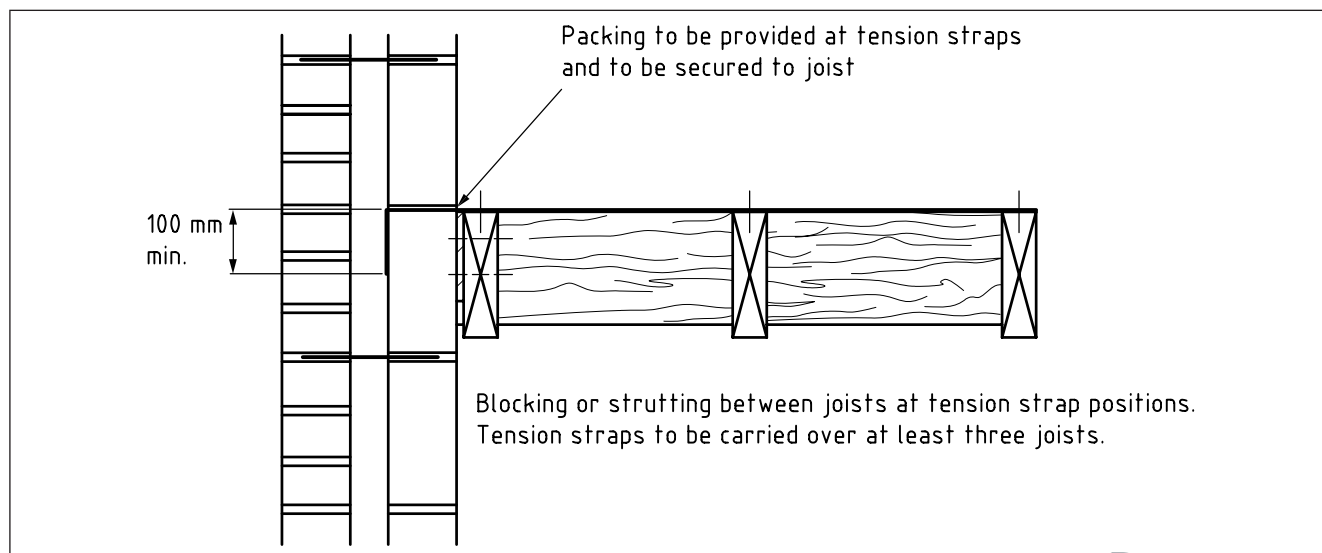


Figure 8 Timber floor using double joist hanger acting as tie

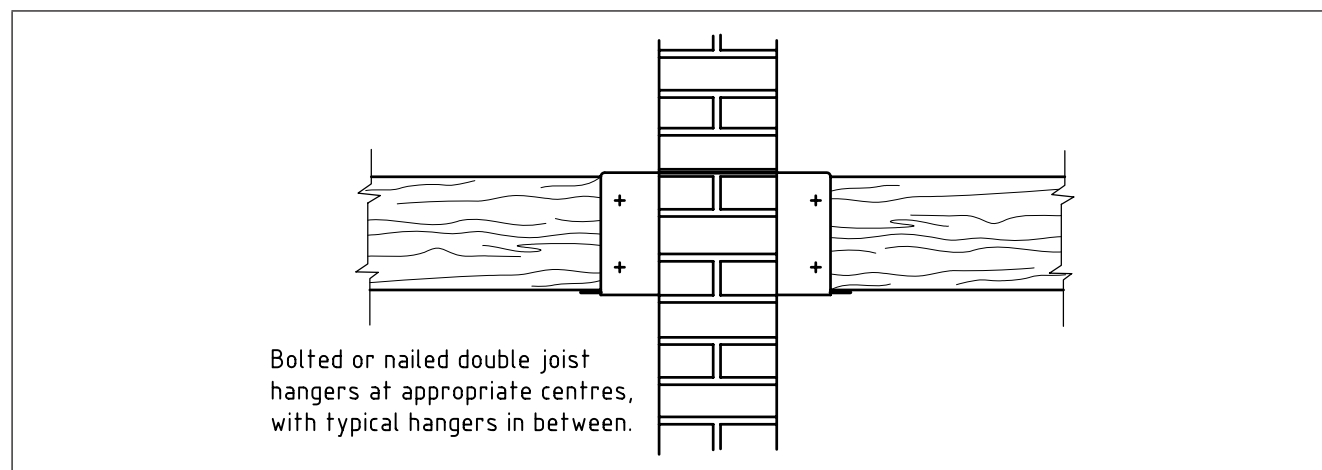


