British Standard

Code of practice for use of masonry —

Part 3: Materials and components, design and workmanship

ICS 91.080.30

Committees responsible for this British Standard

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Autoclaved Aerated Concrete Products Association

Brick Development Association

British Ceramic Research Ltd.

British Masonry Society

British Precast Concrete Federation

Construction Confederation

Concrete Block Association

Department of the Environment, Transport and the Regions represented by the Building Research Establishment

Department of the Environment, Transport and the Regions Construction Services Directorate

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Institution of Structural Engineers

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Contents

Foreword

This part of BS 5628 has been prepared under the direction of Subcommittee B/525/6, Use of masonry. It supersedes BS 5628-3:1985 and BS 5390, which are withdrawn.

This edition of BS 5628-3 is a full revision of the standard.

BS 5628 is published in the following parts:

— *Part 1: Structural use of unreinforced masonry*;

— *Part 2: Structural use of reinforced and prestressed masonry*;

— *Part 3: Materials and components, design and workmanship*.

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

Annex A to this standard repeats the content of BS 8000-3 in order to provide designers with the recommendations for basic workmanship necessary in order to achieve the design recommendations of this standard.

At the time of publication of BS 5628-3:2001, "ordinary" European Standard specifications (ENs) for masonry products have not yet been published as British Standards. (Some have, however, been ratified by CEN.) In addition the ENs do not contain the necessary content for them to be considered as harmonized European Standards. The conversion process from ENs to harmonized ENs is already underway via revision. Because of this incomplete situation this standard makes reference to neither ENs nor harmonized ENs for masonry products. However, it is expected that:

— BS EN 771, the specification for masonry units, will supersede BS 187, BS 3921, BS 6073, BS 6457 and BS 6649;

— BS EN 845, the specification for ancillary components, will supersede BS 1243, BS 5977-2, BS 6178 and DD 140-2;

— BS EN 998, the specification for mortar, will supersede BS 4721 and BS 5838-2.

Where materials, components and methods of design and construction are not covered by this or any other British Standard, this does not discourage their use. The designer may need to be satisfied by reference to the appropriate manufacturers' literature and test certificates, if any, issued by competent, independent authorities to ensure that the materials and methods to be employed provide a level of performance at least equal to that recommended in this standard.

As a code of practice this part of BS 5628 takes the form of guidance and recommendations. It should not be quoted as though it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

This standard was drafted on the assumption that the execution of its recommendations is entrusted to appropriately qualified and competent people.

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, pages i to vi, pages 1 to 123 and a back cover.

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1 Scope

This part of BS 5628 gives general recommendations for the design, construction and workmanship of masonry, including materials and components and the main aspects of design, other than structural, which is covered by BS 5628-1 and -2.

The recommendations in this standard are based on experience of single-leaf and cavity walls with and without insulation within the cavity.

No specific recommendations for the use of random rubble walling are given, the methods of construction and appearance of which will vary locally according to the type of stone available and traditional practice. However, general principles are laid down in this standard.

This standard does not cover the use of natural stone panels as cladding to structural masonry and steel and concrete frames.

NOTE Recommendations about the use of natural stone panels as cladding to structural masonry and steel and concrete frames are given in BS 8298.

This standard is not necessarily appropriate to the repair and restoration of old buildings. Guidance on cleaning and surface repair of masonry built of natural stone, cast stone and brick is given in BS 8221.

This standard does not necessarily cover the use of proprietary systems. The user is referred to the particular recommendations of any technical approval in this case.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part 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 12:1996, *Specification for Portland cement*.

BS 146:1996, *Specification for Portland blastfurnace cements*.

BS 187:1978, *Specification for calcium silicate (sandlime and flintlime) bricks*.

BS 476-20, *Fire tests on building materials and structures — Part 20: Method for determination of the fire resistance of elements of construction (general principles)*.

BS 476-21, *Fire tests on building materials and structures — Part 21: Methods for determination of the fire resistance of loadbearing elements of construction*.

BS 476-22, *Fire tests on building materials and structures — Part 22: Methods for determination of the fire resistance of non-loadbearing elements of construction*.

BS 476-23, *Fire tests on building materials and structures — Part 23: Methods for determination of the contribution of components to the fire resistance of a structure*.

BS 493, *Specification for airbricks and gratings for wall ventilation*.

BS 743, *Specification for materials for damp-proof courses*.

BS 882:1992, *Specification for aggregates from natural sources for concrete*.

BS 890, *Specification for building limes*.

BS 1047, *Specification for air-cooled blastfurnace slag aggregate for use in construction*.

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

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

BS 1197-2, *Specification for concrete flooring tiles and fittings — Part 2: Metric units*.

NOTE BS 1197-2 is obsolescent.

BS 1199 and 1200:1976, *Specifications for building sands from natural sources*.

BS 1243:1978, *Specification for metal ties for cavity wall construction*.

BS 1289-1, *Flue blocks and masonry terminals for gas appliances — Part 1: Specification for precast concrete flue blocks and terminals*.

BS 3148, *Methods of test for water for making concrete (including notes on the suitability of the water)*.

BS 3416:1991, *Specification for bitumen-based coatings for cold application, suitable for use in contact with potable water.*

BS 3797, *Specification for lightweight aggregates for masonry units and structural concrete.*

BS 3837-1, *Expanded polystyrene boards — Part 1: Specification for boards manufactured from expandable beads.*

BS 3837-2, *Expanded polystyrene boards — Part 2: Specification for extruded boards.*

BS 3892, *Pulverized-fuel ash.*

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

BS 4027:1996, *Specification for sulfate-resisting Portland cement.*

BS 4721, *Specification for ready-mixed building mortars.*

BS 4729, *Specification for dimensions of bricks of special shapes and sizes.*

BS 4841-1, *Rigid polyurethane (PUR) and polyisocyanurate (PIR) foam for building applications — Part 1: Specification for laminated board for general purposes.*

BS 4887-1, *Mortar admixtures — Part 1: Specification for air-entraining (plasticizing) admixtures.*

BS 5224, *Specification for masonry cement.*

BS 5268-5:1989, *Structural use of timber — Part 5: Code of practice for the preservative treatment of structural timber.*

BS 5262, *Code of practice for external renderings.*

BS 5440-1, *Installation of flues and ventilation for gas appliances of rated input not exceeding 60 kW (1st, 2nd and 3rd family gases) — Part 1: Specification for installation of flues.*

BS 5493:1977, *Code of practice for protective coating of iron and steel structures against corrosion.*

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

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

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 5838-2, *Specification for dry packaged cementitious mixes — Part 2: Prepacked mortar mixes.*

BS 5977-2, *Lintels — Part 2: Specification for prefabricated lintels.*

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

BS 6178-1, *Joist hangers — Part 1: Specification for joist hangers for building into masonry walls of domestic dwellings.*

BS 6213, *Selection of construction sealants — Guide.*

BS 6398:1983, *Specification for bitumen damp-proof courses for masonry.*

BS 6399-1, *Loading for buildings — Part 1: Code of practice for dead and imposed loads.*

BS 6399-2, *Loading for buildings — Part 2: Code of practice for wind loads.*

BS 6399-3, *Loading for buildings — Part 3: Code of practice for imposed roof loads.*

BS 6431, *Ceramic floor and wall tiles.*

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

BS 6461-1, *Installation of chimneys and flues for domestic appliances burning solid fuel (including wood and peat) — Part 1: Code of practice for masonry chimneys and flue pipes.*

BS 6510, *Specification for steel windows, sills, window boards and doors.*

BS 6515, *Specification for polyethylene damp-proof courses for masonry.*

BS 6561, *Specification for zinc alloy sheet and strip for building.*

BS 6588:1996, *Specification for Portland pulverized-fuel ash cements.*

BS 6649, *Specification for clay and calcium silicate modular bricks.*

BS 6676-1, *Thermal insulation of cavity walls using man-made mineral fibre batts (slabs) — Part 1: Specification for man-made mineral fibre batts (slabs).*

BS 6676-2, *Thermal insulation of cavity walls using man-made mineral fibre batts (slabs) — Part 2: Code of practice for installation of batts (slabs) filling the cavity.*

BS 6699, *Specification for ground granulated blastfurnace slag for use with Portland cement.*

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 7583:1996, *Specification for Portland limestone cement.*

BS 8000-2, *Workmanship on building sites — Part 2: Code of practice for concrete work.*

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

NOTE For the convenience of users of this standard the text of BS 8000-3 is reproduced here, in Annex A.

BS 8000-16, *Workmanship on building sites — Part 16: Code of practice for sealing joints in buildings using sealants.*

BS 8004:1986, *Code of practice for foundations.*

BS 8103, *Structural design of low-rise buildings.*

BS 8233:1999, *Sound insulation and noise reduction for buildings — Code of practice.*

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 — 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.*

BS EN 573-4, *Aluminium and aluminium alloys — Chemical composition and form of wrought products — Part 4: Forms of products.*

BS EN 942, *Timber in joinery — General classification of timber quality.*

BS EN 1304, *Clay roofing tiles for discontinuous laying — Products definitions and specifications.*

BS EN 1652:1998, *Copper and copper alloys — Plate, sheet, strip and circles for general purposes.*

BS EN 1806, *Chimneys — Clay/ceramic flue blocks for single wall chimneys — Requirements and test methods.*

BS EN 10025:1993, *Hot rolled products of non-alloy structural steels — Technical delivery conditions.*

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

BS EN 10111, *Continuously hot-rolled low carbon steel sheet and strip for cold forming — Technical delivery conditions.*

BS EN 10143:1993, *Continuously hot-dip metal coated steel sheet and strip — Tolerances on dimensions and shape.*

BS EN 12167, *Copper and copper alloys — Profiles and rectangular bar for general purposes.*

BS EN 12588:1999, *Lead and lead alloys — Rolled lead sheet for building purposes.*

BS EN 12878, *Pigments for the colouring of building materials based on cement and/or lime — Specifications and methods of test.*

BS ISO 11600, *Building construction — Sealants — Classification and requirements.*

BS EN ISO 12944, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems.*

BS EN ISO 14713:1999, *Protection against corrosion of iron and steel in structures — Zinc and aluminium coatings — Guidelines.*

DD 140-1, *Wall ties — Part 1: Methods of test for mortar joint and timber frame connections.*

DD 140-2:1987, *Wall ties — Part 2: Recommendations for design of wall ties.*

3 Terms and definitions

For the purposes of this part of BS 5628, the following terms and definitions apply.

NOTE Other associated definitions which may be of use to the user of this standard can be found in BS 6100-1 and -5.

3.1
ashlar
surface appearance of a vertical construction of plain blocks of stone, finely dressed and jointed to given dimensions and laid to courses
[BS 6100-5.2:1992, **520 3303**]

3.2
band course
plain contrasting course, that may be one of a number of courses, flush, projecting or recessed, carried horizontally along the face of a building or other structure
[BS 6100-5.1:1992, **510 2216**]

3.3
bed joint
horizontal joint in masonry
[BS 6100-5.1:1992, **510 1404**]

3.4
bond
<of materials> adhesion between materials
[BS 6100-1.5.2:1987, **152 1002**]

3.5
bond
<of masonry units> arrangement of masonry units

NOTE 1 Generally this arrangement is such that the vertical joints of one course do not coincide with those of courses immediately above and below.

NOTE 2 Adapted from BS 6100-5.1:1992, **510 1401**.

3.6
capping
construction that protects the top of a wall, but does not shed rainwater clear of the surfaces of the wall beneath
[BS 6100-5.1:1992, **510 1204**]

3.7
cavity tray
DPC that bridges a wall cavity to lead moisture to the external face of a wall
[BS 6100-5.3:1984, **530 4009**]

3.8
cavity wall
wall of two leaves effectively tied together and with a space between them

NOTE 1 The cavity is usually at least 50 mm wide.

NOTE 2 Adapted from BS 6100-1.3.1:1992, **131 2103**.

3.9
cavity wall insulation material
thermal insulation material positioned in a cavity
[BS 6100-1.3.1:1992, **131 2403**]

3.10
cavity wall tie
re-formed component built into the two leaves of a cavity wall to link them

NOTE Adapted from BS 6100-1.3.1:1992, **131 5219**.

3.11
cladding
external vertical, or near-vertical non-loadbearing covering to a structure
[BS 6100-1.3.1:1992, **131 1004**]

NOTE 1 Cladding is generally subject to lateral loading.

NOTE 2 Cladding may be continuous or in panels.

3.12
closer
portion of a masonry unit used to maintain bond
[BS 6100-5.3:1984, **530 1019**]

3.13
collar joint
wall joint within a wall or vertical joint between walls built in parallel, continuous throughout height and length
[BS 6100-5.1:1992, **510 1409**]

3.14
collar-jointed wall
wall of two leaves (not more than 25 mm apart and effectively tied together) that enable both exposed faces to be built fair faced

NOTE 1 The term "collar-jointed wall" is also known as "double-leaf wall".

NOTE 2 Adapted from BS 6100-1.3.1:1992, **131 2104**.

3.15
coping
construction that protects the top of a wall, balustrade or parapet and sheds rainwater clear of the surfaces beneath
[BS 6100-5.1:1992, **510 1205**]

3.16
course
single layer of masonry units of uniform height, including the bed joint
[BS 6100-5.1:1992, **510 1303**]

3.17
cross joint
joint, other than a bed joint, usually at right angles to the face of a wall
[BS 6100-5.1:1992, **510 1406**]

3.18
damp-proof course
DPC
device, usually comprising a layer or strip of material, placed within a wall, chimney or similar construction to prevent passage of moisture
[BS 6100-5.1:1992, **510 1503**]

3.19
damp-proof course brick
clay brick that is used to resist rising damp
[BS 6100-5.3:1984, **530 2015**]

NOTE The properties of damp-proof course bricks are specified in BS 3921.

3.20
datum
reference point for a series of measurements
[BS 6100-1.5.3:1988, **153 1015**]

3.21
diaphragm wall
wall of two leaves of masonry, separated by a wide cavity, but connected by vertical webs of masonry to improve structural performance

NOTE Adapted from BS 6100-1.3.1:1992, **131 2109**.

3.22
drip
projection below a horizontal surface that prevents water flowing back to a wall
[BS 6100-5.1:1992, **510 1504**]

3.23
efflorescence
crystalline deposit of salts on a surface as a result of the evaporation of water from a salt solution

NOTE Adapted from BS 6100-5.1:1992, **510 4001**.

3.24
face insulated block
block with thermal insulation material bonded to one face during manufacture

3.25
fair faced
surface built neatly and evenly without applied finish
[BS 6100-5.1:1992, **510 2202**]

3.26
fixed support
support to the edge of a wall that restrains the wall against lateral movement and also substantially against rotation

3.27
free-standing wall
wall or part of a wall, exposed on both faces, that stands above any horizontal lateral support
[BS 6100-1.3.1:1992, **131 2110**]

3.28
frog
depression formed in one or both of the largest surfaces of a brick
[BS 6100-5.3:1984, **530 2003**]

3.29
grouted reinforced cavity wall
cavity wall, designed to resist mainly lateral loading, in which reinforcement surrounded by concrete or mortar is located in the cavity

NOTE Adapted from BS 6100-1.3.1:1992, **131 2107**.

3.30
header
shorter face of a masonry unit showing on the face of a wall
[BS 6100-5.3:1984, **530 1017**]

3.31
insulation board
rigid rectangular unit of thermal insulation material of uniform thickness, typically of cellular plastic material

3.32
insulation slab
resilient, semi-rigid, rectangular unit of thermal insulation material of uniform thickness, usually of mineral wool
[BS 6100-1.3.1:1992, **131 2411**]

NOTE The term "insulation slab" was previously sometimes referred to as "insulation batt".

3.33
jamb
vertical part of a wall at an opening
[BS 6100-1.0:1999, **100 3323**]

3.34
jointing
forming and finishing mortar joints as work proceeds without pointing

NOTE Adapted from BS 6100-5.1:1992, **510 1410**.

3.35
lime bloom
film of calcium carbonate formed by carbonation of calcium hydroxide leached to the surface of masonry
[BS 6100-5.1:1992, **510 4002**]

3.36
lintel
beam supporting loads over an opening
[BS 6100-1.3.1:1992, **131 2306**]

3.37
masonry
construction of bricks or blocks

NOTE Adapted from BS 6100-5.1:1992, **510 1101**.

3.38
masonry unit
brick or block

3.39
mortar
mix of one or more inorganic binders, aggregates, water, and sometimes additives and/or admixtures

3.40
mortar joint
joint between masonry units filled with mortar
[BS 6100-5.1:1992, **510 1411**]

3.41
movement joint
joint designed and located in masonry to accommodate movement

NOTE Movement may be due to, for example, changes in temperature and/or moisture content.

3.42
panel wall
wall that forms an in-filling between structural members
[BS 6100-1.3.1:1992, **131 2118**]

3.43
perforation
void which passes through a masonry unit

3.44
perpend joint
vertical cross joint that appears in the face of a wall between two masonry units

NOTE Adapted from BS 6100-5.1:1992, **510 1408**.

3.45
pistol unit
brick with accurately sized rebate, manufactured or sawn from a whole brick

NOTE Pistol units are often used to fit over and mask a support.

3.46
pointing
filling a partly raked back mortar joint to provide a finish
[BS 6100-5.1:1992, **510 1419**]

3.47
quoin
block of a special shape for the construction of a corner

NOTE Adapted from BS 6100-5.1:1992, **510 2208**.

3.48
reference panel
panel of masonry erected and retained on a building site, used to establish the visual acceptability of materials and workmanship to be maintained during construction work

3.49
retaining wall
wall designed to resist lateral pressure from a mass of material

NOTE Adapted from BS 6100-1.0:1999, **100 1205**.

3.50
rubble
stone of irregular shape and size
[BS 6100-5.2:1992, **520 1614**]

3.51
sample panel
panel of masonry erected on a building site as a means of comparing materials with an established reference panel

3.52
shell bedding
bedding consisting of two separate strips of mortar at the outer and inner faces of blocks in horizontal joints

3.53
simple support
support to the edge of a wall that may permit rotation but restrains the wall against lateral movement

3.54
single-leaf wall
solid wall of bricks or blocks laid to overlap in one or more directions
[BS 6100-1.3.1:1992, **131 2101**]

3.55
sleeper wall
low loadbearing wall to provide intermediate support to a suspended ground floor

NOTE Adapted from BS 6100-1.3.1:1992, **131 2116**.

3.56
slip
brick or block specially manufactured or cut to a thickness of between 20 mm and 50 mm

NOTE Adapted from BS 6100-5.3:1984, **530 2013**.

3.57
slip tie
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

NOTE Slip ties are usually a metal straight rod or metal flat strip.

3.58
soldier course
course of masonry units set on their ends with their stretcher faces visible
[BS 6100-5.1:1992, **510 4005**]

3.59
solid brick
brick without frogs or with frogs up to 20 % of its volume, but with no through holes or perforations

3.60
special shaped brick
brick with shape or size other than a standard parallel faced rectangular prism

3.61
stretcher
longer face of a masonry unit showing on the face of a wall
[BS 6100-5.3:1984, **530 1018**]

3.62
string course
moulded course, that may be one of a number of courses, that projects from a wall
[BS 6100-5.1:1992, **510 2217**]

3.63
veneered wall
wall of which the facing and backing are joined, but not designed to result in common action under load
[BS 6100-1.3.1:1992, **131 2114**]

3.64
weathered
having an upper surface sloped to throw off water
[BS 6100-5.1:1992, **510 1505**]

3.65
weathering
sloped surface to throw off water

3.66
weephole
hole through a wall that drains water to its outer face
[BS 6100-5.1:1992, **510 1506**]

4 Materials and components

4.1 General

Recommendations concerning the durability of materials and components are given in **5.6**.

NOTE A checklist for ordering clay and calcium silicate bricks is given in Annex E.

4.2 Masonry units

NOTE Consideration needs to be taken if working with units of greater than 20 kg. Guidance on regulatory requirements and design options to avoid heavy units can be found in manufacturers' literature or in [1].

4.2.1 *Clay*

Clay masonry units should conform to:

— BS 3921 or BS 6649 for clay bricks;

— BS EN 1806 for clay flue blocks.

4.2.2 *Calcium silicate*

Calcium silicate masonry units should conform to BS 187 or BS 6649.

4.2.3 *Concrete*

Concrete masonry units should conform to:

— BS 1289-1 for concrete flue blocks;

— BS 6073-1 for precast concrete masonry units;

— BS 6457 for reconstructed stone masonry units.

4.2.4 *Special shaped bricks*

Special shaped bricks should conform to BS 4729.

4.2.5 *Natural stone*

For a particular application stone should be selected with regard to availability in sufficient quantities in the desired colour and unit size.

NOTE Primary classification of building stones is ordered into the three major groups:

— igneous stone (principally granite, basalt, diorite and serpentine);

— sedimentary stone (principally limestone and sandstone); and

— metamorphic stone (principally slate and marble).

4.3 Materials for mortar

NOTE Epoxy and polymer resins can be used in various forms to joint masonry.

4.3.1 *Cement*

Cement should conform to:

— BS 12:1996, Class 42.5/32.5 for Portland cement;

— BS 4027:1996, Class 42.5 for sulfate-resisting Portland cement;

— BS 146:1996, Class 42.5/32.5 for Portland blastfurnace cements;

NOTE 1 Only Portland blastfurnace cements in which the ground granulated blastfurnace slag is limited to a maximum of 35 % may be taken as equivalent to Portland cement for use in mortar.

— BS 6588:1996, Class 42.5/32.5 for Portland pulverized-fuel ash cements;

NOTE 2 Only Portland pulverized-fuel ash cements in which the pulverized-fuel ash (fly ash) content is limited to 35 % may be taken as equivalent to Portland cement for use in mortar.

NOTE 3 Both Portland blastfurnace cements and Portland pulverized-fuel ash cements may be produced by weigh batching and blending at a mixer, using cement conforming to BS 12, blastfurnace slag to BS 6699 or pulverized fuel ash to BS 3892.

— BS 7583:1996, Class 42.5/32.5 for Portland limestone cement;

— BS 5224 for masonry cement.

4.3.2 ***Limes***

Limes should conform to BS 890.

4.3.3 ***Sand and aggregates***

4.3.3.1 *Natural aggregates*

Aggregates from natural sources should conform to:

— BS 1199 and 1200 for aggregates for mortar;

— BS 882 for aggregates for concrete.

4.3.3.2 *Lightweight aggregates*

Lightweight aggregates should conform to BS 3797.

4.3.4 ***Pre-mixed mortars***

4.3.4.1 *Ready-mixed lime:sand for mortar*

Ready-mixed lime:sand for gauging with cement should conform to BS 4721.

4.3.4.2 *Retarded ready-to-use mortars*

Ready-to-use retarded cement:lime:sand and cement:sand mortars should conform to BS 4721.

NOTE 1 As used here, "sand" includes all recommended aggregates.

NOTE 2 Ready-to-use building mortars are factory made mortars which contain cement set-retarding admixtures. No further treatment is necessary before use.

4.3.4.3 *Dry pre-packed cementitious mortar mixes*

Dry pre-packed cementitious mortar mixes should conform to BS 5838-2.

4.3.5 ***Admixtures and additions***

4.3.5.1 *Mortar plasticizers*

Mortar plasticizers should conform to BS 4887-1.

NOTE For guidance on use see **5.7.1.3** and BS 8000-2.

4.3.5.2 *Colouring pigments*

Pigments used for colouring mortars should conform to BS EN 12878.

4.3.6 ***Water***

Water should be clean and should not contain any material, either in solution or in suspension, in a quantity sufficient to either have harmful effect on the mortar or on metals, or to impair the durability of the construction. In practice, mains water or other potable supplies are satisfactory. However, in cases where water supplies are of doubtful quality, the methods of water sampling and testing should conform to BS 3148.

4.4 Cavity wall ties

Cavity wall ties should conform to BS 1243 or DD 140-1. For guidance on the selection and use of cavity wall ties see Table 1 for corrosion resistance and **5.3.5**.

4.5 Metal support and restraint components

4.5.1 *General*

Materials that should be used for support and restraint components (such as angles, brackets, anchorages, dowels and fixings, including bonding ties, joist hangers and lateral restraint straps) are given in Table 1.

In selecting metal support and restraint component materials, Table 1, **5.6.7.1** and Table 2 should be considered together.

NOTE 1 A variety of metal components is available to tie and provide restraint for masonry cladding. Typical applications are illustrated in Figure 7, Figure 8, Figure 9, Figure 10, Figure 11, Figure 12 and Figure 13.

NOTE 2 A variety of metal components is available to support masonry cladding panels and corbelled forms of masonry. Typical applications are illustrated in Figure 16 and Figure 17.

Table 1 — Materials for metal support and restraint components and recommended protection levels

Durability category	Base material	Form	Grade and standard that should be conformed to	Protective measures to be carried out after fabrication
A	Hot-dip galvanized low carbon steel	Sheet	BS EN 10143:1993, Z1 or Z2, coating type G 600. Minimum mass of coating 600 g/m² including both sides	All external cut edges to be protected using a one-pack chemical resistant paint conforming to HF1A to HF2F in part 4 of Table 4H of BS 5493:1977 and modified to give adequate adhesion to the fixing.[a]
			BS EN 10143:1993, Z1 or Z2, coating type G 275. Minimum mass of coating 275 g/m² including both sides	Coating to be applied after fabrication to the external surfaces and consisting of either: a) solution conforming to types 1 or 2 of BS 3416:1991 and of minimum thickness 25 µm; or b) a one-pack chemical resistant paint conforming to HF1A to HF2F in part 4 of Table 4H of BS 5493:1977 and modified to give adequate adhesion to the fixing.[a] Where the zinc is removed on internal surfaces during fabrication, e.g. by welding, further protection should be applied to these areas.
B	Low carbon steel	Strip	BS EN 10111	Post-galvanizing conforming to BS EN ISO 1461. Minimum mass of coating of 920 g/m² including both sides, i.e. 460 g/m² on any surface.
			BS EN 10025:1993 grade S275J0	
C	Low carbon steel	Strip	BS EN 10111	Post-galvanizing conforming to BS EN ISO 1461. Minimum mass of coating of 1 880 g/m² including both sides, i.e. 940 g/m² on any surface.
			BS EN 10025:1993 grade S275J0	

[a] BS 5493:1977 has been proposed for obsolescence and has been partially replaced by BS EN ISO 12944 and BS EN ISO 14713.

Table 1 — Materials for metal support and restraint components and recommended protection levels *(concluded)*

Durability category	Base material	Form	Grade and standard that should be conformed to	Protective measures to be carried out after fabrication
D	Copper alloys	—	BS EN 1172 BS EN 12167	Material other than phosphor bronze to be formed either: a) by bending at dull red heat and allowing to cool in still air; or b) by cold forming and subsequently stress relief annealing at 250 °C to 300 °C for 30 min to 1 h. Effectiveness of stress relieving of cold formed components to be tested by the supplier using the mercurous nitrate test described in BS EN ISO 196.
	Austenitic stainless steel minimum 18/8 composition and excluding free machining specifications	Strip, bar, rod, tube or wire	BS EN 10088-1	—
E	Austenitic stainless steel minimum 18/8 composition and excluding free machining specifications (molybdenum chrome nickel alloys only)	Strip, bar, rod, tube, wire	BS EN 10088-1	—

Table 2 — Protection of metal support and restraint components (including wall ties) built into masonry

Type of component	Situation	Durability category of exposure given in Table 1 (materials and recommended protection)		
		For buildings not exceeding three storeys	For buildings exceeding three storeys	For buildings located in an aggressive environment (e.g. coastal sites)
Sliding anchors, anchorages, bonding ties, shear ties, brick slip ties, continuous support angles, support brackets and cavity wall ties	In contact with, or embedded in, an internal wall only	All categories		
	In contact with, or embedded in, an inner leaf of an external cavity wall	C, D or E	D or E	E
	In contact with, or embedded in, an outer leaf of an external cavity wall or a single-leaf external wall			
Dowels and restraint straps, joist hangers and reinforcement for non-structural use	In contact with, or embedded in, an internal wall only	All categories		
	In contact with, or embedded in, an inner leaf of an external cavity wall	A, B, C, D or E	A, B, C, D or E	E
	In contact with, or embedded in, an outer leaf of an external cavity wall or a single-leaf external wall	C, D or E	D or E	E
Lintels installed with or without a DPC tray	All situations	As specified in BS 5977-2 for the appropriate type of lintel (i.e. installed with or without a DPC tray)	Not normally applicable. If used special conditions may be necessary	

4.5.2 *Joist hangers*

Joist hangers for vertical support only should conform to BS 6178-1.

4.6 Reinforcement

Reinforcement and post tensioning for structural use should follow the recommendations of BS 5628-2.

Reinforcement for non-structural use, e.g. crack control (see **5.4.5**), should be protected against corrosion (see **5.6.7**).

4.7 Damp-proof courses (DPCs), including cavity trays

Materials for DPCs and cavity trays should conform to:

— BS 6398 for bitumen;

— BS 3921 and BS 743 for damp-proof course bricks;

— BS 6515 for polyethylene;

— BS 743 for all others.

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

NOTE The suitability criteria for materials for DPCs are set out in **5.5.5** and Table 3.

Table 3 — Physical properties and performance of materials for DPCs

Material	Minimum mass kg/m²	Minimum thickness mm	Joint treatment to prevent water moving: Upward	Joint treatment to prevent water moving: Downward	Liability to extrusion	Durability	Other considerations
(A) Flexible *(continued)*							
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, grades C104 or C106 in the O condition	Approximately 2.28	0.25	Lapped at least 100 mm	Welded or welted	Not under pressure met in normal construction	Highly resistant to corrosion. If soluble salts are present, protected 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, E and F 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 A 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 3 — Physical properties and performance of materials for DPCs *(continued)*

Material	Minimum mass	Minimum thickness	Joint treatment to prevent water moving		Liability to extrusion	Durability	Other considerations
	kg/m²	mm	Upward	Downward			
(A) Flexible *(concluded)*							
Polyethylene, low density (0.915 g/cm³ to 0.925 g/cm³) complying with BS 6515	Approximately 0.5	0.46	Seal with double-sided adhesive tape	Welted	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 movements normally occurring up to the point of failure of the wall	Accommodates considerable lateral movement. When used as a cavity tray, pre-formed 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/mm²	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 3 — Physical properties and performance of materials for DPCs *(concluded)*

Material	Minimum mass kg/m²	Minimum thickness mm	Joint treatment to prevent water moving		Liability to extrusion	Durability	Other considerations
			Upward	Downward			
(C) Rigid							
DPC bricks of Designation 1 or 2 conforming to BS 3921:1985	—	Two courses, laid to break joint, bedded in 1:3 Portland cement: sand	No joint problems	Not suitable	—	No deterioration	Particularly appropriate where DPC is required to transmit tension, e.g. in freestanding walls. DPC Designation 1 bricks are required for buildings. DPC Designation 1 or 2 may be used in external works
Slate conforming to BS 743 and most granites	—	Two courses, laid to break joint, bedded in 1:3 Portland cement: sand	No joint problems	Not suitable	—	No deterioration	—

4.8 Sealants

Sealants should conform to BS 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.

NOTE Guidance on the application of sealants and on back-up materials in sealed joints is given in **5.4.4**.

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.

4.9 Airbricks, gratings and flues

Airbricks and gratings should conform to BS 493. Flues should follow the recommendations given in BS 5440-1 or BS 6461-1, as appropriate.

Unless satisfactory local experience exists, clay products should not be used in limestone masonry or concrete products used in sandstone masonry. These restrictions avoid the risk of attack by run-off from limestone and concrete, respectively.

4.10 Sills

Sills can be purpose made components or can be constructed from suitably durable materials. Sill materials should conform to the British Standards given in Table 4.

NOTE For guidance on DPCs below sills, see **5.5.7.6**.

Table 4 — Sill materials

Material	Standard that should be complied with
Brick and block	BS 187, BS 3921 or BS 6073-1 and BS 4729
Cast 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, BS EN 942 and BS 5642-1

4.11 Lintels

Lintels should conform to the appropriate British Standard given in Table 5.

NOTE At present lintels of natural stone are not specified in any published British Standard.

Table 5 — Lintels

Material	Standard that should be complied with
Autoclaved aerated concrete Cast concrete Reinforced concrete Prestressed concrete	BS 5977-2
Pressed steel Rolled low carbon steel	BS 5977-2
Reinforced masonry	BS 5628-2
Timber	BS 5977-2

4.12 Copings

Copings can be purpose made components or can be constructed from suitably durable materials. Coping components and/or materials and the British Standard to which they should conform are given in Table 6.

NOTE 1 For guidance on the design of and the need for DPCs below copings, see **5.5.7.13**.

NOTE 2 Table 13 provides information regarding the durability of masonry in finished construction.

Table 6 — Copings

Material	Standard that should be complied with	Recommended thickness mm
Aluminium	BS EN 515, BS EN 573-3, BS EN 573-4, BS EN 485-1 and BS EN 485-2	0.6 to 0.9
Brick and block	BS 187, BS 3921 or BS 6073-1 and BS 4729	—
Cast stone	BS 5642-2	—
Clay tile	BS EN 1304 or BS 6431	—
Concrete (cast)	BS 5642-2	—
Concrete tile	BS EN 490 or BS 1197-2	—
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[a]
Natural stone	BS 5642-2	—
Zinc	BS 6561	not less than 0.8

[a] Code number 4 in BS EN 12588:1999.

4.13 Flashings and weatherings

Flashings and weatherings should conform to the relevant British Standards given in Table 7.

NOTE For guidance on the use of flashings and weatherings, see **5.5.7.12**.

Table 7 — Flashings and weatherings

Material	Standard that should be complied with	Recommended thickness mm
Aluminium alloy	BS EN 485-1, BS EN 485-2, BS EN 573-3, BS EN 573-4, 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[a]

[a] Code number 4 in BS EN 12588:1999.

4.14 Insulation materials

Insulation materials should conform to the relevant British Standard given in Table 8.

NOTE Insulation materials may be installed in the cavity of a cavity wall to partially or fully fill it (see **5.5.4.2.7**). Insulation materials are produced in different forms to suit the various installation methods used (see Table 8 and **A.5.4.4**).

Table 8 — Insulation materials

Insulation material	British Standard	Code of practice for installation
(A) For installation during construction of masonry to fill the cavity partially		
Mineral wool slabs (glass or rock fibre)	—	—
Expanded polystyrene bead boards	BS 3837-1	—
Extruded expanded polystyrene boards	BS 3837-2	—
Polyurethane (PUR) boards	BS 4841-1	—
Polyisocyanurate (PIR) boards	BS 4841-1	—
Foamed glass slabs	—	—
(B) For installation during construction of masonry to fill the cavity fully		
Mineral wool insulation slabs (glass or rock fibre)	BS 6676-1	BS 6676-2
(C) 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

5 Design

5.1 General

5.1.1 *Factors to be considered*

When designing masonry, the following factors should be taken into account. For:

— choice of masonry unit materials see **4.2**;
— structural stability see **5.2** and **5.3**;
— accommodation for movement see **5.4**;
— resistance to rain penetration see **5.5**;
— durability see **5.6**;
— mortar for jointing see **5.7**;
— performance in fire see **5.8**;
— thermal properties see **5.9**;
— sound control see **5.10**;
— masonry bonds and other constructional details see **5.11** and Annex C;
— the appearance of fair faced masonry see Annex D;
— workmanship see clause **6**;
— health and safety issues see also note to **4.2**.

5.1.2 *Loading*

The dead, imposed and wind loads to be allowed for during the structural design of masonry should be in accordance with BS 6399-1, -2 and -3.

5.1.3 *Foundations*

The design of foundations should be in accordance with the recommendations of BS 8004:1986.

5.2 Design for stability

5.2.1 *Masonry in general*

Masonry should be designed to have strength, stiffness and stability suitable for the intended purpose. Consideration should be given to the interaction of the whole structure, of which the masonry forms a part. Connections of other elements with the walls should be sufficient so as to transmit all vertical and lateral loads safely to the foundations. If necessary during construction, temporary support for masonry should be used, e.g. where composite action is required.

The structural design of masonry should be in accordance with the recommendations of BS 5628-1 and -2, and for low-rise buildings should be in accordance with the recommendations of BS 8103.

The stiffness and stability should be derived from one or more of the following, depending upon the type of masonry:

a) thickness in relation to height and length;

NOTE The effective thickness of the wall is reduced by chases and/or recessed joints.

b) self weight;

c) presence of piers;

d) interaction with other walls, columns, floors, roofs or structural elements.

The effect of introducing openings, movement joints or slip planes should be carefully considered.

The need for robust construction, including the effect of accidental loading should always be taken into account in the design.

5.2.2 *Walls subjected to concentrated loads*

Where a concentrated load occurs in a wall, e.g. at a lintel or beam bearing, provision should be made for the local bearing stress in the design (see BS 5628-1). Where necessary, suitable bearing plates, spreader beams, padstones, piers or columns should be provided. (For lintels or beam bearings see **5.3.4**.)

Certain types of cellular, frogged or hollow unit which are otherwise suitable for the construction of the wall may not provide sufficient bearing strength at points of concentrated load and may need to be filled.

5.2.3 *Walls subjected to imposed lateral load only*

5.2.3.1 *Free-standing walls*

The design of free-standing walls should be in accordance with the recommendations of BS 5628-1 or -2.

NOTE Empirical guidance on maximum height and minimum foundation width of brick or block masonry free-standing walls is given in [2]. Similar guidance on reinforced, diaphragm and wide plan (e.g. chevron and staggered) free-standing walls, in addition to guidance on steel reinforcement size, is given in [3].

5.2.3.2 *Walls with edge restraint*

5.2.3.2.1 *Maximum areas of walls*

The design of walls with edge restraint which are subject to wind loads should be in accordance with the recommendations of BS 5628-1. However, certain rectangular walls and gables in buildings up to and including four storeys high may be proportioned as in Table 9, subject to the following conditions.

a) The walls should be in buildings no higher than four storeys, situated in the wind zones shown in Figure 1.

NOTE The effective thickness of the wall will be reduced by chases and/or recessed joints.

b) The walls should be free from any doors, windows or other openings, unless either:

— intermediate supports are provided, such as those shown in Figure 2a); or

— the total area of such openings is not greater than 10 % of the appropriate maximum area given in Table 9, or 25 % of the actual area of the wall, whichever is the less, and no opening is less than half its maximum dimension from the edge of the wall, other than its base, or from any other opening [see Figure 2b)].

c) In a single-leaf, collar-jointed or grouted reinforced cavity wall, the distance between the supports should be not more than 40 times the total thickness of the wall.

d) Interaction with other walls, columns, floors, roofs or structural elements.

e) In a cavity wall:

— the distance between supports should be not more than 30 times the total thickness of the masonry in the wall;

— the thickness of each leaf should be not less than 100 mm, excluding plaster or render;

— the cavity width should be not more than 100 mm;

— wall ties should be spaced in accordance with **5.3.5** and **A.5.4.2**.

f) Pitched-gable ends which have support at the top (see **5.3.3**) should be regarded as equivalent to a rectangular area the height of which is measured to half way up the triangular portion [see Figure 2c)]. Three- or four-sided support should be assumed as appropriate.

g) Mortar should not be weaker than Designation (iii) (see Table 14).

Table 9 — Maximum permitted areas of certain types of wall in square metres (m²)

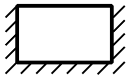
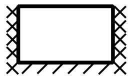
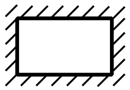
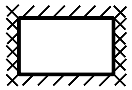
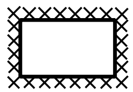
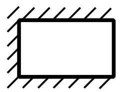
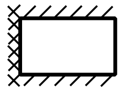
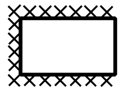
Wind zone	Height m	Category and type of wall					
							
		A		B		C	
		Cavity wall	190 mm solid wall	Cavity wall	190 mm solid wall	Cavity wall	190 mm solid wall
1	5.4	11.0	13.5	17.5	19.0	26.5	28.5
	10.8	9.0	11.5	13.0	15.5	17.5	21.5
2	5.4	9.5	12.0	14.0	17.0	21.0	24.0
	10.8	8.0	9.5	11.5	14.0	13.5	17.5
3	5.4	8.5	10.5	12.5	15.0	15.5	20.0
	10.8	7.0	8.5	10.0	12.0	11.5	15.5
4	5.4	8.0	9.5	11.0	13.5	13.0	17.0
	10.8	6.5	7.5	9.0	11.0	10.5	13.5
Wind zone	**Height m**	**Category and type of wall**					
							
		D		E		F	
		Cavity wall	190 mm solid wall	Cavity wall	190 mm solid wall	Cavity wall	190 mm solid wall
1	5.4	20.5	29.0	32.0	41.0	32.0	41.0
	10.8	15.5	23.5	24.0	32.5	32.0	41.0
2	5.4	17.5	25.5	27.0	35.5	32.0	41.0
	10.8	13.0	20.5	19.0	28.5	28.0	36.5
3	5.4	14.5	22.5	22.0	31.0	30.5	40.5
	10.8	11.0	17.5	14.5	24.5	24.5	31.5
4	5.4	12.5	19.5	18.0	27.5	27.0	35.0
	10.8	9.5	14.5	12.5	21.0	21.5	27.5

Table 9 — Maximum permitted areas of certain types of wall in square metres (m^2) *(concluded)*

Wind zone	Height m	Category and type of wall					
							
		G		H		I	
		Cavity wall	**190 mm solid wall**	**Cavity wall**	**190 mm solid wall**	**Cavity wall**	**190 mm solid wall**
1	5.4	8.5	10.0	14.0	19.0	19.5	30.5
	10.8	7.0	8.0	10.0	14.5	15.5	21.5
2	5.4	7.5	8.5	10.5	16.5	17.0	24.5
	10.8	6.0	7.0	9.0	11.0	13.0	17.5
3	5.4	6.5	7.5	9.5	13.5	14.5	20.0
	10.8	5.0	6.0	7.5	9.0	11.5	15.0
4	5.4	6.0	6.5	8.5	10.5	12.5	17.0
	10.8	4.0	5.5	6.5	7.5	10.0	12.5

NOTE 1 Types of support are described in **5.2.3.2.2** and are represented as:

a) free edge;

b) simple support;

c) fixed support.

NOTE 2 The term "solid" is used in this table to denote single-leaf walls, collar-jointed walls (see **3.14**) or grouted reinforced cavity walls. The 190 mm solid walls are of any brick, or blocks of compressive strength not less than 3.5 N/mm^2.

NOTE 3 Cavity walls consist of:

a) an outer leaf, 100 mm minimum in thickness, of any brick, or blocks of compressive strength not less than 14.0 N/mm^2;

b) an inner leaf, 100 mm minimum in thickness, of any brick, or blocks of compressive strength not less than 3.5 N/mm^2.

If either leaf of a cavity wall is increased to 140 mm using blocks of the respective strength, the areas given in this table may be increased by 20 %.