Figure 9 Timber floor using typical joist hanger

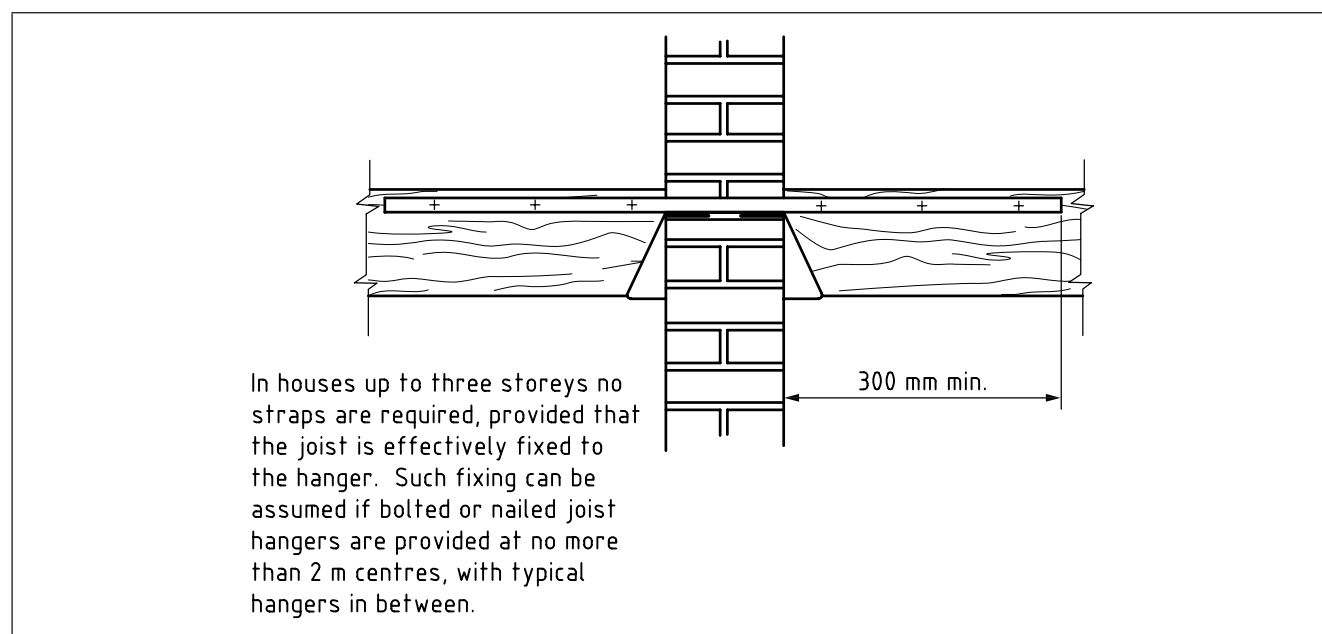


Figure 10 Timber floors abutting internal wall