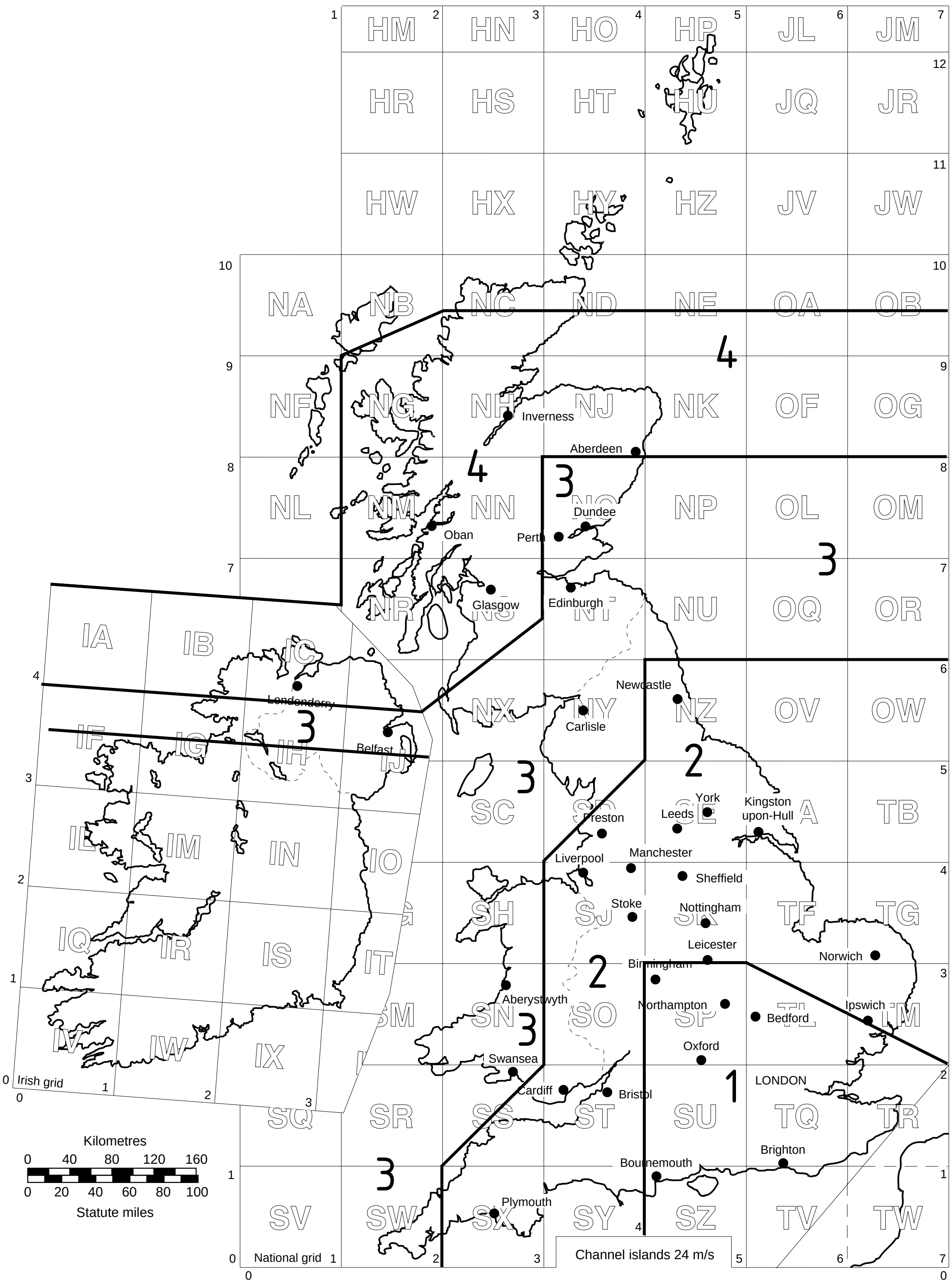
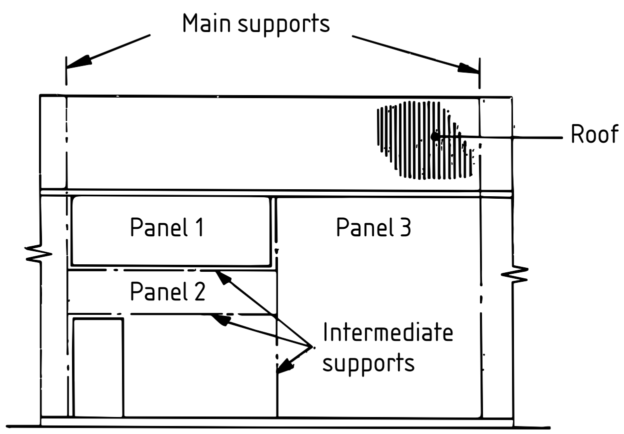
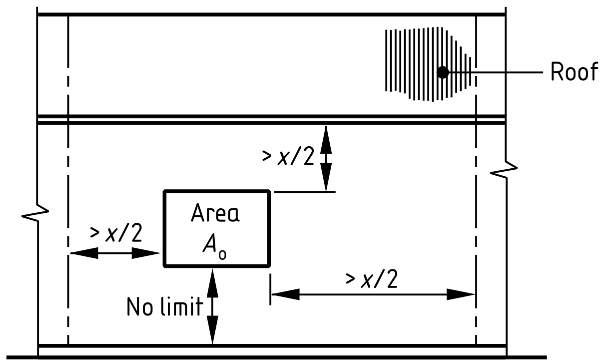


Figure 1 — Wind zones



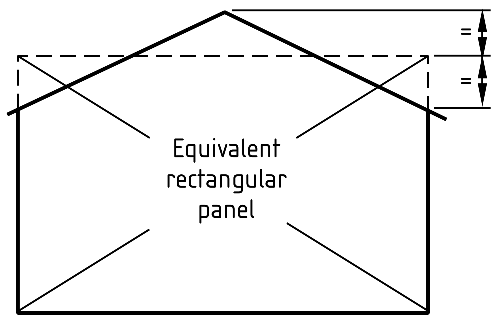
a) Example of division of a wall into panels with intermediate supports



b) Effect of opening in a wall where

x is the maximum dimension of opening (height or length);

A_0 is the permitted area of opening



c) Gable walls

Figure 2 — Walls with edge restraint

5.2.3.2.2 *Support conditions*

The wall should be adequately connected to its support and all supports should be sufficiently strong and rigid to carry the transmitted loads (see Figure 3). A fixed support may be assumed in a single-leaf, collar joint or grouted-cavity wall in the cases shown in Figure 3a) and Figure 4 or where the wall abuts, and is adequately tied to, a column capable of resisting horizontal forces applied to it without excessive deflection.

Dimensions in millimetres

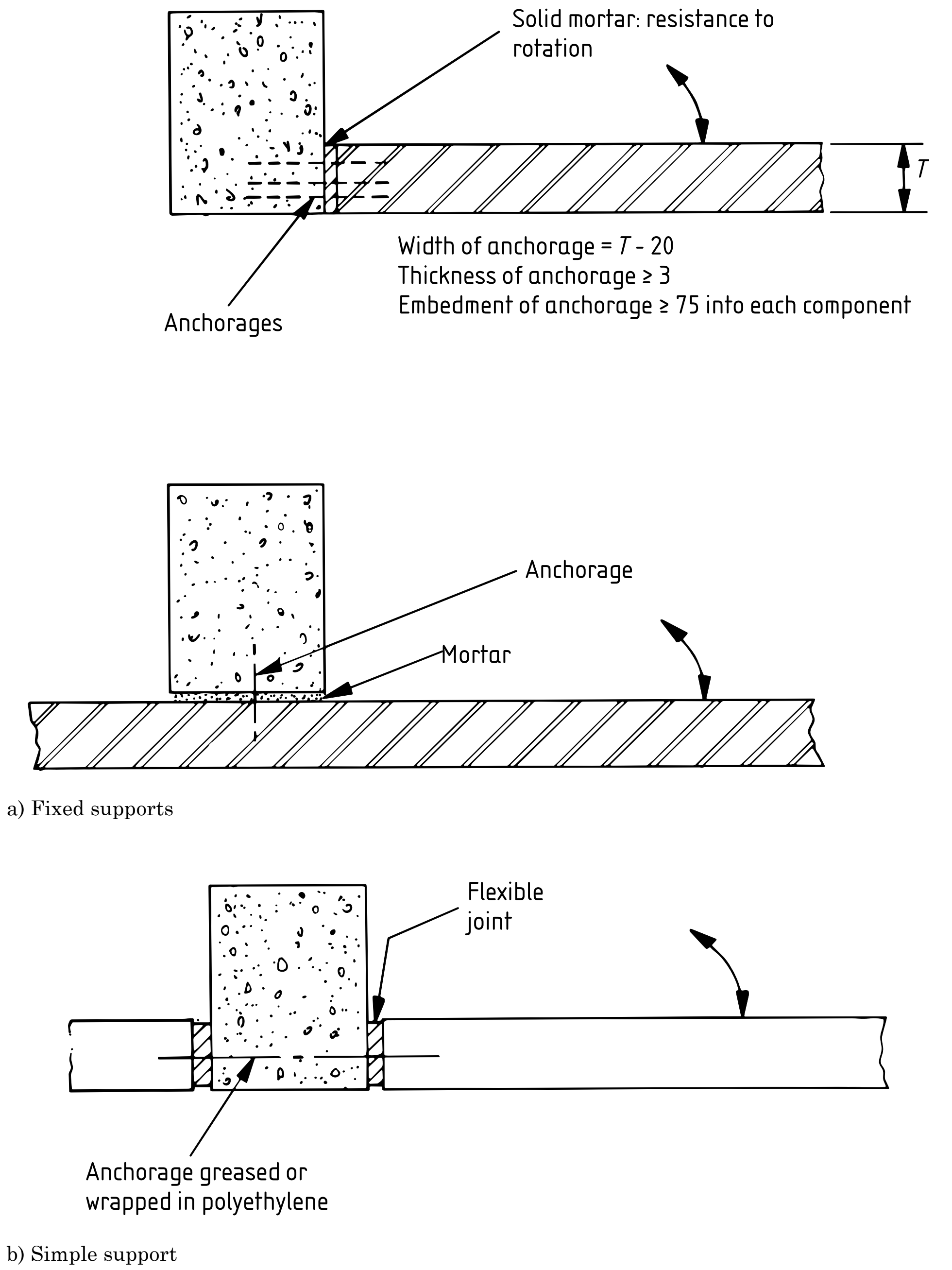


Figure 3 — Simple and fixed supports

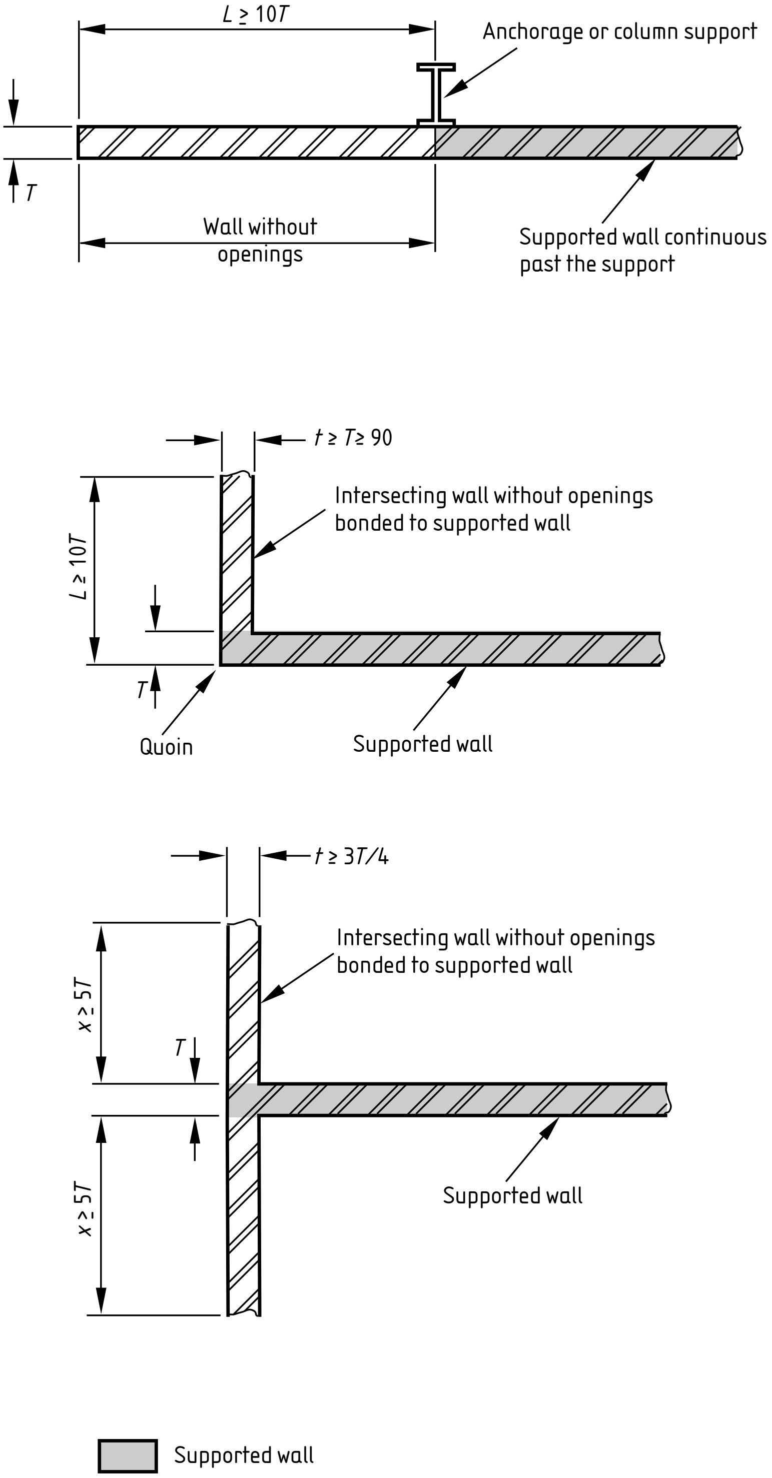


Figure 4 — Fixed support assumed in a single-leaf, collar joint or grouted-cavity wall

A fixed support may be assumed in a cavity wall in the cases shown in Figure 5.

A simple support may be assumed where the wall is permitted to rotate but is restrained against lateral movement.

The design should contain provisions for any chases cut in the wall (see **5.3.8**).

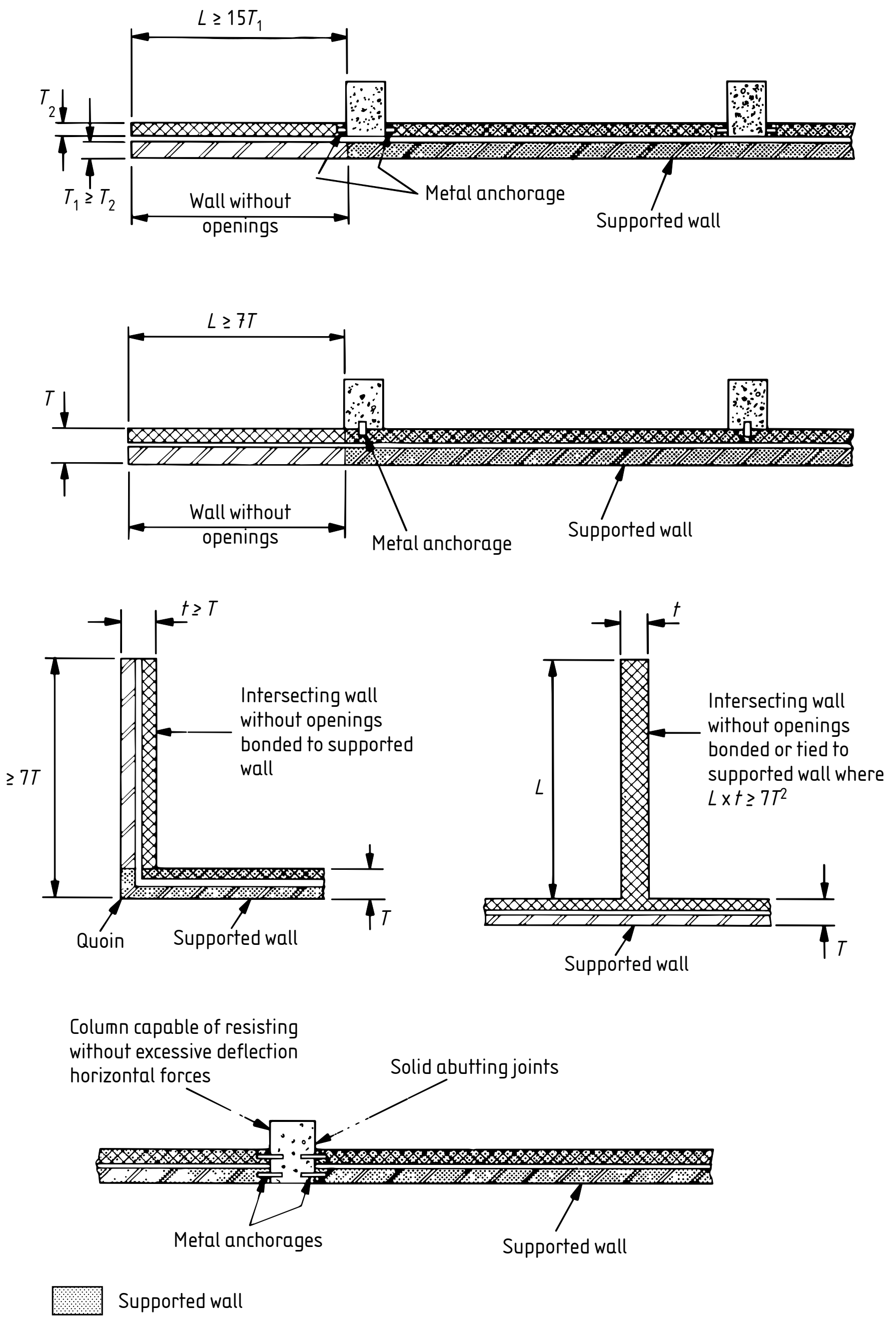


Figure 5 — Fixed support assumed in a cavity wall

5.2.3.3 *Internal walls or partitions not designed for imposed loading*

An internal wall or partition should be laterally restrained by horizontal or vertical continuous or intermittent supports (similar to those given in Table 9), unless it is designed as a free-standing wall (see **5.2.3.1**). The length or height of the wall in relation to its thickness should be within the limits given in Figure 6.

The following factors, which affect stability, should be provided for in the design:

a) accommodation for movement (see **5.4**);

b) presence and position of openings;

c) presence and position of abutting walls;

d) chasing (see **5.3.6**);

e) the likelihood of exceptional lateral loading, arising from the nature of the use of the building;

f) wind load;

g) any necessary fire resistance.

When an internal wall or partition is to be plastered, a thickness of not more than 13 mm of plaster to one or both sides of the partition should be included when determining the thickness of the wall for design in accordance with Figure 6. Dry lining should not be considered as contributing to the thickness of the wall.

NOTE 1 Until the wall has been plastered it will not have its final strength.

NOTE 2 Figure 6 is derived from the following empirical formulae.

a) If the wall is restrained at both ends but not at the top then:

— $t > L/40$ and $t > H/90$ or $t > H/15$ with no restriction on the value of L; or

— $t < L/40$ and $t > L/59$ and $t > (H + 2L)/133$.

b) If the wall is restrained at both ends and at the top then:

— $t > L/40$ and $t > H/90$ or $t > H/30$ with no restriction on the value of L; or

— $t < L/40$ and $t > L/110$ and $t > (3H + L)/200$.

c) If the wall is restrained at the top but not at the ends then $t > H/30$;

where

t is the effective thickness, i.e. the thickness of a wall, pier or column assumed in calculating the slenderness ratio, in millimetres (mm);

H is the height in millimetres (mm);

L is the length in millimetres (mm).

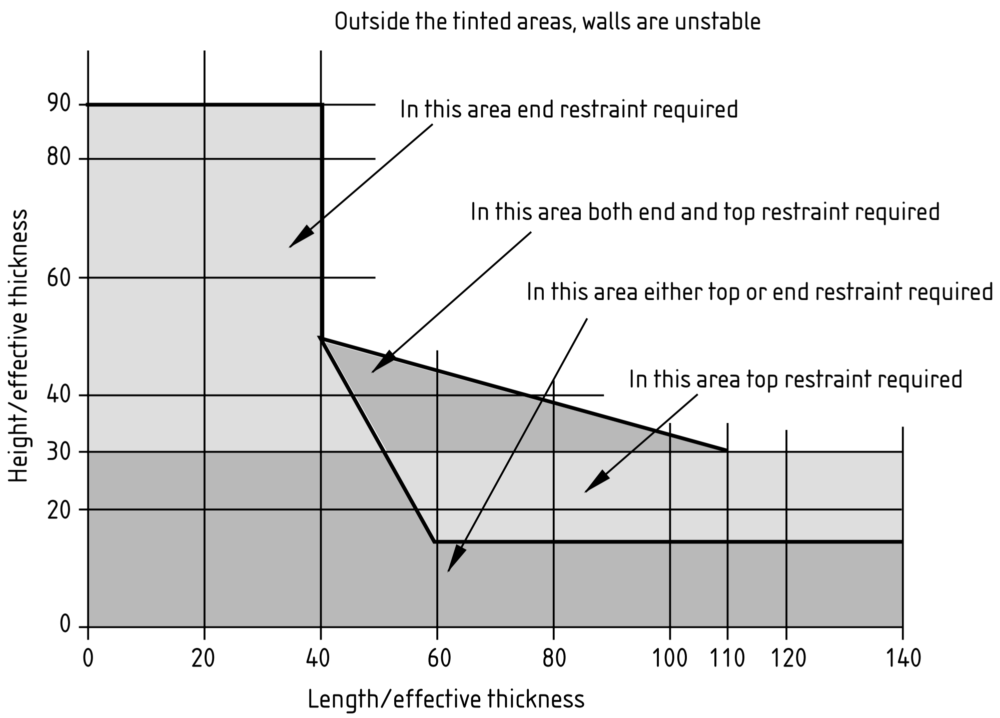


Figure 6 — Limiting dimensions of walls for stability

5.2.4 ***Adhesion of mortar***

In any masonry construction, there should be adequate adhesion between the masonry units and the mortar.

Where the design relies on flexural strength and no guidance is given in BS 5628-1 on the adhesion characteristics of the particular masonry units and mortar Designations, the adhesion should pass the preliminary tests as described in BS 5628-1.

5.3 Structural detailing for stability

5.3.1 ***General***

Structural interactions of walls, floors and roofs as described in **5.2.1** depend upon detailing of bearing, strapping and tying and any other connections of the various elements of the structure. (See Figure 7, Figure 8, Figure 9, Figure 10, Figure 11, Figure 12 and Figure 13 for typical connections and their locations.) In the particular case of low-rise buildings BS 8103 should be referred to.

In Figure 7, the encircled numbers labelling a feature refer to the figure showing the feature in more detail. Where more than one type of restraint system is given at an element intersection, only one of the options should be used.

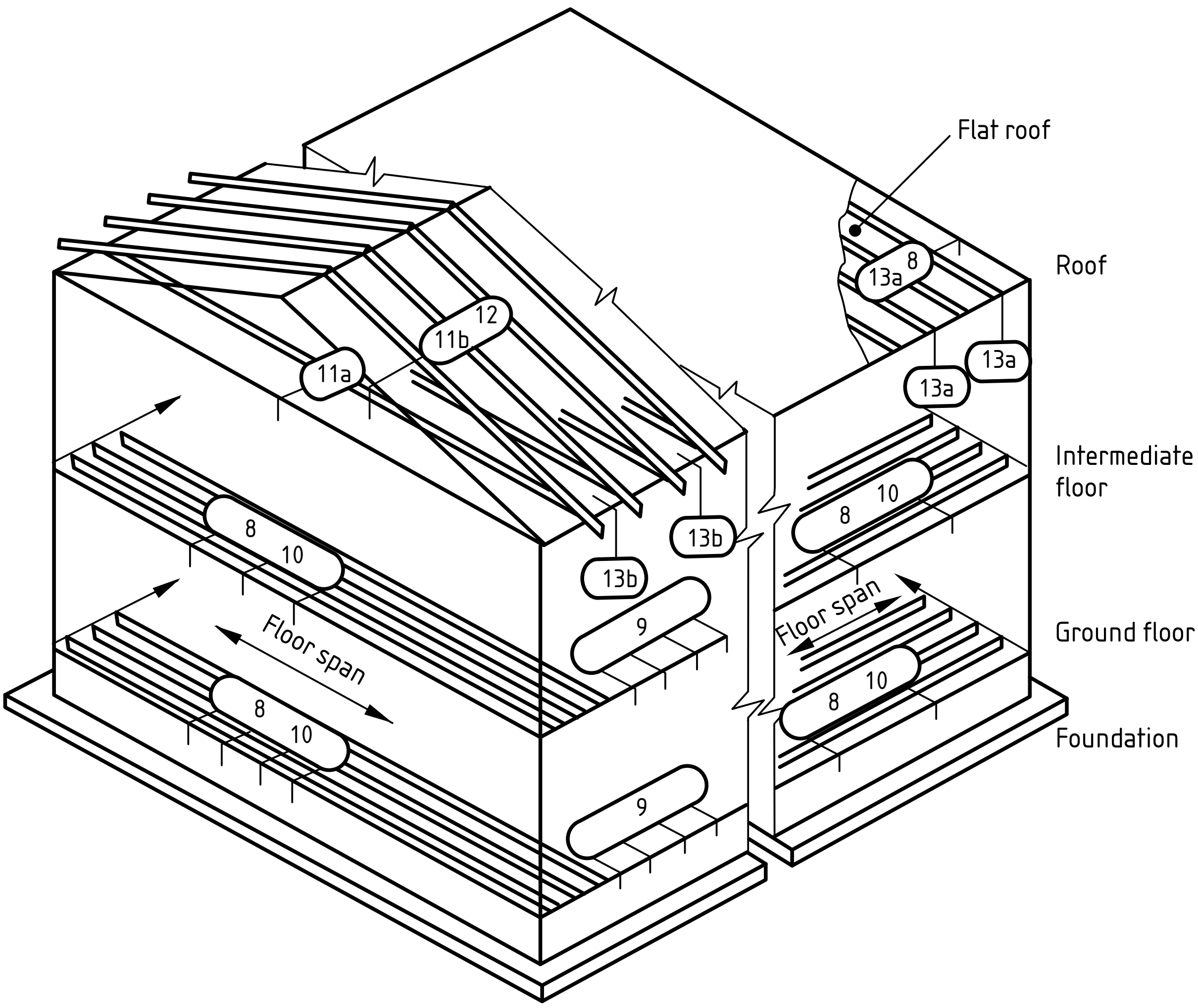


Figure 7 — Location and types of connection necessary between elements of a typical building

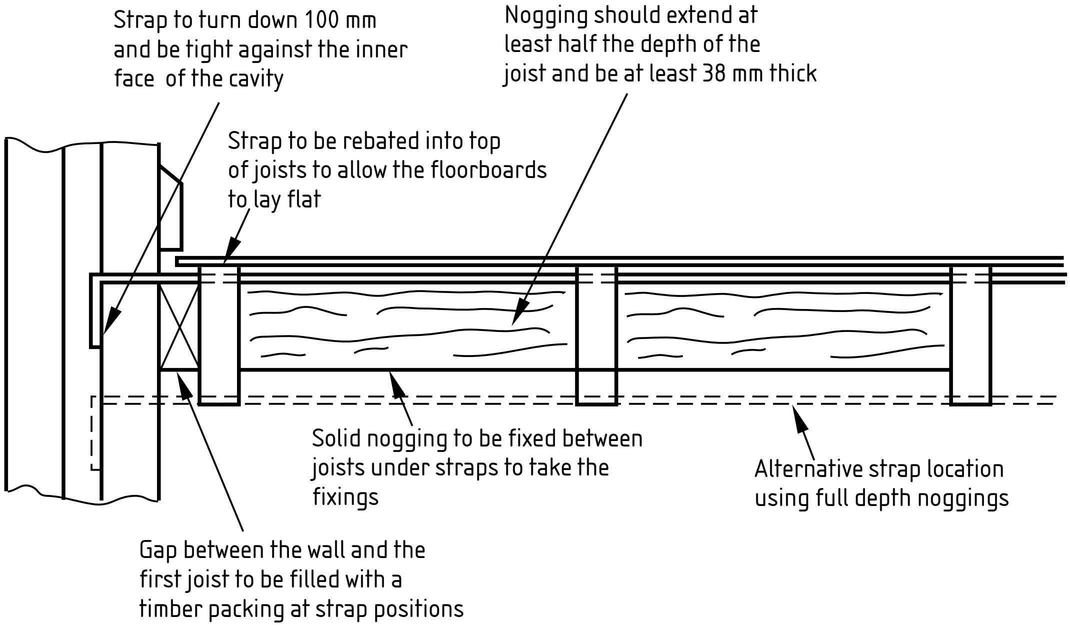
5.3.2 *Floors*

Typical ways of connecting floors with walls are shown in Figure 8, Figure 9 and Figure 10. Where floors are required to provide lateral restraint, the recommendations of BS 5628-1:1992, Annex C, or BS 8103 should be followed.

Where practicable, suspended timber floors near to the ground should be supported independently of the main structure by sleeper walls. Where this is not practicable, offsets or corbels from external walls may be used. Suspended timber floors at other levels should be built into the walls or supported by offsets, corbels or joist hangers. Timber wall plates should not be built into any wall.

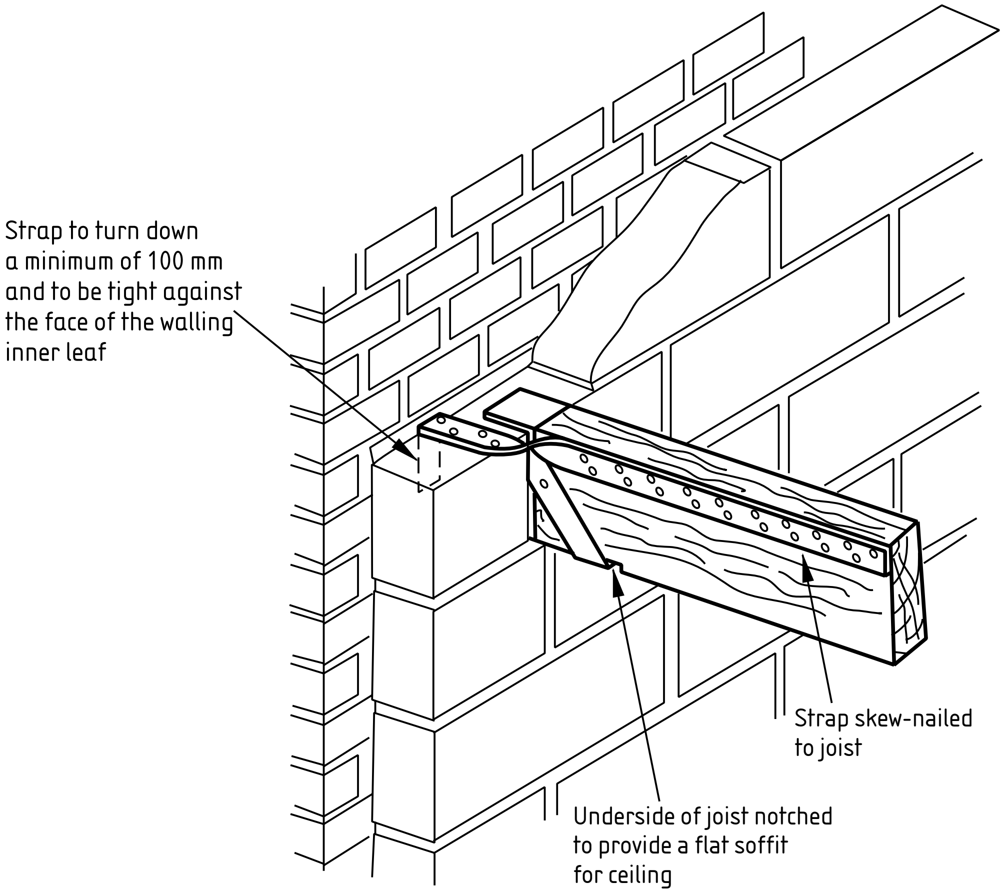
Unreinforced concrete floors laid on the ground, or on fill, should not also bear on walls as this can give rise to cracking as a result of differential movement.

The bearing of all types of floor and support fittings should be not less than 75 mm. Concrete floors should have a bearing of not less than 90 mm, however, this bearing may be reduced at the discretion of the designer provided relevant factors such as loading, span, tolerances, height of support and the provision of continuity reinforcement should be taken into account.



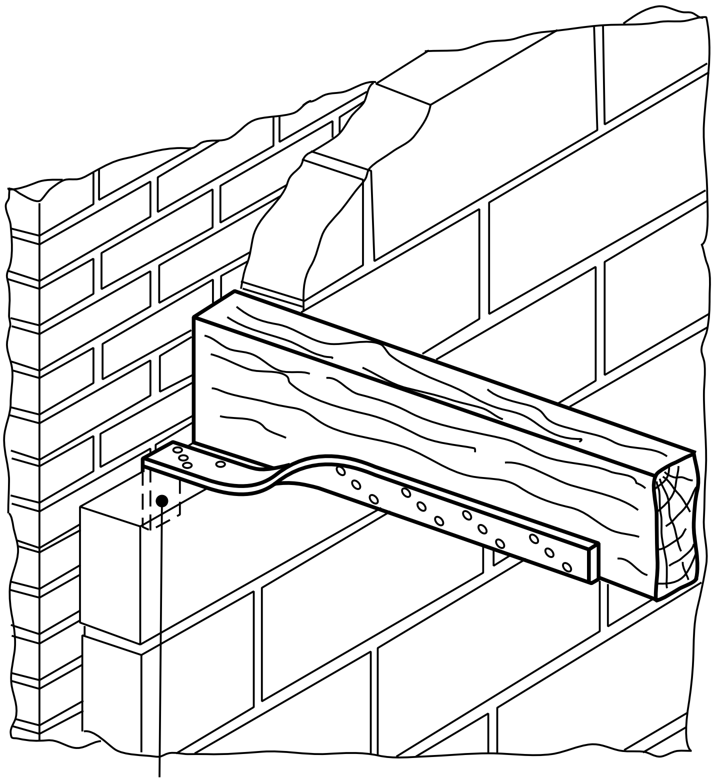
The strap should be carried over at least three joists and be secured with four fixings of which at least one should be in the third joist, or in the nogging beyond the third joint.

Figure 8 — Timber floor spanning parallel with a wall



a) Timber floor supported on standard joist hanger

Figure 9 — Alternative methods of supporting floor joists and providing restraint

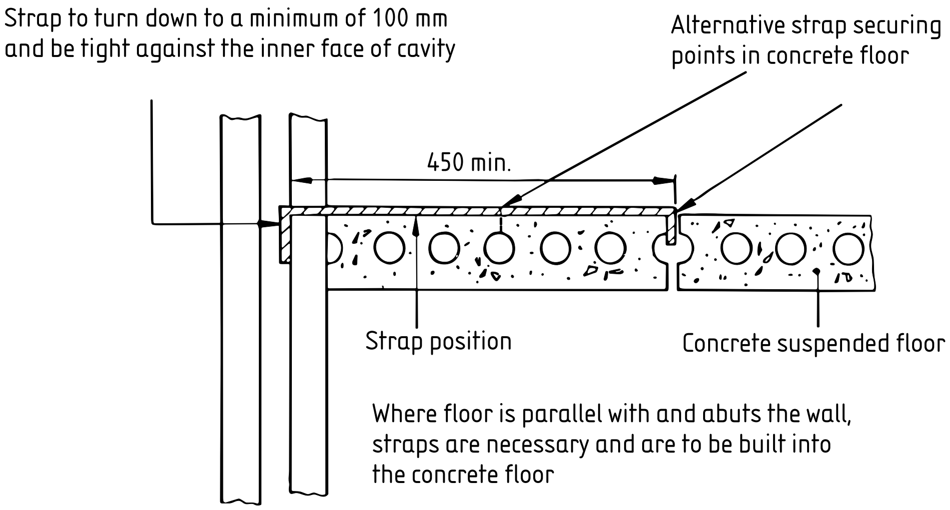


No strap is necessary provided joists are at 1.2 m spacing or closer and bear at least 90 mm into the wall. Otherwise, strap as shown; on top of the joist with the strap turned up or on one side of joist with strap turned sideways (alternative positions are shown in BS 5628-1:1992, Figure 11).

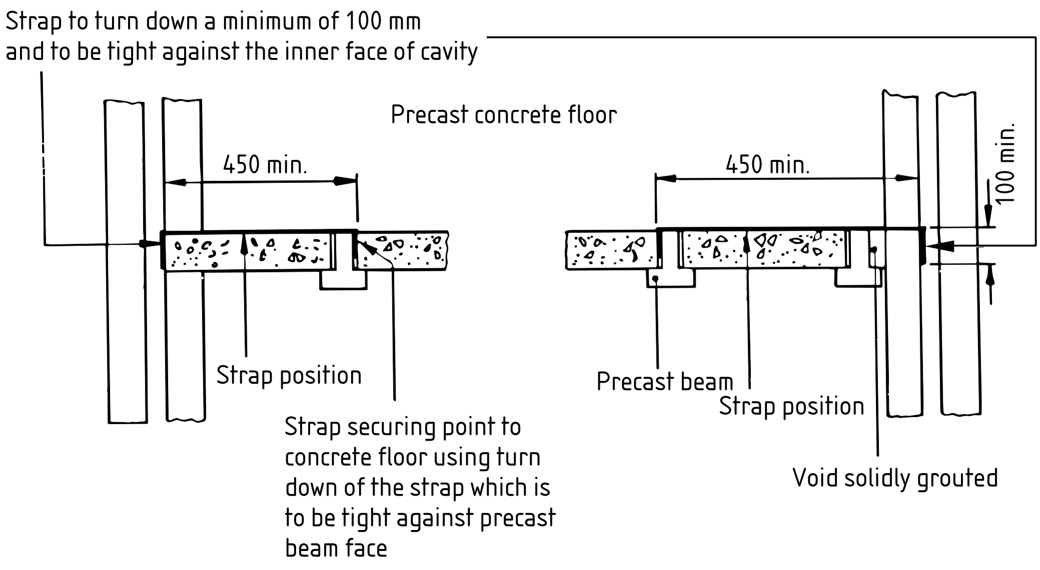
b) Timber floor bearing on to wall

Figure 9 — Alternative methods of supporting floor joists and providing restraint *(concluded)*

Dimensions in millimetres



a) Concrete suspended floor abutting wall



Typical edge detail

Alternative edge detail

b) Precast concrete beam and block type floor abutting or spanning on to wall

Figure 10 — Alternative methods of connecting concrete slab floors

5.3.3 ***Roofs***

Where roofs are needed to provide lateral restraint for the wall, reference should be made to BS 5628-1:1992, Annex C and BS 8103.

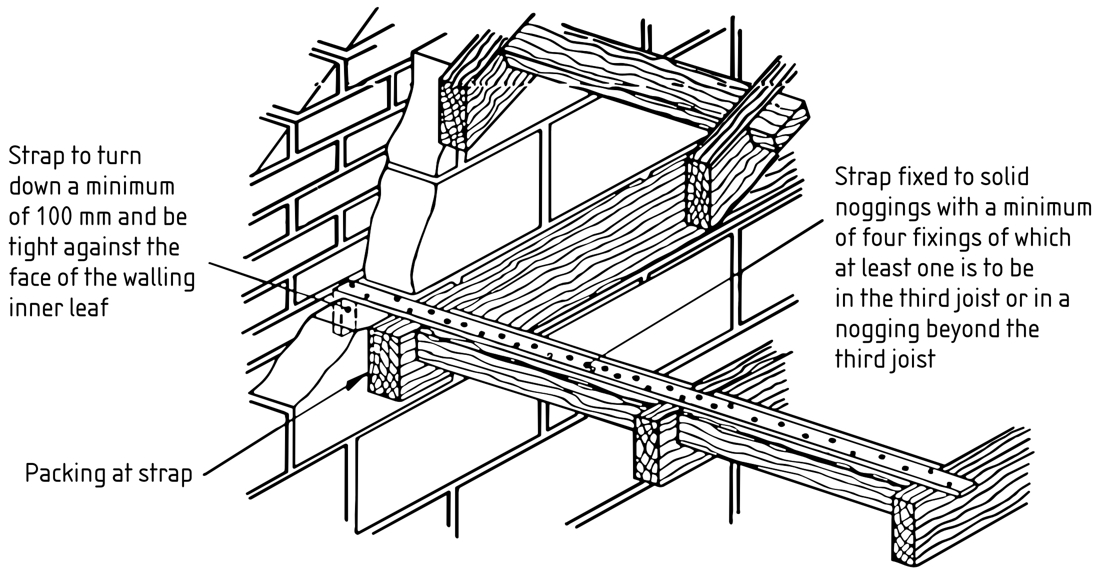
Typical ways of connecting roofs with walls are shown in Figure 11, Figure 12 and Figure 13. The design should follow the recommendations given in BS 5628-1:1992, Annex C, and BS 8103.

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

Concrete roofs should have a bearing of not less than 90 mm; however, this bearing may be reduced at the discretion of the designer provided relevant factors such as loading, span, tolerances, height of support and the provision of continuity reinforcement should be taken into account.

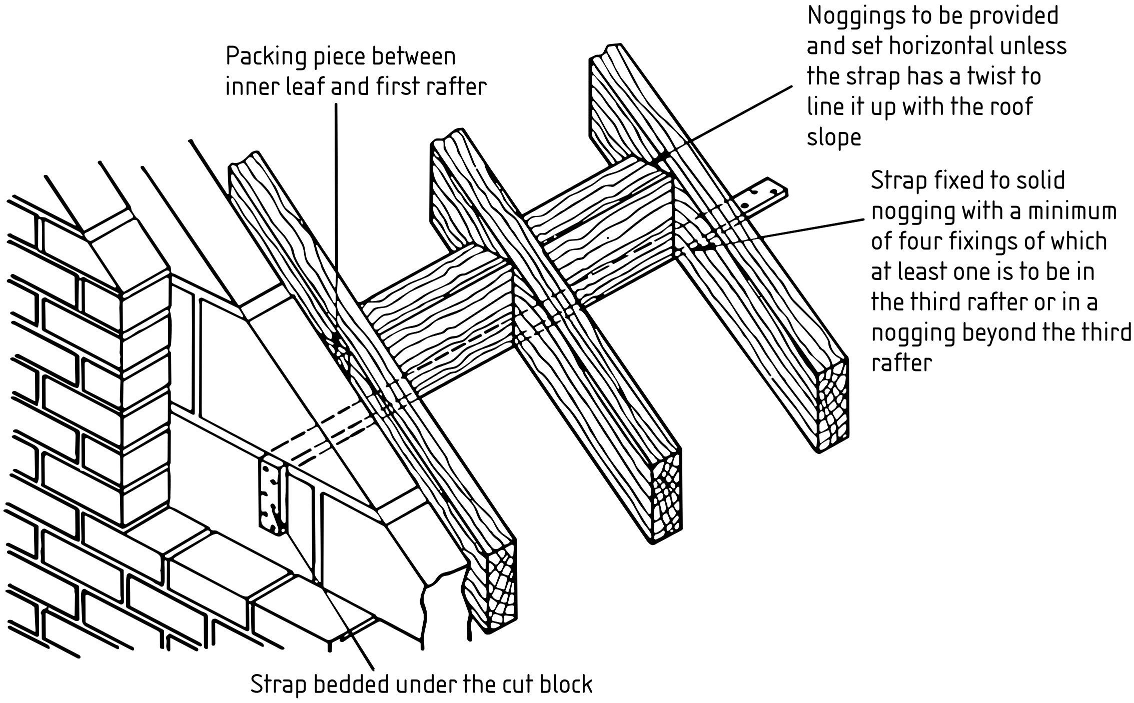
NOTE 1 Binders or other beams giving rise to concentrated loads on the wall may need to be provided with a padstone or spreader beam (see **5.2.2**).