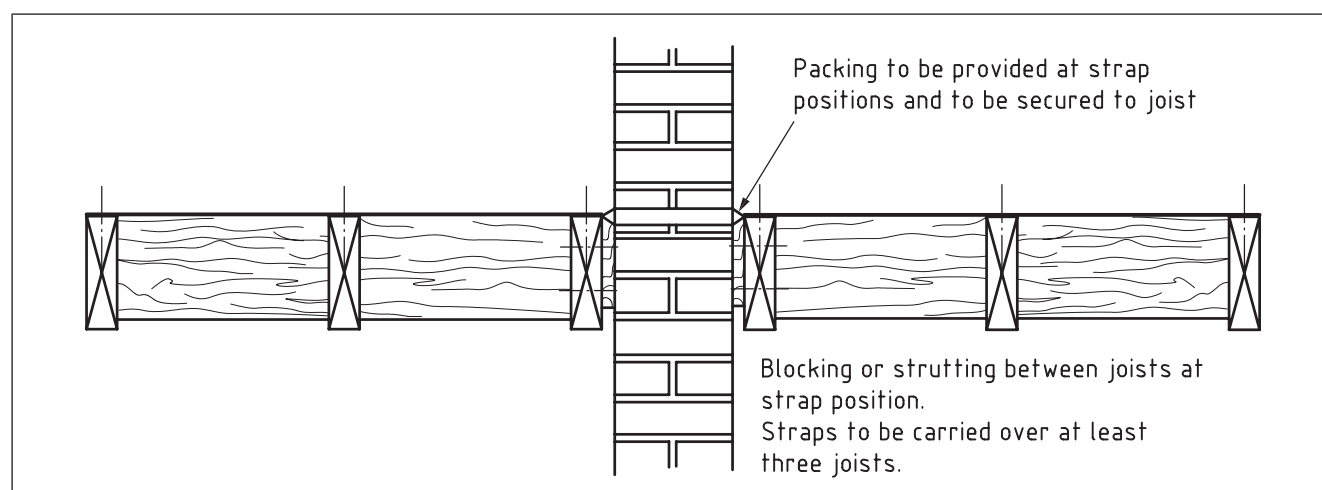


Figure 11 In-situ floors abutting internal wall

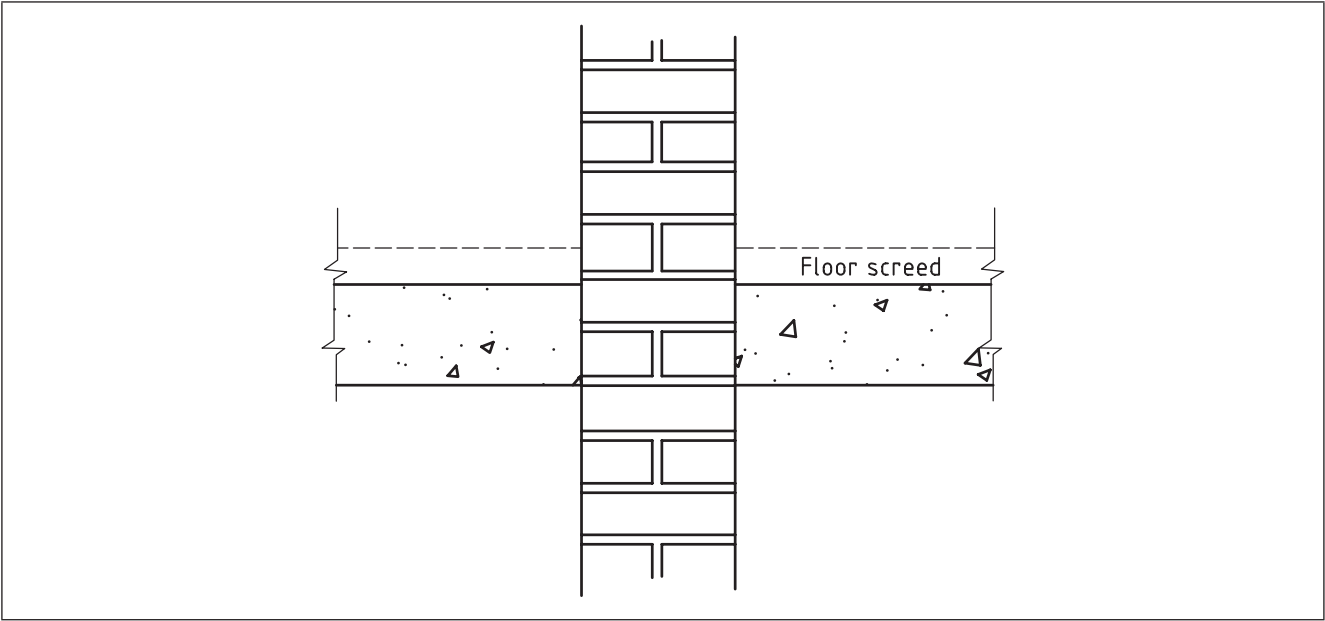