NOTE 2 Where detailing the bearings of flat roofs upon walls, the danger of displacement of the top courses of masonry as a result of thermal movements in the roof and deflection of the structure should be taken into account. Temperature variations can be reduced by providing external insulation or reflective coatings to the roof.



a) Strapping at ceiling where roof spans parallel with a wall (similar detail for flat roof spanning parallel with wall)

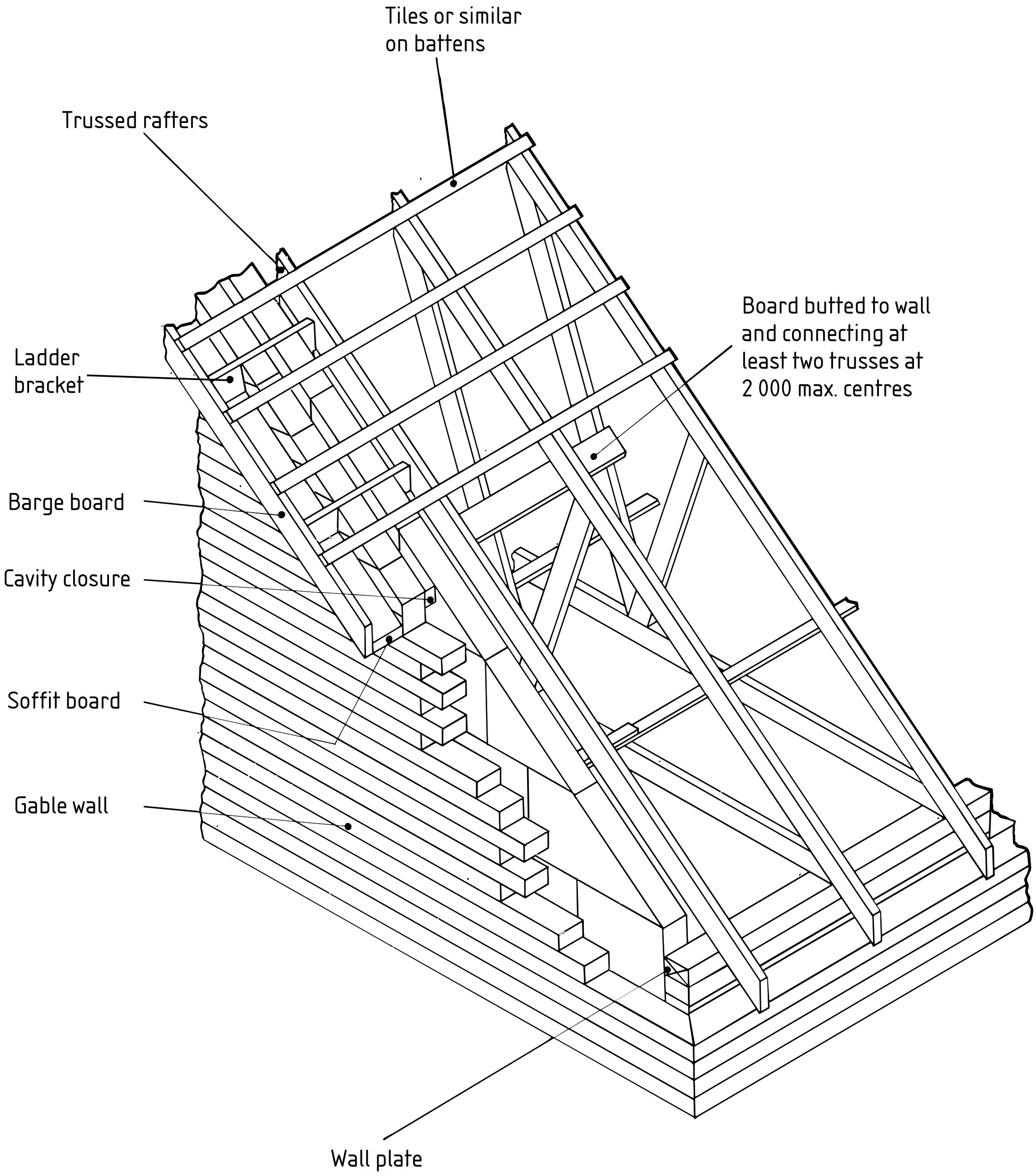
Figure 11 — Tying of pitched roofs to gable walls



b) Connections at gable verge line

Figure 11 — Tying of pitched roofs to gable walls *(concluded)*

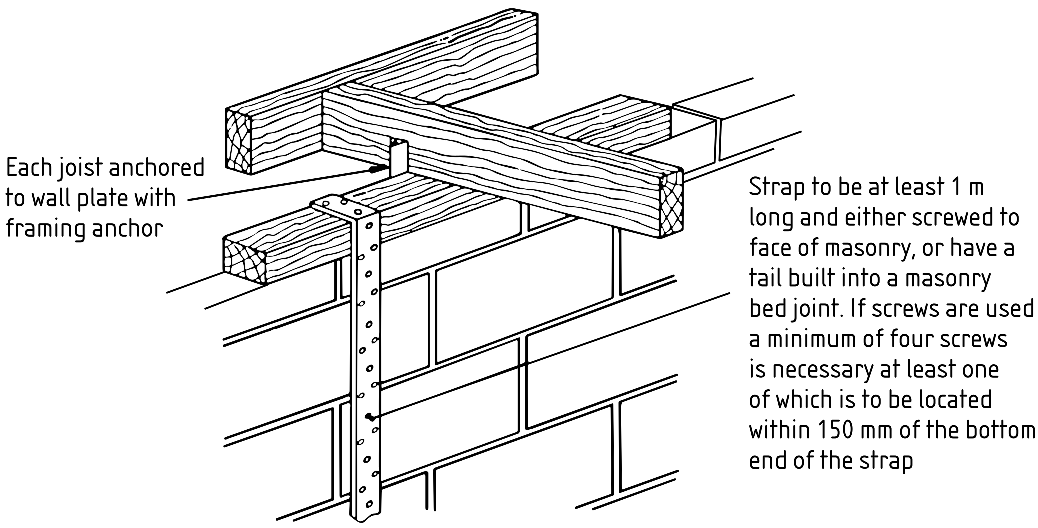
Dimensions in millimetres



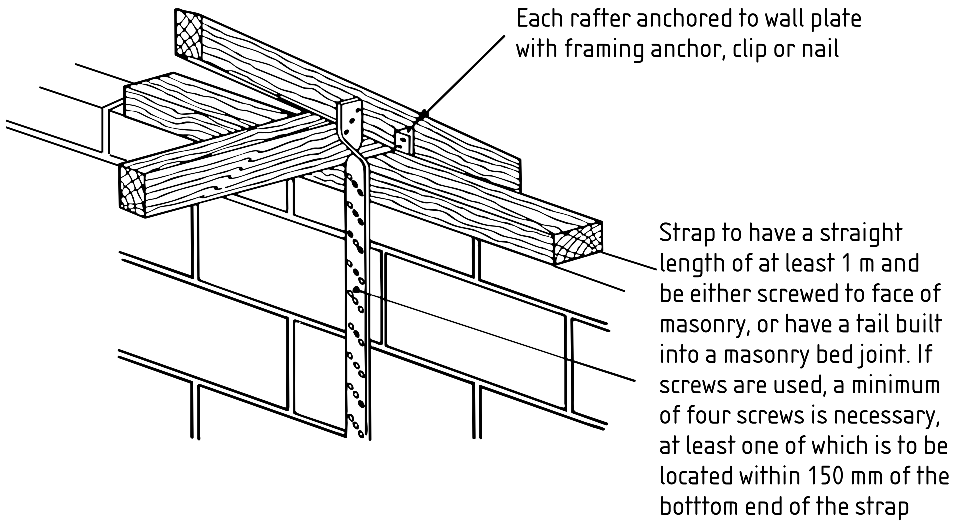
NOTE 1 Boards should span at least two rafters and be butted up to the wall.

NOTE 2 The soffit board should be securely fixed to the ladder bracket and should also be a close fit to the wall.

Figure 12 — Truss roof without straps



a) Flat roof



b) Pitched roof

NOTE Vertical restraint straps as detailed in a) or b) should be provided at centres not exceeding 2 m, but each trussed rafter should be fixed to the wall plate.

Figure 13 — Restraining roofs against displacement

5.3.4 ***Support over openings***

Masonry should not be supported on window or door frames which are not designed for the purpose. Where lintels are used, these should have bearings commensurate with the solidity of the support (see **5.2.2**) and the load for which they are designed and in any case not less than 100 mm in length. Lintels should not bear on a short length of cut block. Where possible, the masonry should be set out to provide a full length, whole depth unit under a bearing.

Pressed steel lintels should have a bearing of not less than 150 mm in length and may need stiffening over the bearing length to resist the total load. Protective measures for steel lintels, including provision of DPCs where appropriate, should conform to BS 5977-2.

Where composite lintels, e.g. prestressed concrete plank lintels, are used, no chase or hole should be formed in the area comprising the composite section nor should any inclusion, such as joists, be built into this section, with the exception of DPC materials which intrude not more than one-quarter of the width of the bed joint or 30 mm, whichever is the lesser. Installation should follow the recommendations of the manufacturers.

5.3.5 ***Wall ties***

5.3.5.1 *Selection and strength of wall ties*

The leaves of a cavity wall should be tied together by wall ties. The design compressive and tensile resistance of the ties relevant to the nominal cavity width should exceed the design lateral loads to which they will be subjected. The choice of the type of tie and spacing depends on the cavity width. Table 2 gives recommendations for the selection of wall ties with regard to severity of exposure.

NOTE Guidance on the selection of ties for normal applications is given in Table 10 and in DD 140-2. Ties with suitable retaining devices are available for retaining insulation materials against one masonry face. Special ties are also available for masonry cladding of (timber, steel or concrete) frame constructions.

5.3.5.2 *Density and positioning of ties*

The density should be not less than:

— 2.5 ties/m^2 for walls in which both leaves are not less than 90 mm thick;

— 4.9 ties/m^2 for walls having either leaf no greater than 90 mm thick.

Ties should be evenly distributed over the wall area, except around openings, and preferably should be staggered.

At the vertical edges of openings and at vertical unreturned or unbonded edges (e.g. at movement joints and up the sloping verge of gable walls), additional 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.

5.3.5.3 *Embedment of ties*

When ties are to be bedded in mortar joints, they should be sandwiched between mortar in the horizontal bed joints at the time the units are laid. The length of the tie should be sufficient to give a minimum embedment of 50 mm having regard to normal site tolerances for cavity width and centring of the tie. Suitable minimum lengths are given in Table 10.

Table 10 — Selection and spacing of wall ties

Least leaf thickness (one or both) mm	Type of tie	Cavity width mm	Equivalent number of ties /m²	Spacing of ties: Horizontal mm	Spacing of ties: Vertical mm
(A) Spacing of ties					
65 to 90	All	50 to 75	4.9	450	450
>90	[See Table 10**(B)**]	50 to 300	2.5	900	450

(B) Selection of wall ties: types and lengths

Least leaf thickness (one or both) mm	Normal cavity width[a] mm	Permissible type of tie: Tie length[b] mm	Permissible type of tie: Shape name in accordance with BS 1243:1978	Permissible type of tie: Type number in accordance with DD 140-2:1987
75	not greater than 75	200	Butterfly, double triangle or vertical twist	Types 1, 2, 3 or 4, selected on the basis of the design loading and design cavity width. Prescriptive rules for selection, and a model calculation, are given in DD 140-2:1987.
90	76 to 90	225	Double triangle[c] or vertical twist	
90	91 to 100	225	Double triangle[d] or vertical twist	
90	101 to 125	250	Vertical twist	
90	126 to 150	275	Vertical twist	
90	151 to 175	300	Vertical twist	
90	176 to 300	[b]	Vertical twist style[e]	

[a] Where face insulated blocks are used the cavity width should be measured from the face of the concrete.

[b] This column gives the tie lengths, in 25 mm increments, that best meet the performance recommendation that the embedment depth will not be less than 50 mm in both leaves after taking into account all building and materials tolerances but that the ties should also not protrude from the face. For cavities wider than 180 mm the length should be calculated as the structural cavity width plus 125 mm and the nearest stock length selected. The designer may vary the length in particular circumstances, provided that the design recommendations continue to be met.

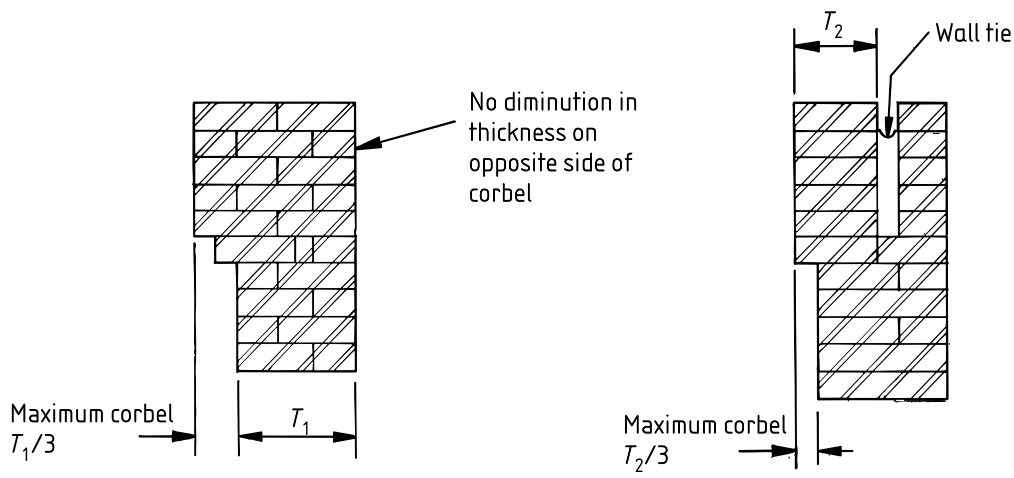
[c] The minimum length exceeds the maximum length specified under BS 1243:1978 but 225 mm double triangle format ties, which otherwise conform to the requirements of BS 1243 should be suitable.

[d] Double triangle ties of shape similar to those of BS 1243, having a strength that conforms to Type 2 of DD 140-2, are manufactured. Specialist tie manufacturers should be consulted if 225 mm long double triangle format ties are needed for 91 mm to 100 mm cavities.

[e] The strength and stiffness of masonry/masonry ties to DD 140 ranges from Type 1, the stiffest, to Type 4, the least stiff. For ties to BS 1243 the vertical twist is the stiffest and the butterfly the least stiff.

5.3.6 ***Corbelling***

Where courses are corbelled out, one above the other, for structural stability, the extent of corbelling should not exceed that shown in Figure 14, unless the work is otherwise supported or reinforced. A corbelled feature work may be built with restraint fixings subject to structural engineering design.



a) Section through solid walling

b) Section through cavity walling

Figure 14 — Extent of corbelling

5.3.7 ***Chimneys***

Where a chimney is not supported by adequate bracing, or otherwise made secure, its height (measured from the level of the highest point in line with the roof, gutter or other part of the building, and including any pot or flue terminal) should be no greater than four and a half times its least width at that level. (See **5.5.7.11** and Figure 24.)

5.3.8 ***Provision for services and fittings***

When making provision for services and fittings, designers should ensure that fixings, chases or holes do not impair any of the functions of the wall.

The design should contain provision for the effects of chasing on stability, particularly where walls or leaves are constructed of hollow units, and the recommendations set out in BS 5628-1 considered. In walls or leaves constructed of solid units, the depth of horizontal chases should be no greater than one-sixth of the thickness of the single-leaf at any point, and the depth of vertical chases should be no greater than one-third of the thickness of the single-leaf at any point.

The cutting of holes up to approximately 300 mm^2 square (i.e. holes of approximately square cross-section) in the wall to accommodate items of equipment may be permitted.

The design should contain provision regarding the effect on the stability of the masonry where heavy fittings are to be fixed to a wall.

5.4 Movement in masonry

5.4.1 *Sources of movement*

5.4.1.1 *General*

The design should include provision for movement.

After construction, buildings are subject to small dimensional changes, which can be caused by one or more of the following factors:

a) change in temperature (see **B.4**);

b) change in moisture content (see **B.5**);

c) adsorption of water vapour (see **B.5**);

NOTE Adsorption is the term used to describe the bonding of water molecules to the surface of molecules in the masonry material. It should not be confused with absorption, which refers to the entry of water molecules into the pores of the masonry.

d) chemical action, e.g. carbonation (see **B.6**);

e) deflection under loads;

f) ground movement and differential settlement.

To guard against dimensional changes occurring as a result of sulfate attack, the recommendations set out in **5.6.4** should be followed.

Masonry is not completely free to expand or contract because restraints are often present, and thus compressive or tensile forces can develop and these can lead to bowing or cracking. Where the compressive forces are applied eccentrically, e.g. where panel walls are not supported across their whole thickness, the risk of bowing is increased. Where there are stress concentrations, for example, at openings or at changes in height, thickness or direction of walls, and where stronger mortars than those recommended in **5.6.6** are used, the risk of cracking is also increased.

5.4.1.2 *Movement and materials*

Movement characteristics of masonry units made of clay, calcium silicate, concrete and stone are likely to vary within each material type, due to differences in raw materials and/or manufacture, but movement characteristics differ more significantly between units of different types of material.

All materials expand and contract in response to thermal changes. In addition, clay materials undergo an irreversible expansion after their manufacture as moisture is adsorbed from the atmosphere. Other masonry materials shrink following manufacture to reach the equilibrium state.

Units made from different types of material should not be bonded together in masonry in a manner that would cause stress to develop as a result of dissimilar characteristic movement, e.g. a veneered wall of clay brick bonded to a backing of concrete masonry. Where anticipated movements are different in magnitude and nature, parts of masonry of different material type should be effectively separated, e.g. by vertical or horizontal movement joints and/or slip planes. Alternatively, they should be suitably reinforced (see Annex B and **5.4.2.3.2**).

The causes of cracking in buildings, including movements, and guidance for a broader understanding of the factors and mechanisms involved are reviewed in [4].

5.4.1.3 *Effects of insulation*

Generally, changes in temperature, moisture content or rate of drying-out due to the presence of insulation, do not need to be taken into account when considering movement in masonry. However, for brick masonry of certain clay bricks in applications where restraint is low (e.g. cladding) and high levels of solar heating are anticipated because of orientation, reduced spacing between movement joints is beneficial. In such cases the manufacturer should be consulted.

5.4.2 *Accommodation of movement in masonry*

5.4.2.1 *Movement joints*

Movement joints should be provided in the masonry to accommodate its expansion and/or contraction due to changes in temperature and the moisture characteristics of the masonry units. Joints should be built-in as work proceeds.

When designing movement joints in separating walls, party walls or compartment walls, the reduction in the efficiency of the wall as an insulator of sound, or as a fire barrier (see **5.8**), should be taken into consideration.

Where necessary, slip ties or dowels strong enough to provide lateral stability should be incorporated. They are usually of metal rod or flat strip and one end is anchored, or otherwise fixed, into masonry on one side of a movement joint. The other end is built-in but debonded to allow the joint to open and close while preventing movement in any other direction.

5.4.2.2 *Slip planes*

Slip planes should be designed to allow parts of the construction to slide, one in relation to the other, thus reducing shear stresses in the adjacent materials.

The design and positioning of movement joints and slip planes should be carefully considered, to ensure that in addition to accommodating movements, such joints or planes do not impair the stability of the wall or any of its functions.

In external walls, movement joints and slip planes should be sealed, protected or otherwise designed to prevent water penetration (see **5.4.4**).

Fixings and services should not interfere with the performance of the joints or slip planes, e.g. by bridging them. Finishes should be discontinuous at movement joints and slip planes, and fixings and fittings should not tie across joints.

5.4.2.3 *Provision of movement joints*

5.4.2.3.1 *General*

These empirical recommendations are applicable to the majority of situations.

It is not necessary to provide movement joints where the length of internal walls or the inner leaves of cavity walls in dwellings is relatively short.

The spacing of the first movement joint from an external or internal angle should be not more than half the general spacing and preferably less where the masonry is continuous at the angle, due to the effect of end restraint of the wall panel.

When more detailed information is needed on basic data and design to accommodate movement, see Annex B. The material manufacturers should also be consulted.

5.4.2.3.2 *Spacing and width of movement joints in clay masonry*

In general, unrestrained or lightly restrained unreinforced walls, e.g. parapets and non-loaded spandrel panels built of membrane-type DPCs, expand 1 mm/m during the life of a building due to thermal and moisture movement changes. The spacing and width of movement joints to control expansion in such walls is governed by the compressibility of fillers and the performance of appropriate sealants (see **5.4.4**). Designers are recommended to consult sealant manufacturers wherever possible, but as a general guide, the width of the joint in millimetres should be about 30 % more than the numerical value of the distance between joints in metres. For example, movement joints at 12 m centres should be about 16 mm wide.

Where a manufacturer can show evidence from experience that the product expands by less than 1 mm/m during the life of a building due to thermal and moisture movement changes, the foregoing guidance may be modified at the designer's discretion.

Experience shows that the expansion of normal storey height walls, as opposed to unrestrained walls, is somewhat less than 1 mm/m during the life of a building and that expansion often reduces with increasing restraint. However, to avoid cracking due to thermal contraction, the spacing between movement joints should never exceed 15 m in unreinforced walls. Closer spacing may be necessary for walls which are less well restrained, e.g. parapets. Where bed joint reinforcement is used, spacings greater than 15 m can be satisfactory, but expert advice should be sought.

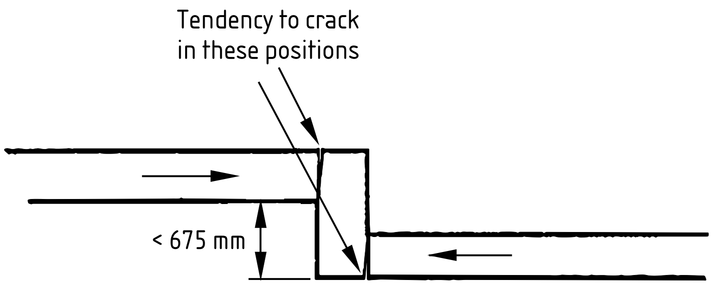
Present evidence suggests that vertical movement of unrestrained walls is of the same order as horizontal movement.

5.4.2.3.3 *Dissimilar clay units*

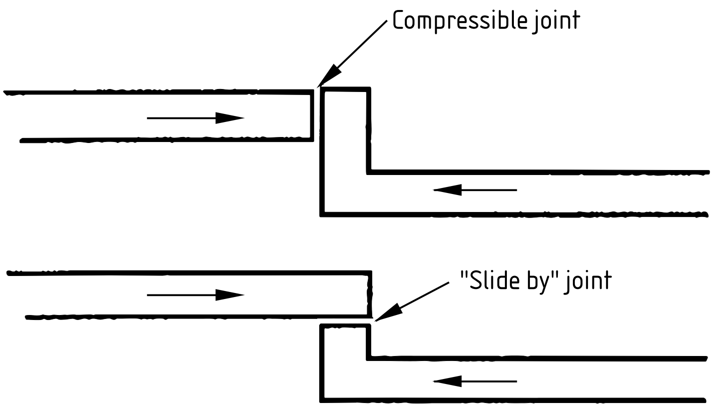
Where clay bricks made from different types of clay are built in the same wall to produce decorative effects, e.g. contrasting bands of colour, differences in their movement characteristics can dictate that more frequent spacing of movement joints is required. The brick manufacturers should be consulted.

5.4.2.3.4 *Short returns in clay masonry*

If a return in the length of clay masonry is less than 675 mm and either adjoining length of masonry exceeds 6 m, the masonry should be interrupted at the return to prevent the development of a mechanical couple and a risk of cracking. This can be effected by the introduction of a vertical, compressible joint or a "slide-by" detail. Returns of 675 mm or more should be regarded as having sufficient inherent flexibility to accommodate the stress caused by the opposing forces (see Figure 15).



a) Mechanical couple in short return of clay masonry



b) and c) Alternative positions for movement joint (preferable)

Figure 15 — Short returns in clay masonry

5.4.2.3.5 *Spacing and width of movement joints in calcium silicate masonry*

Where possible, calcium silicate masonry should be designed as a series of panels separated by movement joints to control contraction. The ratio of length to height of the panels should generally not exceed 3:1. As a rule, vertical joints to accommodate horizontal movement should be provided at intervals of between 7.5 m and 9 m. Movement joints need not generally exceed 10 mm in width. They should be sealed where necessary.

In external walls containing openings, movement joints may be needed at more frequent intervals or the masonry above and below the opening may need to be reinforced in order to restrain movement (see **5.4.5**). The design should pay particular attention to long low horizontal panels of masonry, e.g. those under windows.

External walls of calcium silicate masonry should have a compressible joint to allow for thermal expansion at not more than 30 m intervals.

5.4.2.3.6 *Spacing and width of movement joints in concrete masonry*

Where possible, concrete masonry should be designed as a series of panels separated by movement joints to control contraction. The degree of movement is dependent upon unit type and, as a rule, vertical joints to accommodate horizontal movement should be provided at intervals of between 6 m and 9 m. The ratio of length to height of the panels should generally not exceed 3:1.

In external walls containing openings, movement joints may need to be provided at more frequent intervals or the masonry above and below the opening may need to be reinforced to restrain movement (see **5.4.5**). Particular attention should be paid to long low horizontal panels of masonry, e.g. those under windows.

External walls of concrete masonry should have a compressible joint to allow for thermal expansion at not more than 30 m intervals.

5.4.2.3.7 *Spacing and width of movement joints in natural stone masonry*

To accommodate horizontal movement, and in the absence of specific calculations (see Annex B), vertical joints not less than 10 mm wide should be provided at intervals no greater than 15 m to 20 m, and located no more than 8 m from an external corner.