Figure 12 Beam and block floor abutting internal wall

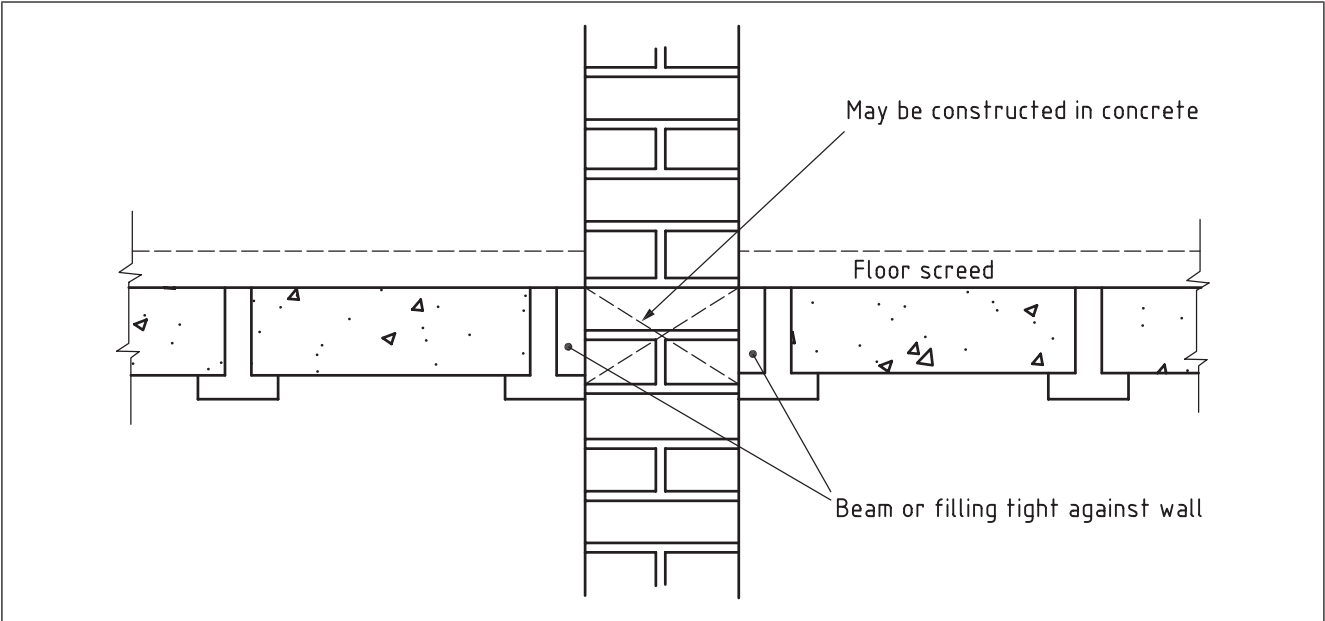
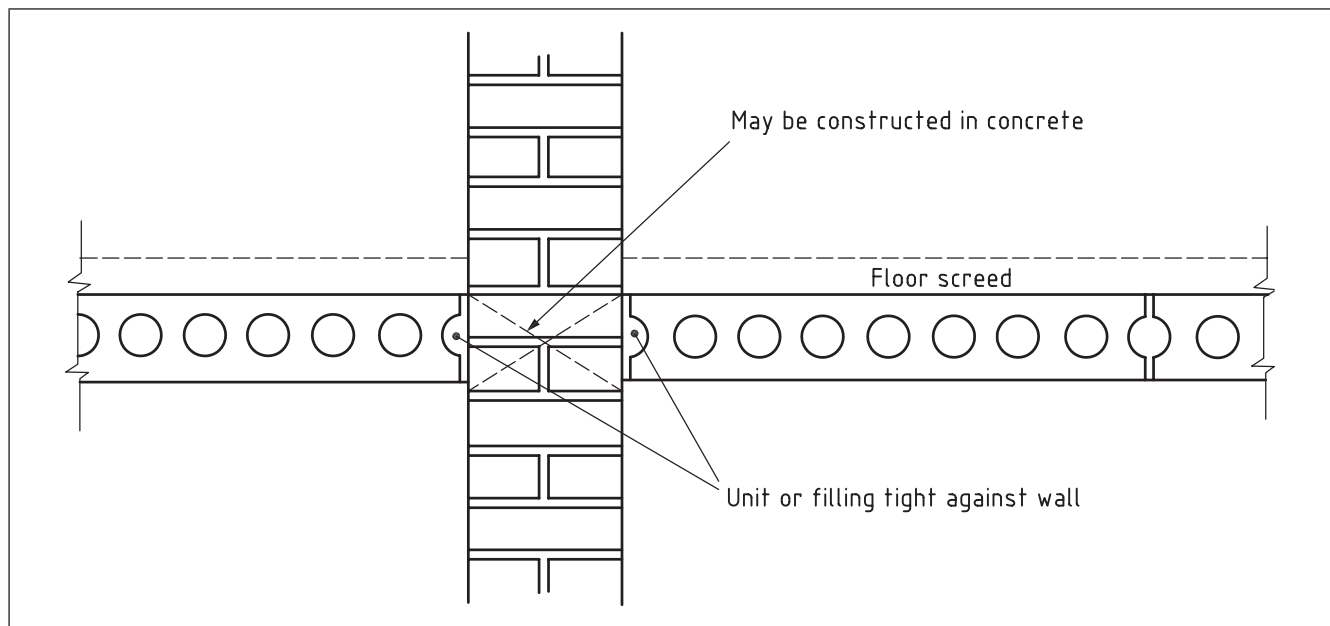


Figure 13 Precast units abutting internal wall



6.1.3 Support over openings

Masonry should not be supported on window or door frames that are not designed for the purpose; lintels should be used.

6.1.4 Random rubble masonry

The characteristic strength of random rubble masonry may be taken as 75% of the corresponding strength of natural stone masonry built with similar materials. In the case of rubble masonry built with lime mortar, the characteristic strength may be taken as one-half of that for masonry in mortar strength class M2 [mortar designation (iv)].

6.1.5 Coefficient of friction

The coefficient of friction between clean concrete and masonry faces may be taken as 0.6.

6.1.6 Basis of design, reinforced and prestressed masonry

Designers should consider whether the proportion of concrete infill in a given cross-section is such that the recommendations of BS EN 1992-1-1 would be more appropriate than the recommendations of this Published Document.

6.1.7 Serviceability limit states

6.1.7.1 Deflection

In BS EN 1990:2002+A1, A.1.4.2 (2), a note allows serviceability criteria to be given in the National Annex; no figures have been given in the UK National Annex for masonry, but the following rules have been found to be satisfactory in UK practice.

- a) The final deflection (including the effects of temperature, creep and shrinkage) of all elements should not, in general, exceed length/125 for cantilevers or span/250 for all other elements.

- b) Consideration should be given to the effect on partitions and finishes of that part of the deflection of the structure taking place after their construction. A limiting deflection of $\text{span}/500$ or 20 mm, whichever is the lesser, is suggested.
- c) If finishes are to be applied to prestressed masonry members, the total upward deflection, before the application of finishes, should not exceed $\text{span}/300$ unless uniformity of camber between adjacent masonry units can be ensured.

In any calculation of deflections the design loads and the design properties of materials should be those recommended for the serviceability limit state in BS EN 1996-1-1:2005, Section 7. For reinforcement, stresses lower than the characteristic strengths given in BS EN 1992-1-1 may need to be used to reduce deflection or control cracking.

6.1.8 Accidental forces

In addition to designing the structure to support loads arising from normal use, there should be a reasonable probability that it will not collapse catastrophically under the effect of misuse or accident. No structure can be expected to be resistant to the excessive loads or forces that could arise due to an extreme cause, but it should not be damaged to an extent disproportionate to the original cause.