5.4.2.3.8 *Placing of movement joints*

Features of the building which should be considered when determining joint positions in masonry are:

a) intersecting walls, piers, floors, etc.;

b) window and door openings;

c) changes in height or thickness of walls;

d) chases in walls;

e) movement joints in the building as a whole or in floor slabs.

Areas above doors and above or below windows may benefit from being reinforced to distribute tensile stresses (see **5.4.5**).

5.4.3 *Filler for movement joints*

The material for filling movement joints to accommodate expansion should be easily compressible to approximately 50 % of its original thickness. Flexible cellular polyurethane, cellular polyethylene or foam rubbers are satisfactory materials. Hemp, fibreboard, cork and similar materials should not be used for expansion joints in clay brick masonry, but may be used for contraction joints in calcium silicate and concrete masonry.

5.4.4 *Sealing movement joints*

5.4.4.1 *General*

Movement joints should be sealed where resistance to water penetration is necessary.

The width of the joint should be sufficient to accommodate both reversible and irreversible movements, without damage to the seal. Hence the width of the joints should be related to their spacing and to the ability of the sealant to accommodate movement.

Guidance on the selection of sealants is given in BS 6213.

5.4.4.2 *Design of sealed movement joint*

To ensure adequate bond of sealant to the masonry, the depth of the seal should be not less than 10 mm. Certain single-part, moisture cured sealants are best used in joints of small cross-section due to their excessive curing time in thick sections. Optimum performance in butt joints is obtained when the width to depth ratio of the sealant bead lies within the range 2:1 to 1:1 for elastoplastic sealants (including one- and two-part polysulfides), or the range 1:1 to 1:2 for plastoelastic sealants.

Movement joints in masonry walls are generally deep in relation to their width. In order to fill the inner portion of the joint, filler material should be positioned to leave the correct depth to accommodate the sealant.

The sealant should be applied against a firm backing so that it is forced against the sides of the joint under sufficient pressure to ensure good adhesion. The filler material should not react with or adhere to the sealant.

If a bond breaker is necessary, it should be positioned between the filler material and the sealant. A cross-linked, closed-cell polyethylene foam provides a suitable combined filler and bond breaker. The foam should have small cells or a surface skin. Its section should be approximately 25 % wider than the joint so that when the sealant is applied it is forced against the sides of the joint and does not displace the back-up.

5.4.5 ***Reinforcement***

Reinforcement should be used in masonry walls of calcium silicate or concrete to minimize cracking which can occur above or below openings where the vertical cross-sectional area of the masonry is much less than that of the masonry on either side. The reinforcement should be long enough to distribute the stress to a position where the vertical cross-sectional area of the wall is able to accommodate it.

Reinforcement should be adequately protected against corrosion (see Table 2 and **5.6.7.2**).

5.4.6 ***Accommodation for movement of adjoining structural members***

5.4.6.1 *Walls supported by structural members*

Where a wall is built on a suspended floor or beam and is not designed for composite action, it may be necessary to make allowance for deflection of the supporting member by providing a separation joint at the base of the wall and/or by including bed joint reinforcement in the lower part of the wall.

Consideration should be given to the need for slip planes under the bearing of lintels or beams to separate the wall from structural members which can produce a horizontal movement, e.g. longer span concrete lintels or beams.

5.4.6.2 *Partitions beneath structural members*

Where a partition is designed not to carry any vertical load from the structure it should be separated by a gap or by a layer of resilient material to accommodate the deflection of structural members above it. Consideration should be given to the need for lateral restraint and fire integrity should be maintained.

5.4.6.3 *Masonry cladding to framed structures*

5.4.6.3.1 *General*

Masonry cladding to framed buildings should be designed to prevent cracking as a result of stresses generated by differential movement between the masonry and the frame.

Cladding, irrespective of the type of masonry units from which it is built, should be provided with adequate lateral edge restraint (see **5.2.3**).

Some particular cases of design to limit the effect of differential movement and yet to provide stability of the panel are described in **5.4.6.3.2**, **5.4.6.3.3** and **5.4.6.3.4**.

5.4.6.3.2 *Masonry cladding to concrete loadbearing structures*

Concrete structures are subject to movement in the vertical direction due to shrinkage and creep of the concrete structural elements. This movement will be in opposition to thermal expansion of the cladding. In addition, in the case of cladding of clay units, there will also be irreversible moisture expansion.

If masonry cladding is built-in tightly between horizontal beams or floor slabs, these opposing movements can cause excessive stresses in the masonry, particularly if there is eccentricity, e.g. where cladding overhangs its support.

To prevent excessive stress occurring, horizontal compressible joints should be provided to accommodate the differential movement. Such a compressible joint should be provided at the top of any masonry cladding built up to the underside of any horizontal element of the structure (or any supporting component fixed to it, see Figure 16).

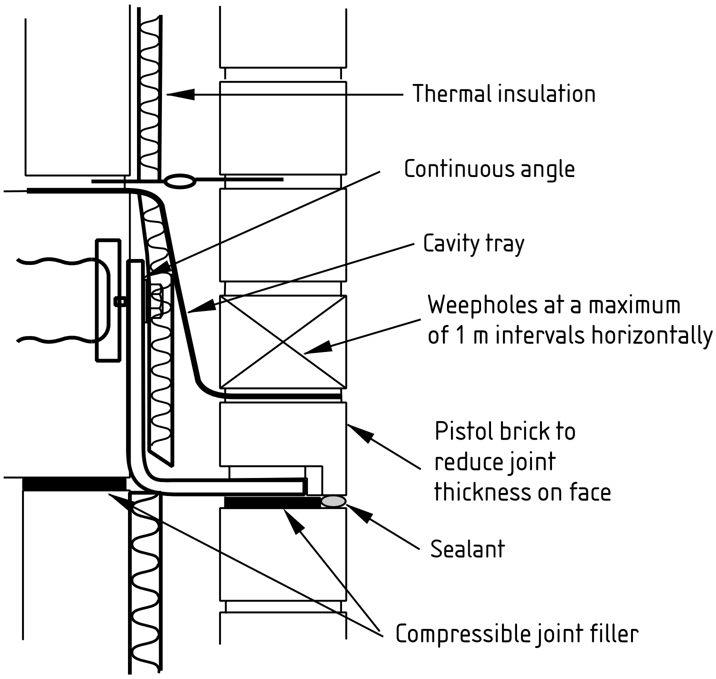


Figure 16 — An example of a support system showing provision for movement

With cladding of calcium silicate or concrete masonry the differential movement between the cladding and the concrete structure is less. This is because the long term moisture movement of both cladding and structure involves shrinkage and thermal expansion of the cladding is the only opposing movement.

Provision for differential movement by the inclusion of a compressible horizontal joint eliminates the stabilizing effect of a mortared joint or simple restraint fixings (see **5.2.3.2.2**) and so a means of providing restraint against lateral forces will generally be necessary. Sliding anchor restraint fittings are available (see Figure 17 for a typical example).

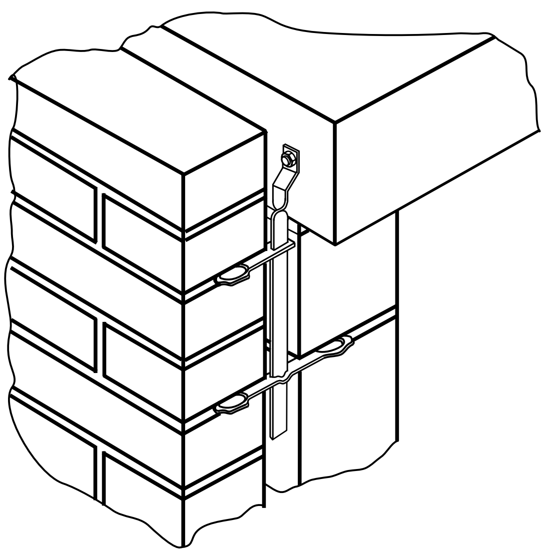


Figure 17 — Head restraint wall tie

Where ties and restraint fixings are fitted between cladding and frame they should be designed to permit appropriate movement.

5.4.6.3.3 *Masonry cladding to steel frame structures*

The design should provide for a compressible horizontal joint at the top of any masonry cladding built up to the underside of any horizontal element of the structure to avoid stresses due to differential movement between frame and cladding. Steel frame structures are not subject to shrinkage movement and so vertical differential movement is due only to thermal and moisture movements of the cladding.

For internal walls, if eccentric loading and short returns (see **5.4.2.3.4**) are avoided, panel walls of clay masonry in multi-storey steel structures can usually be built into, and tied rigidly to, the frame.

Concrete and calcium silicate masonry should not be tied rigidly to the frame, but adequate lateral restraint should be provided.

5.4.6.3.4 *Masonry cladding to timber frame structures*

Masonry cladding to a timber framed structure is usually supported on the same foundations as the framed structure and not on the frame itself, although it is generally tied to it to enhance lateral stability.

Movement of the timber frame and movements of masonry in response to thermal and moisture changes are dissimilar. Building details should accommodate the vertical movement between frame and cladding. For example by:

a) use of timber frame wall ties that tolerate relative vertical movement between the frame and the cladding;

b) provision of a gap between the top of the cladding and oversailing frame members such as eaves ladders and the feet of trussed rafters.

Window and door frames are usually fixed to the timber structure and project across the cavity and into an opening in the masonry cladding. Building details should accommodate any tendency for joints between the cladding and the underside of sills to close and between cladding and the heads to open as a result of differential movement between the structural frame and cladding (see Figure 18).

NOTE When timber platform ground floor is used add 3 mm to the differential movement allowances quoted.

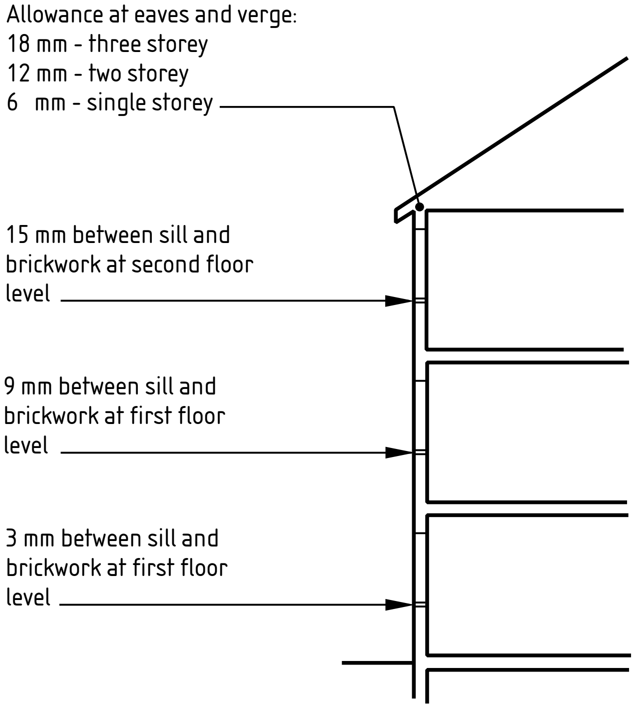


Figure 18 — Recommended allowances for differential movement between the timber frame structure and brick cladding

5.4.6.3.5 *Frame movement due to wind load*

Masonry cladding to framed structures subject to sway in response to wind loads, e.g. in tall single storey frame structures, should be designed to accommodate the movement.

The masonry may be tied to the frame and designed to move with it by permitting limited rotation at the DPC at the base of the wall.

Alternatively, the masonry may be designed as a structurally self-supporting wall. Any connection to the frame should not be fixed in a manner that restricts the anticipated movement.

5.4.6.3.6 *Masonry walls as wind bracing*

Where masonry walls are provided to form wind bracing in a frame structure, they should be built-in rigidly to the surrounding framework. The masonry should be designed not only to resist the stresses due to the imposed load, but also the stresses which can arise from differential movement between the masonry and the frame.

5.4.6.4 *Masonry slips*

The use of brick or block slips applied to the edge of concrete slabs or beams is not recommended. Where their use is unavoidable, panels of slips should be isolated from movement and stresses in adjoining masonry.

5.5 Exclusion of water

5.5.1 *General*

The penetration of water into the fabric of a building has serious consequences for the health of the occupants and for the long term serviceability of the structure. Building defects are the most common cause of water penetration through the building envelope. The source of water can be from precipitation or from ground water.

5.5.2 ***Rain penetration***

By their nature masonry walls are not waterproof. The specification, design, detailing and construction of the total wall element should contain provisions for appropriate resistance to rain penetration in relation to local exposure conditions [5].

An assessment of local wall spell indices should be made (see **5.5.3**). For each type of wall, in any particular building, the most exposed part should be given particular attention as this will affect decisions concerning the choice of design and materials.

Guidance on resistance to rain penetration of different forms of masonry construction and the factors affecting rain resistance are described in **5.5.4** and the designer should select a construction appropriate to the local wall spell index.

5.5.3 ***Categories of exposure to wind-driven rain***

The quantity of rain falling at any point on a vertical wall surface depends on both the intensity of the rainfall and the direction and speed of the wind.

Rainfall varies considerably across the country and is largely unaffected by local features. Conversely, the wind speed is affected significantly by local features such as the spacing and height of neighbouring trees and buildings and whether the ground is flat or steeply rising.

BS 8104 allows calculations for different orientations. Annual average values can be calculated as well as quantities for the worst likely spell in any 3 year period. It permits corrections to be made for ground terrain, topography, local shelter, and the form of the building concerned.

BS 8104 gives recommendations for two methods of assessing exposure of walls to wind-driven rain, namely the local spell index method and the local annual index method. The local spell index method should be used when assessing the resistance of a wall to rain penetration. The local annual index is intended for use when considering the average moisture content of exposed building material or when assessing durability, the effects of the weather on the appearance of materials and components and the likely growth of mosses and lichens.

Exposure categories defined in terms of wall spell indices calculated using the local spell index method specified in BS 8104 are given in Table 11. The indices, derived as they are from inherently variable meteorological data, should not be regarded as precise. Where assessment produces an index near the borderline between categories the designer should decide which is the most appropriate category for the particular case, using local knowledge and experience.

Table 11 — Categories of exposure to local wind-driven rain

Category of exposure		Calculated quantity of wind-driven rain[a] litres/m^2 per spell
1	Sheltered	Less than 33
2	Moderate	33 to less than 56.5
3	Severe	56.5 to less than 100
4	Very Severe	Not less than 100

[a] Maximum wall spell index calculated using the local spell index method specified in BS 8104.

BRE Report BR 262 [6] provides a simplified procedure for assessing exposure to wind-driven rain for walls up to 12 m high. It is primarily intended for low rise domestic buildings, but may also be considered suitable for other categories of buildings of similar scale. This simplified guidance is based on a map which defines zones in which calculations, in accordance with BS 8104, predict similar exposure conditions. The zones are numbered 1 to 4 and correspond with categories defined in Table 11.

The calculations defining the mapped zones in [6] assume worst case conditions and so provide very conservative guidance. As such [6] can restrict the choice of construction. A greater choice is obtained by more specific assessment using BS 8104.

5.5.4 *Selection of external wall construction to resist rain penetration*

5.5.4.1 *General*

The following factors that affect the resistance to wind-driven rain should be considered in relation to other functions of walls such as strength, durability, sound and thermal insulation:

a) type of masonry unit;

b) mortar composition;

c) thickness of leaf;

d) presence of cavities;

e) width of air space, if any, within any cavity;

f) mortar joint, profile and finish;

g) presence, type and thickness of any cavity insulation;

h) architectural features and local practice;

i) presence of applied external surface finishes;

j) quality of workmanship to be achieved on site.

NOTE These factors are not listed in order of importance.

5.5.4.2 *Detailed considerations*

5.5.4.2.1 *Type of masonry unit*

When subjected to wind-driven rain, walls constructed of dense masonry units, i.e. those with low water absorption characteristics, only absorb a relatively small quantity of water. A greater proportion of the water runs down the face of the walling and can be blown into and through it via paths in the mortar joints, particularly at the interface between the mortar and the masonry units (see **5.5.4.2.6**).

Masonry units having relatively high water absorption characteristics will absorb water running over a wall surface in conditions of driving rain. If the duration of the rainfall is short this behaviour can be considered beneficial because it prevents most of the water reaching the mortar joints. However, when the surface of the material approaches saturation point water tends to run more readily down the surface and, as in walls of dense units, can penetrate via paths at the mortar joints. In Very Severe and prolonged conditions of driving rain, water can be absorbed further into the masonry units and eventually reach their inner surface, first as dampness and then as free water. Generally rain ceases long before such complete saturation and water evaporates from the wall by the drying effect of wind and air movement.

These two modes of action are sometimes referred to as the “raincoat effect”, in the case of dense, low absorption units, and the “overcoat effect”, in the case of high absorption units. Solid walling can ultimately be penetrated by prolonged exposure to wind-driven rain regardless of the water absorption characteristics of the masonry units.

5.5.4.2.2 *Mortar composition*

Mortars vary in water permeability relative to their cement content, high strength mortars of Designation (i) and (ii) (see Table 14) being the most resistant to water penetration. These mortar Designations are often used in conjunction with dense, low water absorption clay bricks. This combination is satisfactory but should not be regarded as providing a near waterproof construction (see **5.5.4.2.6**).

Strong dense mortars such as Designations (i) and (ii) are not suitable for use with some other types of masonry units and selection is governed by other factors such as accommodation of movement, durability and strength. Designation (iii) and (iv) mortars are often more appropriate.

Of the various mixes recommended for the mortars of each designation those incorporating lime in their composition show an improvement in bond development. As a consequence they show a better resistance to rain penetration than those mortars based on air entrainment and/or mineral materials other than lime. However, in practice, this advantage is not likely to be of great significance.

5.5.4.2.3 *Thickness of leaf*

The resistance to rain penetration of a single-leaf wall is dependent upon its thickness. Table 12 shows the recommended minimum thicknesses for both rendered and unrendered single-leaf walls for various categories of exposure (as defined in Table 11).

With regard to rain resistance a waterproof cladding system (as listed in **5.5.4.2.9**) applied to single-leaf masonry is satisfactory in all categories of exposure.

Where hollow blocks are used in external walls, the use of shell bedding can reduce rain penetration.

Table 12 — Single-leaf masonry — Recommended thickness of masonry for different types of construction and categories of exposure

Type of masonry	Minimum constructional thickness[a] mm	Maximum recommended exposure zone from Table 11 for each construction			
		Unrendered	Rendered in accordance with BS 5262	Externally insulated	Impervious cladding
Clay or calcium silicate	90	Not recommended	1	3	4
	215	1	2	3	4
	328	1	3	3	4
	440	2	3	3	4
Dense concrete	90	Not recommended	1	3	4
	215	1	2	3	4
	250	1	3	3	4
	328	1	3	3	4
	440	2	3	3	4
Lightweight concrete	90	Not recommended	1	3	4
	190	Not recommended	2	3	4
	215	Not recommended for blocks with open surface texture	3	3	4
	328	1	3	3	4
	440	2	3	3	4

[a] Based on work sizes and excluding render thickness.

5.5.4.2.4 *Cavity walls*

Cavity walls with a minimum outer leaf thickness of 90 mm can perform acceptably in all categories of exposure (see Table 11). However, consideration may be given to the use of a thicker outer leaf to reduce the quantity of water reaching the cavity.

In cavity walls, some water will inevitably penetrate the outer masonry leaf in prolonged periods of wind-driven rain, but proper design and positioning of DPCs and trays (see **5.5.5**) and of any insulation will minimize the risk of penetration further into the building. Where the cavity is unavoidably bridged, e.g. at window and door openings, correct detailing is necessary (see **5.5.5**).

The inner leaf of a cavity wall should not be relied upon to resist water penetration.

5.5.4.2.5 *Width of air space within any cavity*

In cavity walls the space between the two leaves of masonry is intended to prevent any water from passing from the outer leaf to the inner one. In most situations a cavity wall with an outer leaf of 90 mm minimum thickness, a 50 mm cavity and an inner leaf is satisfactory. In conditions of Severe or Very Severe categories of exposure (as defined in Table 11), consideration should be given to the use of wider cavities.

5.5.4.2.6 *Mortar joint, profile and finish*

The masonry unit to mortar interface is the position in the wall most vulnerable to rain penetration. A microscopic labyrinth of voids exists at the interface because of the physical nature of mortar bonding. The interface is also a likely location for capillary cracks due to imperfect adhesion between a mortar and masonry units. The interface can be degraded further by cracking due to moisture and thermal movements subsequent to construction.

Whatever the type of masonry, filled cross and bed joints minimize the risk of rain penetration.

The tooling involved in finishing joints such as those with bucket handled and struck weathered profiles firms the mortar, reducing its permeability at the surface, and pushes it tight to the masonry units, thereby improving its adhesion to them. Both factors are beneficial in resisting rain penetration.

Recessed joint profiles form ledges which impede the run-off of water and encourage it to enter the walling at the mortar/masonry unit interface. Those formed by raking out the mortar without subsequent tooling to firm its surface further increases the vulnerability of the wall to rain penetration. Recessed joints also reduce the width of the mortar joints. Compared with bucket handled and struck weathered profiles, the risk of rain penetration is greater with recessed joints.

When recessed joints are contemplated for use in other categories of exposure than Sheltered (as defined in Table 11), the manufacturer of the masonry units should be consulted.

5.5.4.2.7 *Cavity insulation*

If a thermal insulation material is installed within the cavity of a cavity wall (see **5.9.3**) and is not done correctly, it can increase the risk of rain penetration of the wall [6].

In a "partial-fill system", insulation material is built-in so that a free airspace is retained. This airspace should be of a minimum target width of 50 mm. Face insulated masonry units should be used with a retained air space.

In a "full-fill system", the space between the inner and outer masonry leaves is filled with insulation material either by building it in as construction proceeds or by injecting or blowing it into the cavity after the wall has been completed.

The space for full-fill insulation should be of a minimum target width of 50 mm, but the risk of rain penetration will be reduced by specifying a wider cavity.

5.5.4.2.8 *Architectural features and local practice*

Architectural features have an important effect on the risk of rain penetration. Design details may increase the tendency for masonry to be wetted than by incident rainfall alone (see **5.6.5**).

Examples of features that cause concentrated wetting are listed below.

a) Areas of glazing or cladding can produce large amounts of surface run-off water. Unless there is a gutter to collect it, or a projecting sill to throw it clear, excessive wetting and possible water penetration can occur in any masonry below.

b) Recessed band courses can cause local concentration of wetting. Corresponding intrusions into the cavity due to the setting back of masonry units to form the feature should be avoided unless appropriate damp-proofing measures are taken to prevent water crossing the cavity.

Adequate overhangs and drips or the provision of drainage to take water away from the masonry will reduce the degree of wetting.