Furthermore, owing to the nature of a particular occupancy or use of a structure (e.g. flour mill, chemical plant, etc.), it may be necessary in the design concept or a design appraisal to consider the effect of a particular hazard and to ensure that, in the event of an accident, there is an acceptable probability of the structure remaining after the event, even if in a damaged condition.

Where there is the possibility of vehicles running into and damaging or removing vital loadbearing members of the structure in the ground floor, the provision of bollards, walls, retaining earth banks, etc. should be considered.

All buildings should be robust against misuse and accidental forces that could arise. For Consequence class 1 buildings (see Clause 3), no additional measures are likely to be necessary other than design to BS EN 1996-1-1.

For Consequence class 2A buildings (see Clause 3) the recommendations for Consequence class 1 buildings are appropriate with the additional provision that effective horizontal ties, or effective anchorage of suspended floors to walls, should be installed. Guidance is given on meeting these provisions in 6.5.

For Consequence class 2B buildings (see Clause 3) the recommendations for Consequence class 1 buildings are appropriate with the additional provision that either effective horizontal ties and effective vertical ties to supporting walls and columns should be installed, or the notional removal of vertical loadbearing elements of the construction, one at a time, should be demonstrated to be possible without causing collapse. In the event that the notional removal of vertical loadbearing members cannot be accepted, such members should be designed as key elements. Guidance on meeting these provisions is given in 6.5.

The designer should consider whether special precautions or temporary propping are necessary to ensure the overall stability of the structure or of individual elements during construction.

6.1.9 Structural properties

6.1.9.1 General

The following clauses contain non-contradictory, complementary information relating to the shear strength of reinforced masonry designed to BS EN 1996-1-1.

6.1.9.2 Shear in bending (reinforced masonry walls)

At sections in certain laterally loaded walls there may be substantial compressive stresses from vertical loads. In such cases the shear may be adequately resisted by friction in the plain masonry (see 6.1.5).

6.1.9.3 Racking shear in reinforced masonry shear walls

When the main reinforcement is placed within pockets, cores or cavities filled with concrete infill, the characteristic shear strength of the unreinforced sections in the masonry, f_{vk} , may be taken to be 0.7 N/mm^2 provided that the ratio of height to length of the wall does not exceed 1.5.

6.1.9.4 Shear in prestressed sections

For prestressed sections with bonded or unbonded tendons, the design shear strength of masonry may be determined directly from a consideration of the characteristic diagonal tensile strength of masonry and the prestress (see 6.4).

6.1.10 Characteristic breaking load of prestressing steel

The characteristic breaking load of prestressing wire, strand and bar should be that specified in BS 4486 or BS 5896, as appropriate.

6.1.11 Elastic moduli

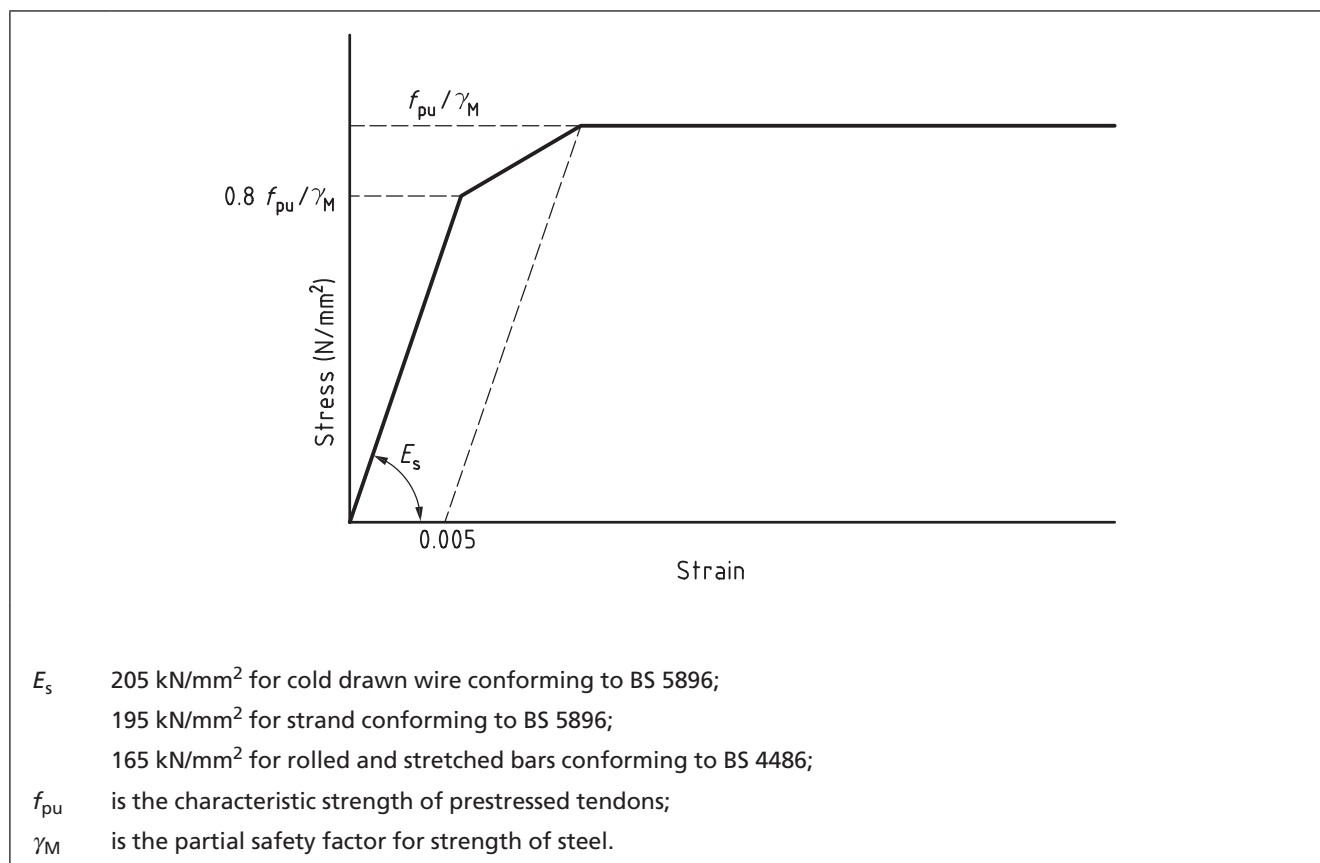
Where elastic methods of analysis are adopted, the following elastic moduli may be used in the absence of relevant test data:

- for concrete infill used in prestressed masonry, the appropriate value of the modulus of elasticity (taken from BS EN 1992-1-1) E_{cm} . Table 8 gives a simplified extract of the information in BS EN 1992-1-1;
- for all steel reinforcement and all types of loading, the elastic modulus, $E_s = 200 \text{ kN/mm}^2$;
- for prestressing tendons, the appropriate value of E_s as given in Figure 14.
- for masonry, the value of the modulus of elasticity E as given in NA to BS EN 1996-1-1:2005, **NA.2.9**.

Table 8 Elastic modulus for concrete infill, E_{cm}

Concrete strength class N/mm^2	E_{cm} kN/mm^2
16/20	29
20/25	30
25/30	31
30/37	33
40/50	35
50/60	37

Figure 14 Typical short-term design stress-strain curves for normal and low stress tendons



6.2 Unreinforced masonry detailed considerations

6.2.1 General

The following clauses contain detailed considerations for the construction of unreinforced masonry which are complementary and non-contradictory to those given in the BS EN 1996 series of Eurocodes.

6.2.2 Cavity walls – Wall ties

6.2.2.1 Selection and strength of wall ties

Table 9 to Table 12 give guidance on the selection of ties for normal application.

6.2.2.2 Density and positioning of wall ties

The density (number of wall ties per square metre) should be in accordance with NA to BS EN 1996-1-1:2005, **NA.2.16**. Wall ties should be evenly distributed except around openings, and should preferably be staggered. At the vertical edges of openings and at vertical unreturned or unbonded edges (for example at movement joints and up the sloping verge of gable walls), additional wall ties should be used at a rate of one tie per 300 mm height or equivalent, placed not more than 225 mm from the edge. (See Figure 15.)