Detailed commentaries on the protection afforded by projecting features such as sills, copings, string courses, roof eaves and verges, and on the concentration of surface run-off of rain water by wind are contained in BS 8104:1992, Annex E.

Local knowledge, experience and the evidence of local traditional forms of construction and building detail should be taken into account (see the foreword of BS 8104:1992).

5.5.4.2.9 *Applied external finishes*

Where walls are exposed to extreme conditions of driving rain, impervious cladding systems such as metals, plastic materials, slates, tile hanging, shingles, timber boarding or sheeting may be required.

Rendering can substantially enhance the rain resistance of single-leaf and cavity walls. The right type of mix, thickness and number of coats should be selected and the wall should be detailed correctly. The recommendations set out in BS 5262 should be followed.

The combination of full-fill insulation and rendering can inhibit the drying out of any moisture that enters the outer leaf of masonry. The moisture content of the outer leaf consequently rises and remains high, increasing the risk of frost action and of sulfate attack of the jointing and rendering mortars, if sulfates are present in the masonry units. Clay bricks of durability Designation MN are not recommended in this situation. Bricks of Designation FN are only recommended when sulfate-resisting Portland cement is used for the jointing and rendering mortar.

The use of masonry paint systems (see BS 6150) and other proprietary external finishes including colourless treatments, e.g. silicone-based water repellents (see BS 6477), can increase the resistance to rain penetration. However, they can also reduce the rate of evaporation of any water from the wall and so the moisture content of the wall can increase. In extreme cases this can cause saturation sufficient to place clay bricks of ML and MN durability Designation at risk of frost damage.

5.5.4.2.10 *Effective workmanship to be achieved on site*

The quality of workmanship actually achieved, both when constructing masonry and when installing any insulation material is a very important factor affecting resistance to rain penetration.

All workmanship should be in accordance with Annex A.

Certain masonry external leaves require particular care in their construction compared with others, e.g. masonry units of low water absorption versus those of high water absorption. From the description of the raincoat effect and the overcoat effect (see **5.5.4.2.1**) it is evident that minor imperfections in the jointing of high water absorption units (overcoat effect) might not be critical since, except in Severe and Very Severe categories of exposure, most periods of wind-driven rain are interrupted by a drying period before the units in the wall have become so saturated that the rain penetrates. In contrast, rain falling on a wall of low water absorption units (raincoat effect) will run down over the glass-like surface to penetrate any imperfections in the jointing.

5.5.5 ***DPCs and cavity trays***

5.5.5.1 *General*

A DPC in a building is intended to provide a barrier to the passage of water from the exterior of the building to the interior, from the ground to the structure or from one part of the structure to another.

Where a DPC is intended to prevent the upward movement of water due to capillary action, joints should be made in accordance with the manufacturer's instructions. Where no instructions are given, a minimum lap of 100 mm should be used. However, where water is moving in a downwards direction, the joints in the DPC should be sealed.

A DPC should extend through the full thickness of the wall or leaf, and preferably project beyond the external face. A DPC or tray should be laid on a smooth bed of fresh mortar. If it is necessary to accommodate differential sliding movement between the units on either side of it, the mortar bed should be trowelled smooth, allowed to set, and then cleaned off before the DPC is laid. Coarse aggregates that might damage the DPC should not be used. DPCs and cavity trays should not be pierced by services, reinforcement, fixings, etc. DPCs should not be bridged by pointing, rendering, plastering, tiling, etc.

5.5.5.2 *Performance*

DPCs and cavity trays should have the following material properties:

a) an expected life at least equal to that of the building;

b) resistance to compression without significant extrusion;

c) resistance to sliding where necessary;

d) adhesion to units and mortar where necessary;

e) resistance to accidental damage during installation and subsequent building operations;

f) workability at temperatures normally encountered during building operations, with particular regard to ease of forming and sealing joints, fabricating junctions, steps and stop ends, and the ability to retain shape.

Information on performance of individual materials currently used for DPCs is provided in Table 3.

BS 8215 gives guidance on the basic principles concerning the function and installation of DPCs in masonry. It contains recommendations for the selection, design and installation of DPCs in both solid and cavity construction.

5.5.5.3 *Junctions*

Detailed three-dimensional drawings should be made of all junctions, steps, angles and stop ends, to enable fabrication either on or off site. Many common details cannot be formed satisfactorily on site, unless they are fabricated in lead. If materials other than lead are to be used in complex situations, then pre-formed cloaks should be specified, so as to restrict the site operation to simple jointing only.

5.5.5.4 *Continuity and support*

Where possible DPCs and cavity trays should be formed from a continuous length of material. Cavity trays should be supported at their joint positions to facilitate effective sealing.

Where required continuous support should be provided to avoid excessive sagging and deformation.

5.5.6 ***Resisting rising damp***

5.5.6.1 *Immediately above ground level*

In every external wall, a DPC should be provided at least 150 mm above the finished level of the external ground or paving. To prevent the transfer of moisture from external walls into solid floors, the damp-proof membrane in the floor, and the DPC in the wall, should overlap a minimum of 100 mm or be sealed.

5.5.6.2 *Below ground level*

In cavity work extending below ground level, the cavity should be filled with fine concrete to 75 mm below finished ground level.

Immediately above ground level, weepholes should be left in the vertical cross joints of the outer leaf at intervals not greater than 1 m.

Where the lowest floor of a building is below ground level horizontal and vertical damp-proof membranes and DPCs are required with continuity between them (see BS 8102).

5.5.6.3 *Cavity trays to exclude soil gas*

In some areas it may be necessary to provide a cavity tray at ground level in place of a DPC to prevent upward movement of moisture as well as to close the cavity to prevent soil gases, e.g. radon and methane, from entering the building through the part of the cavity wall in contact with the ground. Particular attention should be paid to jointing. Where buildings are placed on sites where protective measures are required to prevent the entry of hazardous gases, e.g. radon or methane, particular attention should be paid to the jointing of the DPC or cavity tray to the gas resistant membrane in the floor or other parts of the structure.

The cavity tray should be supported by fine concrete fill in the base of the cavity, or by pre-formed in-fill units, in order to reduce stresses on the cavity tray and its joints. Fill may not be necessary if the cavity tray is made of a self supporting material.

5.5.7 ***Controlling downward movement of water***

5.5.7.1 *Cavity walls*

Cavity wall design should be based on the assumption that rain will penetrate the outer leaf of the wall, even if it is rendered, and run down the inside of that leaf.

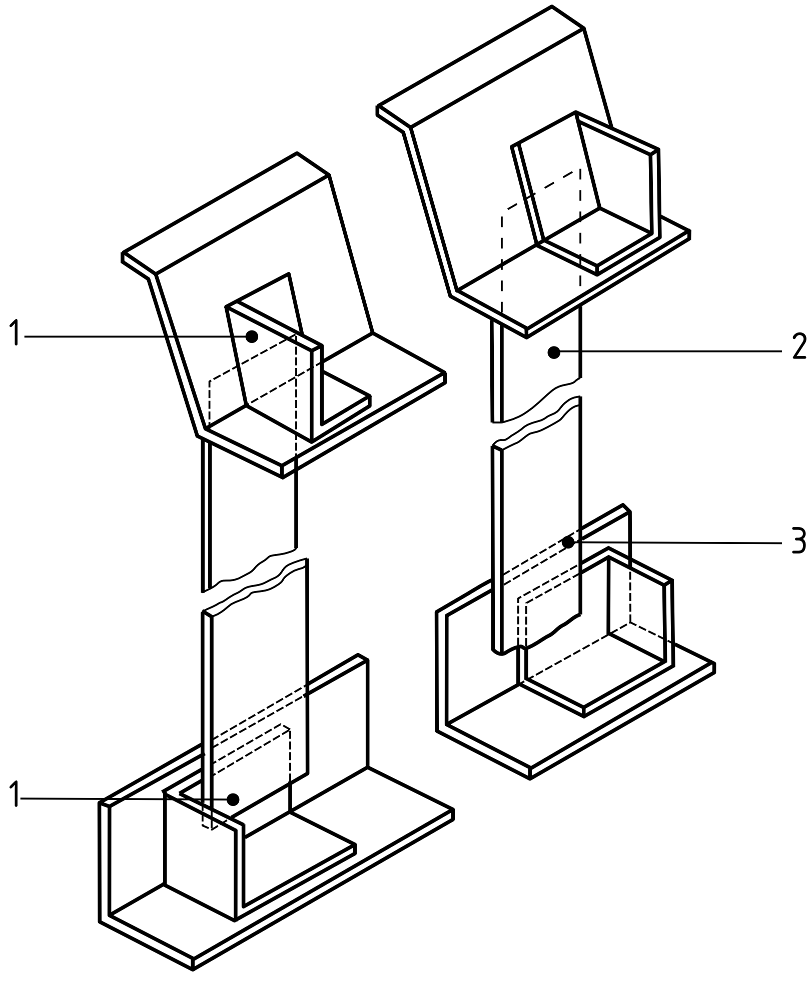
Where the cavity is bridged, e.g. by lintels, structural beams, floor slabs, pipes, and ducts, (see **5.3.8**) DPCs in the form of cavity trays should be provided to divert water away from the inner leaf.

5.5.7.2 *Over openings*

In cavity walls, cavity trays should be provided over all openings (including small openings for ducts, services, etc.), unless they are well protected by a roof or balcony overhang.

The cavity tray should step down or slope across the cavity not less than 150 mm towards the external leaf and, preferably, terminate in a small drip on the face of the wall. This can be difficult to achieve in arches (see **5.11.6**).

The cavity tray over the opening should overlap the vertical DPCs at the jambs to ensure continuity of damp-proof measures (see Figure 19).



1 Stop ends in perpend joints
Stop ends bonded to cavity tray
2 Vertical DPC behind or tight to underside of cavity tray
3 Vertical DPC laps over tray at sill

Figure 19 — Continuity of damp-proof measures

5.5.7.3 *Stop ends*

Where trays are discontinuous stop ends should be fitted.

5.5.7.4 *Weepholes*

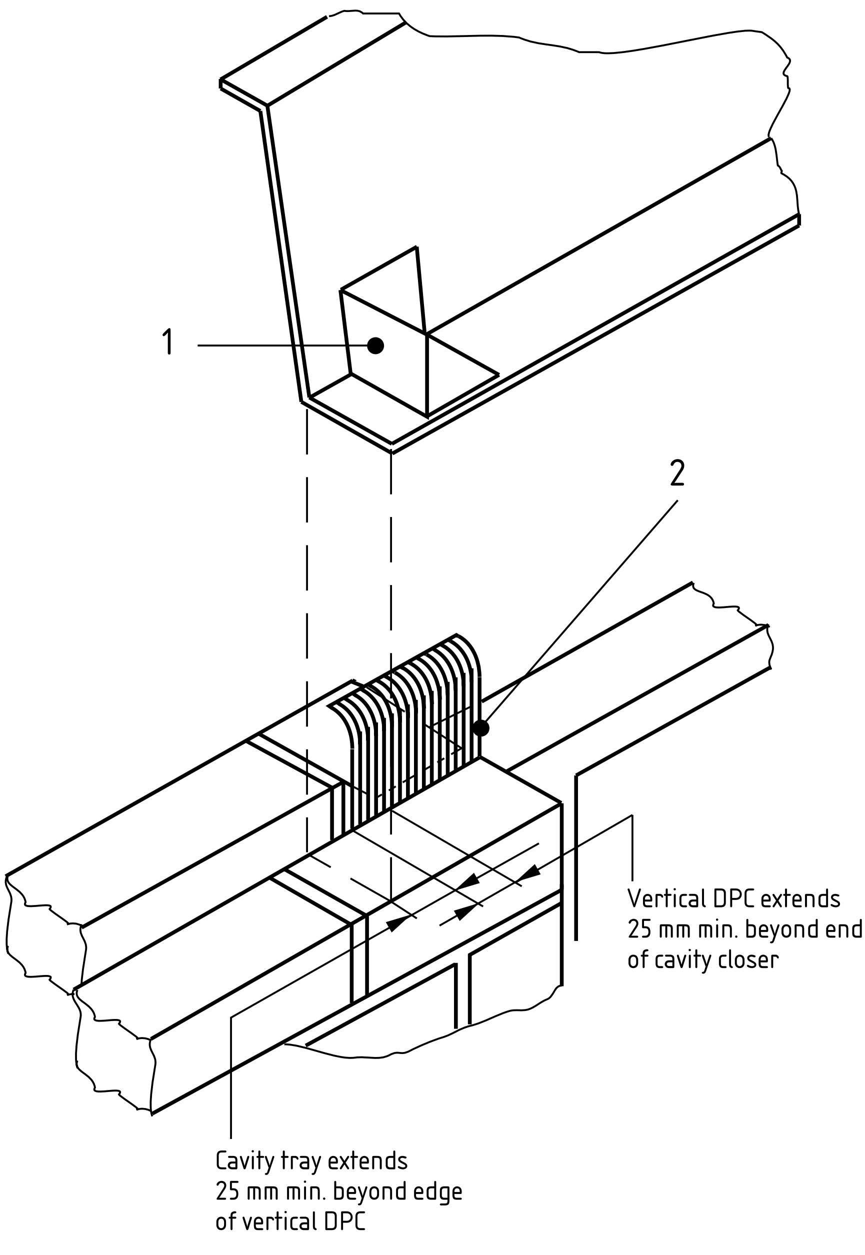
Weepholes should be formed through the outer leaf immediately above the cavity tray. These may be formed in the vertical cross joints at intervals not greater than 1 m. There should be not less than two weepholes over each opening.

Proprietary devices may be installed to form weepholes. They may be designed to drain the cavity but prevent the ingress of wind-driven rain.

Weepholes need not be provided if walls have a rendered external surface finish.

5.5.7.5 *At jambs of openings*

Where a cavity wall is closed at the jambs of openings by masonry, a vertical DPC should be inserted to separate the inner and outer parts of the wall and should extend into the cavity at least 25 mm beyond the width of the closer (see Figure 20).



1 Stop end to cavity tray locates in cross joint of masonry. Cavity tray overlaps in front of the vertical DPC. It should extend beyond the vertical DPC and cover any lintel.
2 To provide continuity of the resistance to moisture penetration ideally the vertical DPC should be tucked up behind the cavity tray. However, where lintels with flat soffits are used then the vertical DPC should be terminated at the underside of the cavity tray or turned back on to the inner leaf.

Figure 20 — Vertical DPC

Any frame should be placed so as to avoid transmitting water past the DPC. Where the frame is to be built-in, the DPC should be secured to the frame before building in. If the frame is to be fixed later, the DPC should be left with a suitable projection to facilitate this. Vertical DPCs at openings should be positioned to overlap any horizontal DPC at the sill of the opening and be overlapped by any cavity tray at the head (see Figure 19).

Proprietary devices are available which function as a vertical DPC and cavity closer. The manufacturer's instructions for installation and linking with associated DPCs at the head and sill should be followed.

5.5.7.6 *Under sills*

All pervious or jointed sills or sub-sills should be provided with a DPC for the full length and width of the sill bed. The DPC should be overlapped by the vertical DPCs at the jambs of the openings (see Figure 19). Where the sill is in contact with the inner leaf, the DPC should be turned up at the back and ends for the full depth of the sill.

5.5.7.7 *Cavity trays over cavity insulation*

Where cavity insulation is present but not installed throughout the full vertical height of the cavity (e.g. up to eaves level in gable ends) a cavity tray should be used immediately above the insulation. The tray should step down (by a minimum of 150 mm) towards the outer leaf and weepholes. Stop ends should be provided.

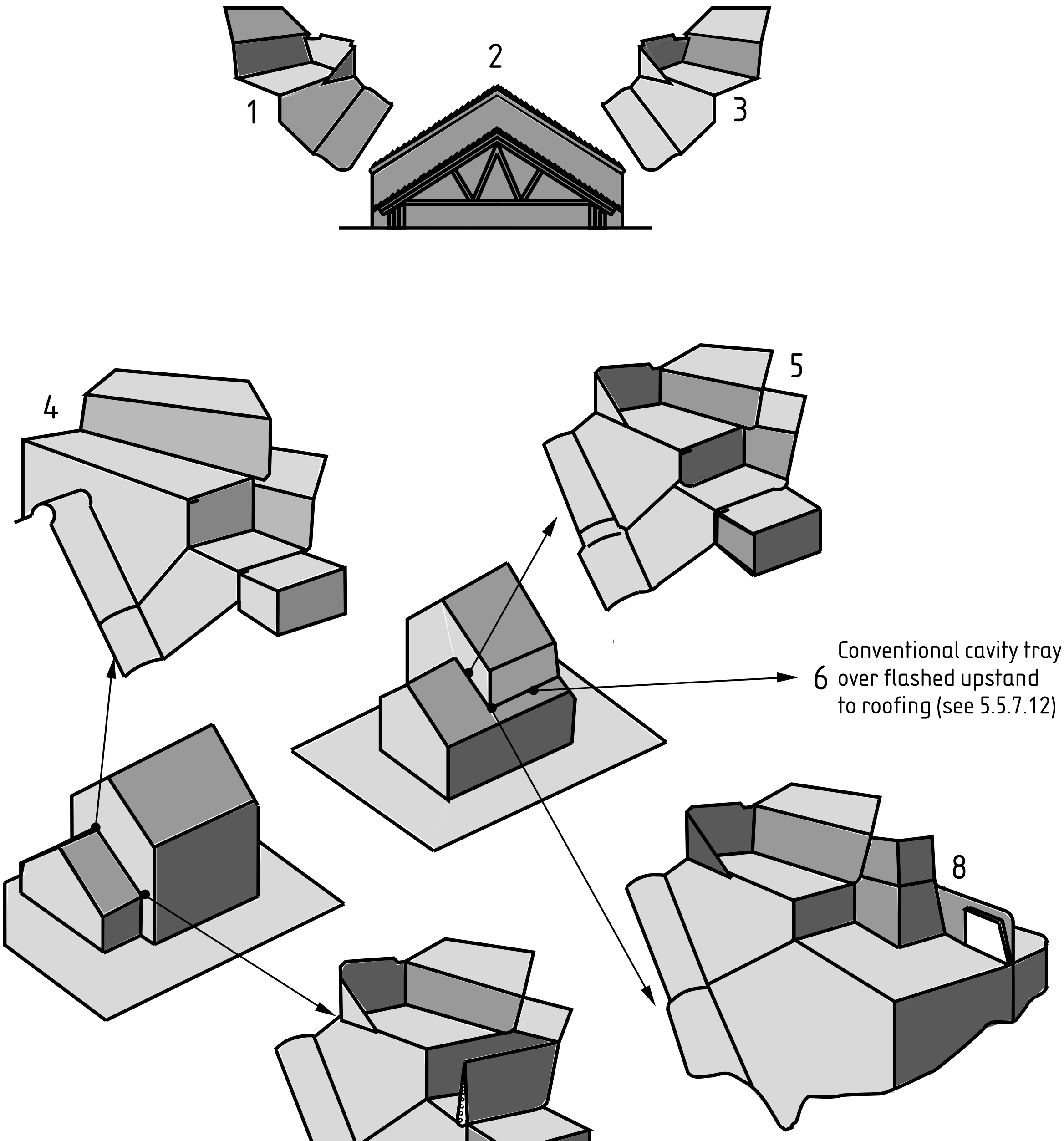
In buildings over 12 m high with insulated cavity walls, cavity trays should generally be used to subdivide the cavity at a maximum of 12 m above ground level and at a maximum spacing of 7 m thereafter.

5.5.7.8 *External wall becoming an internal wall*

Where, in its height, an external wall becomes an internal wall at lower level, as in the case of a roof abutting a wall (e.g. in a stepped terrace of houses, or a porch or conservatory annex) a cavity tray should be installed to drain the cavity above the lower roof level.

Where the abutment is horizontal a cavity tray with stop ends and weepholes should be used. Where a pitched roof abuts such a wall, a cavity tray stepped to correspond with the slope should be used. Alternatively, a system of overlapping pre-formed trays can be installed to collect and discharge water from the cavity (see Figure 21). In either case it is essential that stop ends and weepholes are used.

Proprietary systems are available for this application.



1 Left hand intermediate tray
2 Trays are handed. Viewed toward the gable, the left hand trays discharge to the left and the right hand trays discharge to the right.
3 Right hand intermediate tray
4 Ridge tray
5 Intermediate tray (right hand version)
6 A cavity tray is required above horizontal abutments
7 Out-fall tray
8 Corner tray

Figure 21 — Typical system of overlapping pre-formed cavity trays

5.5.7.9 *Structural frames*

Where masonry is supported by a structural frame, the design should contain provisions to ensure the continuity of trays and DPCs. Where cavity brick masonry is supported on an edge beam, or on a floor slab, a cavity tray should be used to prevent moisture penetration into the structure. Where a column, or other structural member, obstructs the cavity of a wall, the cavity tray should be continuous around the member. Where a structural member bridges a cavity, a vertical DPC should be included between the structural member and the external leaf, and stop ends fitted to any adjacent cavity trays.

Where complex shapes are needed, pre-fabricated cloaks should be considered (see Figure 22).

In general a minimum upstand of 150 mm is necessary.

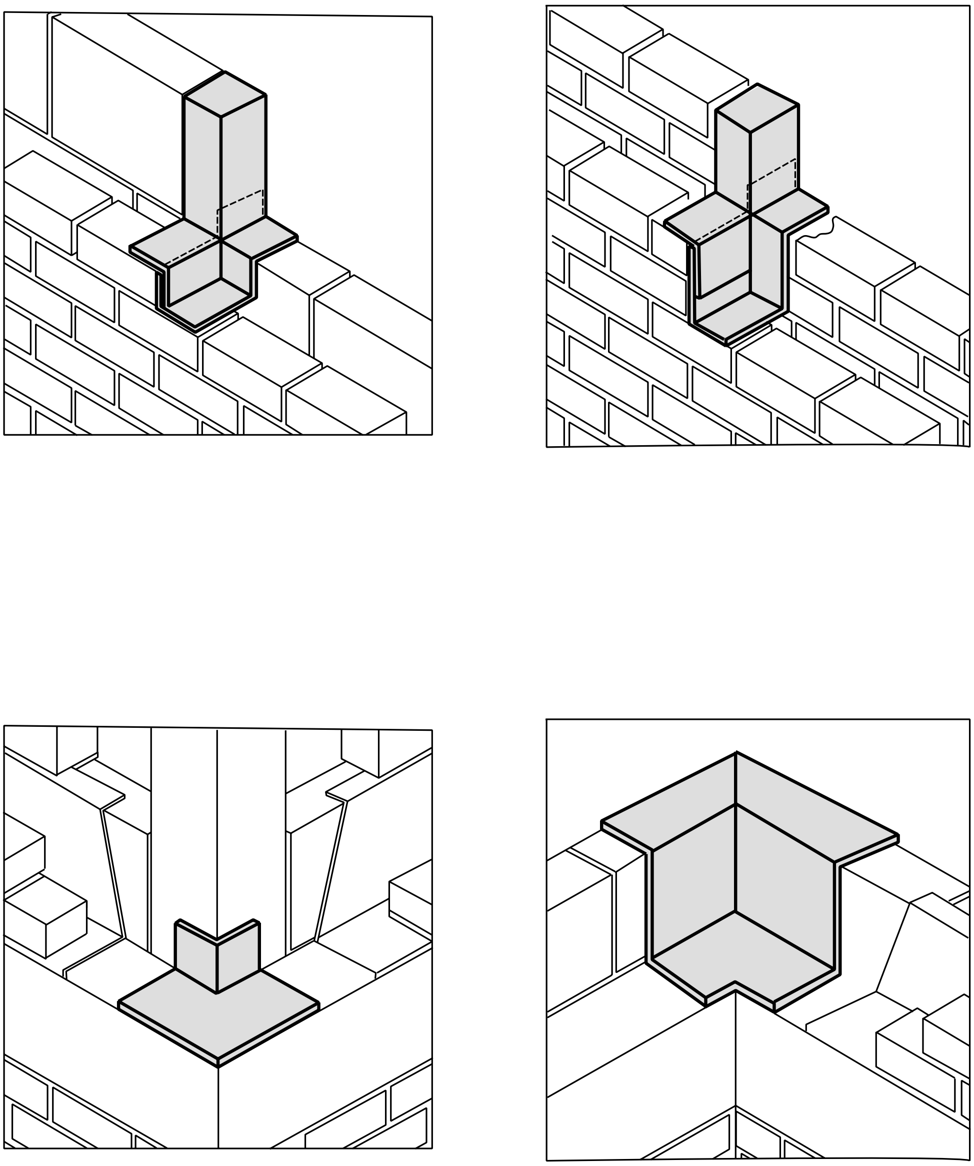


Figure 22 — Typical pre-formed cavity tray cloaks

5.5.7.10 *In parapets*

A DPC should be provided at a height of not less than 150 mm above the top surface of the roof system and lap over the flashing to the roofing to give continuity.

In a cavity parapet wall, a cavity tray should be installed, stepped down at least 150 mm towards the inner or outer part of the wall (see Figure 23).

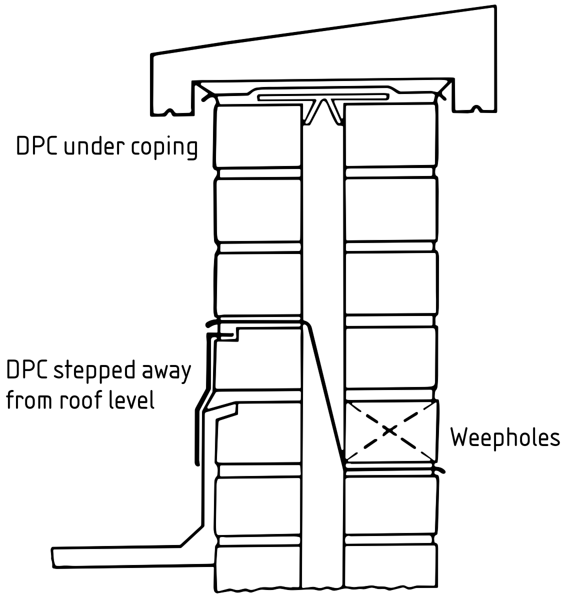


Figure 23 — Cavity parapet walls

Particular care is necessary in the specification and formation of joints in cavity trays in parapet walls (see **5.5.5.4**).

Careful consideration is necessary in deciding which way to slope the tray in a given case. It is safer to slope or step it outwards to direct water towards the outer face, but this can cause staining. If sloped inwards, in exposed locations, moisture can travel along the underside of the tray and gain access to the underside of the roof covering and the interior of the building.

When cavity fill insulation is installed, the tray should always slope or step down to the outer leaf.

It should be noted that the DPC or cavity tray impairs the structural continuity of the parapet and the wall beneath it, and of the coping and the parapet. Structural stability of the parapet should be in accordance with **5.2.1**.

5.5.7.11 *Chimneys*

Chimneys may be built in solid or cavity wall constructions.

Where a chimney stack is:

a) incorporated in an outer cavity wall; and

b) in locations subjected to Severe and Very Severe categories of exposure (as defined in Table 11); and

c) preferably, in general;

the outer leaf and cavity should be continuous around the chimney stack for the full height of the outer wall and then completely surround the chimney stack where it projects above the roof. Corbelling from the chimney breast may be necessary below the roof line, to support the outer leaf at the sides and back of the chimney stack.

DPC trays should be provided to prevent the downward passage of water into the interior of the building. Horizontal trays, through the thickness of the chimney wall, with an upturn at the inner face of the flue, should be linked with the flashing at the intersection with the roof. Figure 24 illustrates typical arrangements.

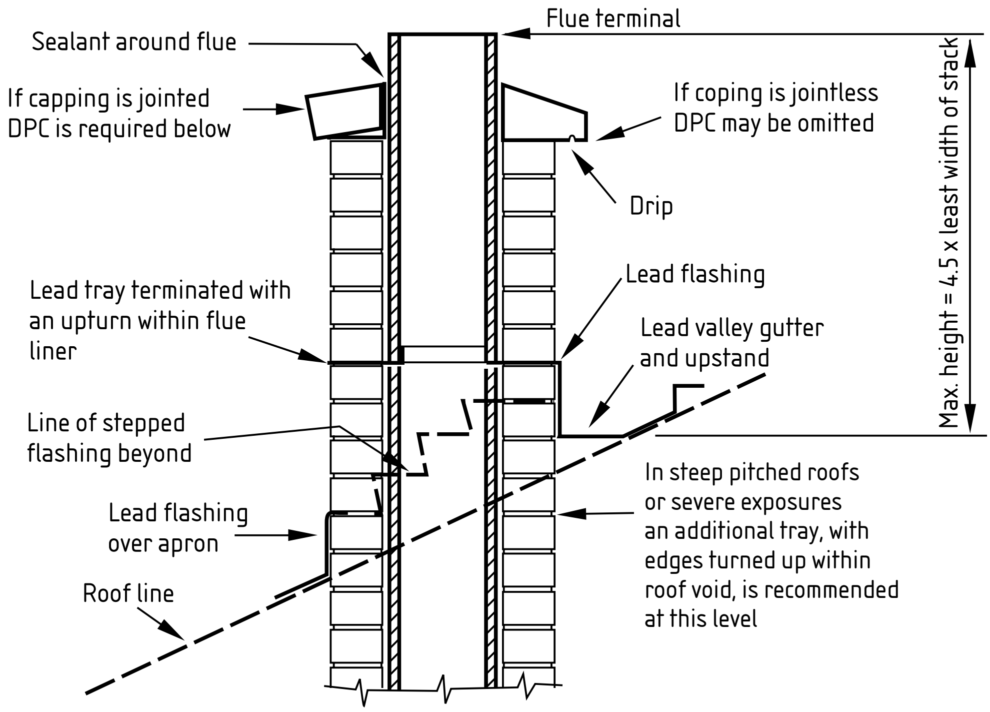


Figure 24 — Detail of chimney stack

It should be noted that a sheet DPC at the point of intersection with the roof structurally separates the masonry and the stability of the chimney stack and its resistance to lateral wind loading needs to be considered. Chimney stacks built in cavity work may be provided with a DPC tray of a material stiff enough to form a cavity tray without being built into the inner leaf and so allowing structural continuity.

A horizontal DPC should always be provided below any coping or capping at the top of the stack.

5.5.7.12 *Flashings and weatherings*

The material to be used for flashings and weatherings should be sufficiently malleable to permit dressing into shape, but sufficiently stiff to maintain its shape and to resist lifting by the wind. Metal flashings other than lead should, preferably, be pre-formed.

Flashings should be located below an associated DPC and/or the cavity tray. They should be bedded into the masonry to a minimum 25 mm depth unless the flashings are supplied already bonded onto a DPC or cavity tray. Joints in the length of the flashing should be welted, sealed or adequately overlapped. If flashings are to be installed into pre-formed chases care should be taken to avoid damage to the DPCs.

Aluminium and aluminium alloy flashing and weatherings should be protected from contact with mortar by a coating of bituminous paint, and are not recommended for natural stone other than granite or sandstone.

The materials should be selected with regard to the risk of corrosion. To avoid staining of masonry from the run-off of rain water (e.g. in the case of copper), the design should contain provisions for the surface treatment of some metals.

5.5.7.13 *Cappings and copings*

Chimney terminals, free-standing walls, parapet walls and retaining walls exposed to the weather, should preferably be provided with a coping (see **3.15**). Drip edge(s) should be positioned a minimum of 40 mm from the face(s) of the wall. Where for aesthetic or other reasons a capping (see **3.6**) is used, special care is needed in the choice of materials, both for the capping and for the walling beneath (see **5.6**).

Where the coping or capping is jointed, a continuous DPC should be provided. In cavity walls horizontal DPCs require support over the cavity.

Resistance to water penetration should not prejudice provision for masonry movement. Movement control joints in masonry should be carried through any coping or capping (see **5.4**).

Consideration should be given to copings being displaced by lateral loads, and to the possibility of vandalism. L-shaped copings and clip-over copings can be more satisfactory in some situations. Where necessary, copings should be suitably fixed down and can be doweled or joggle-jointed together.

5.6 Durability

5.6.1 *General*

5.6.1.1 A major factor influencing the durability of masonry is the degree to which it becomes saturated with water. It can become saturated directly by rainfall, indirectly by water moving upwards from foundations or laterally from retained material as in a retaining wall.

External masonry is much less likely to become saturated where projecting features have been provided to shed run-off water clear of the walling below. Examples of such features are:

a) roof overhangs or copings;

b) throated sills;

c) bell mouths to rendering and similar features at the base of tile hanging and other impermeable cladding.

It should be noted that conventional weathering details do not always protect walls sufficiently in situations of Severe or Very Severe categories of exposure (as defined in Table 11).

Recessed mortar joints can increase water intake into the surface of a wall, placing it at greater risk of frost attack. Therefore, recessed joints are not recommended for external work using clay bricks of the moderate frost resistant category (M) specified in BS 3921:1985.

Impervious finishes, e.g. masonry paint, tiling, or a dense render, can lead to the entrapment of moisture in the masonry if water is able to get behind the finish as a result of poor building detail or imperfections in the finish (see **5.5.4.2.9**).

External masonry will generally be maintained in a drier condition by a moderately porous uncracked render conforming to BS 5262, or by a ventilated cladding such as slate or tile hanging, by weather boarding, and by panels of various materials, e.g. of plastics, timber or metal.

5.6.1.2 Frost can damage both masonry units and mortar, depending on their susceptibility to such damage when frozen in a saturated, or near saturated, condition.

5.6.1.3 When masonry remains wet for long periods and soluble sulfates are present in sufficient quantities, sulfate attack[1)] on mortar joints and other materials containing Portland cement can arise (see **5.6.4**). Soluble sulfates can originate from various sources including some clay bricks.

[1)] Such attack occurs through the expansion and deterioration of mortar as a result of chemical reaction between soluble sulfates and tri-calcium aluminate in Portland cement in the presence of water. The reaction, forming calcium sulfoaluminate (ettringite), is accompanied by an expansion leading to cracking and crumbling of the mortar. In severe cases the expansion can lead to distortion or rotation of the masonry.

5.6.1.4 The durability of masonry with regard to frost action and sulfate attack depends on the characteristics of both the masonry units and the mortar in relation to service conditions. The following factors affect the susceptibility of the masonry to damage.

a) Exposure to weather or to other sources of water (see **5.6.2**).

b) Exposure to aggressive conditions from all sources including the ground (see **5.6.3** and **5.6.4**).

c) The adequacy of the design details adopted in preventing the masonry from becoming saturated, or near saturated (see **5.6.5**).

d) Conditions of highly mobile groundwater.

The design should take into account the choice of masonry units and mortar in the following and similar situations where masonry is likely to become and can remain substantially wet for long periods of time.

a) In chimney terminals, sills, copings and cappings.

b) In free-standing and retaining walls, parapets and chimney stacks.

c) Below DPCs at or near ground level and in foundations, manholes and inspection chambers.

d) In conditions of highly mobile ground water.

The degree to which masonry, used below DPCs at or near ground level, becomes saturated will vary according to the site. Masonry materials are far less prone to problems on a site that is well drained and dry. Where a site is wet, and/or the masonry at or near ground level is subject to saturation, the choice of materials should take this into account.

Paved surfaces adjacent to masonry should be laid to falls so that water is not directed to the masonry.

Where there is greater than 150 mm of masonry exposed between a DPC and the finished ground level, e.g. on sloping sites, the inner leaf of such masonry may act as an earth retaining wall. In some circumstances, water can be transferred into the walling thereby inducing a risk of frost action and sulfate attack, efflorescence, lime leaching and staining of the outer leaf. The application of waterproofing treatments to the rear face of the masonry in contact with the retained ground will avoid such problems.

Earth retaining walls are particularly susceptible to saturation from retained ground in wet weather conditions. Backfill material should be free draining [see Table 13**(K)**].

5.6.2 *Exposure to the weather*

A good indication of the general exposure of the site to wind-driven rain may be obtained as described in **5.5**. However, it should be appreciated that different elements in the same building can be subject to different degrees of exposure. This can affect the choice of materials including insulation (see **5.5.4.2.7**).

In locations subject to Severe or Very Severe categories of exposure, the benefits of protection by overhangs and other projecting features (see **5.6.1**) are particularly valuable. If such protective features are omitted for aesthetic or other reasons, the effects of the increased exposure of the masonry to wetting should be considered (see **5.6.5**).

5.6.3 *Frost action*

5.6.3.1 *General*

Night frosts are common in all parts of the UK, even in mild winters, and horizontal surfaces especially lose heat by radiation to clear night skies. Masonry at subzero temperatures is therefore not uncommon. Low temperatures alone do not damage masonry, but if it is saturated, or near saturated, the water can freeze to form ice within the fabric. As water changes from liquid to solid it expands and induces stress in the materials. Frost resistant materials should be used in the design for masonry unless there are protective features which protect it against severe wetting.

Extra care should be given to the choice of masonry units and mortar if the masonry is liable to be splashed with de-icing salts from roadways or if the building is to be located in conditions of extreme exposure to weather (see **5.6.3.3**).

5.6.3.2 *Clay masonry units*[2)]

For clay masonry units, neither strength nor water absorption are reliable guides for assessing the resistance to freezing and there is no substitute for experience of performance in a particular situation.

Where clay brick masonry is used in situations in which it can become saturated and exposed to cyclic frost action, the frost resistant category (F) specified in BS 3921:1985 should be used.

5.6.3.3 *Calcium silicate masonry units*

For calcium silicate bricks, durability and compressive strength are related, and experience shows that repeated freezing and thawing has little effect on them. Bricks conforming to strength Class 3 of BS 187:1978 possess good frost resistance in most applications, but higher strength classes are recommended for Very Severe categories of exposure. Calcium silicate bricks can suffer deterioration if they are impregnated with strong salt solution and then subjected to intense freezing. Thus, they should not be used in situations where the masonry can be directly wetted by seawater or subjected to contamination by repeated application of road de-icing salts.

5.6.3.4 *Concrete masonry units*

Precast concrete masonry units possess good frost resistance and should be selected following the recommendations of this standard.

5.6.4 ***Sulfate attack***

See also **5.6.1.3**.

Sulfates can be derived from ground waters, from the ground, including made-up fill adjacent to masonry, from flue gases, or from clay masonry units and aggregates. The degree to which soluble salts are extracted depends on the quantity of water available and the permeability of the masonry. For this reason, the design should contain provisions for effective DPCs and the exclusion of water (see **5.5.4**).

Where masonry is likely to remain wet for long periods of time, e.g. in free-standing walls, in earth retaining walls, below DPCs, at or near ground level and in elevations exposed to exceptionally severe wind-driven rain, sulfate attack of mortar can occur if soluble sulfates are also present. In these situations consideration should be given to the use of strong mortar mixes using Portland cement or sulfate-resisting Portland cement. Calcium silicate and concrete masonry do not contain soluble sulfates. However, masonry built of these units can be vulnerable to sulfates from other sources. Expert advice should be sought regarding the selection of concrete masonry units when it is intended to use them where significant concentrations of sulfates could be present, e.g. sulfate bearing ground conditions.

5.6.5 ***Architectural features***

5.6.5.1 *General*

For aesthetic reasons, designers may sometimes include features which lead to increased local exposure of the masonry. As a result, the masonry will be more likely to become very wet or saturated, so increasing the risk of frost damage or disfiguration. In such cases more durable masonry units and mortar should be selected, and this can in turn govern the choice for the whole building. Examples of architectural features leading to increased local exposure are:

a) recessed windows with sloping masonry at the bottom;

b) flush sills;

c) inadequate or non-existent overhangs at verges;

d) large expanses of glazing or impermeable cladding with no effective form of construction at the base designed to shed run-off rainwater clear of the masonry beneath;

e) areas of rendering adjoining the masonry and recessed from it without an efficient seal at the junction, or other detail to prevent the entry of water to the back of the render;

f) vertical tile hanging, the lower edge of which has little or no projection over the walling below.

[2)] There is no test method for assessing the frost resistance of clay products published in a British Standard, although a test has been developed by CERAM Research Ltd. The best evidence of ability to withstand frost damage is provided by brick masonry which has been in service for some years.

5.6.5.2 *Cappings*

Cappings can be brick-on-edge, bonded brick masonry or a purpose-made capping unit. Such cappings give relatively little protection to the masonry beneath, which can become saturated for up to 1 m below the capping level, depending on the water absorption of the masonry units used. It is strongly recommended that parapets and chimneys should be protected by copings and DPCs (see **5.5.7**).

Cappings of brick masonry and tile creasing, even though flaunched with mortar, cannot be relied upon to keep out moisture and require an effective DPC beneath them. Where possible, a one-piece coping, with weathered top and ample overhang, properly throated, is preferred (see **5.5.7.13** regarding the requirement of a DPC below jointed copings).

5.6.5.3 *Chimney stacks*

Because chimney stacks are normally exposed on all four faces and the top, they may be more liable to saturation and frost attack than other parts of a building, especially where an effective coping has not been provided at the terminal.

5.6.6 ***Selection of masonry units and mortar for durability***

5.6.6.1 *General*

Table 13 gives guidance on the choice of masonry units and mortar Designations most appropriate for particular situations with regard to durability. Reference to experience of durability in service of masonry units and mortar produced from local constituent materials in the geographical area concerned can provide valuable guidance.

The recommendations above are for finished work; during construction, masonry units, mortar and recently finished work may need protection (see BS 8000-3).

NOTE For the convenience of users of this standard the text of BS 8000-3 is reproduced here, in Annex A.

5.6.6.2 *Recommendations for the use of natural stone*

Natural stone is usually selected for aesthetic reasons. Nevertheless, it should be durable enough for use in the intended location.

Few natural stones will not give adequate service between eaves and DPC in buildings of domestic scale. Durability will need to be assessed for the more exposed elements of a building, e.g. string courses, sills, copings and cappings, and for harsh climates, e.g. coastal regions, or areas in Severe or Very Severe categories of exposure as defined in Table 11.

Particular care should be exercised when selecting a stone for which there is no previous local experience of its satisfactory use. Petrographical examination, good geological interpretation and the quarrymaster's and/or mason's experience can all contribute to a final assessment of suitability. There are few established test methods for natural stone.

Water run-off from limestone and magnesian limestone can attack sandstone, some granites and some bricks. Masonry material combinations should be chosen that are not vulnerable to such attack. Alternatively, building detail should prevent the flow of water from limestone to other masonry materials.

5.6.7 ***Protection of components embedded in masonry from corrosion***

5.6.7.1 *Metal anchorages, dowels and fixings*

Metal components other than wall ties built into masonry should be selected from Table 1 and Table 2. (For wall ties see Table 10.)

Bolts, nuts, screws, etc. should be given the same protection as the components with which they are to be used and be compatible with these components, e.g. consideration should be given to the possibility of electrolytic action between dissimilar metals.

5.6.7.2 *Reinforcement*

Reinforcement for structural use should be protected as described in BS 5628-2. Reinforcement for non-structural use should be appropriate to the category given in Table 2.

5.6.7.3 *Timber components*

Where joist ends are built into external walls or the inner leaves of cavity walls, they should be treated with preservatives. For guidance, see BS 5268-5. Joists should not project into a cavity.

Table 13 — Durability of masonry in finished construction

Masonry condition or situation		Quality of masonry units and appropriate mortar designations				Remarks
		Clay units	Calcium silicate units	Concrete bricks	Concrete blocks	
(A) Work below or near external ground level						
A1	Low risk of saturation with or without freezing	FL, FN, ML or MN in (i), (ii) or (iii)	Classes 3 to 7 in (iii) or (iv) (see remarks)	$\geqslant$15 N/mm^2 in (iii)	a) of net density $\geqslant$1 500 kg/m^3; or b) made with dense aggregate complying with BS 882 or BS 1047; or c) having a compressive strength $\geqslant$7 N/mm^2; or d) most types of autoclaved aerated block (see remarks) in (iii)	Some types of autoclaved aerated concrete block may not be suitable. The manufacturer should be consulted. If sulfate ground conditions exist, the recommendations in **5.6.4** should be followed. Where Designation (iv) mortar is used it is essential to ensure that all masonry units, mortar and masonry under construction are protected fully from saturation and freezing (see **A.4.1.3.2** and **A.5.1.1**). The masonry most vulnerable in A2 and A3 is located between 150 mm above, and 150 mm below, finished ground level. In this area masonry will become wet and can remain wet for long periods of time, particularly in winter. Where FN or MN clay units are used in A2 or A3, sulfate-resisting cement should be used (see **5.6.4**). In conditions of highly mobile groundwater, consult the manufacturer on the selection of materials (**5.6.1.4**).
A2	High risk of saturation without freezing	FL, FN, ML or MN in (i) or (ii) (see remarks)	Classes 3 to 7 in (ii) or (iii)	$\geqslant$15 N/mm^2 in (ii) or (iii)	As for A1 in (ii) or (iii)	
A3	High risk of saturation with freezing	FL or FN in (i) or (ii)	Classes 3 or 7 in (ii)	$\geqslant$20 N/mm^2 in (ii) or (iii)	As for A1 in (ii)	
(B) DPCs						
B1	In building	DPC 1 as described in BS 3921, in (i)	Not suitable	Not suitable	Not suitable	Masonry DPCs can resist rising damp but will not resist water percolating downwards. If sulfate ground conditions exist, the recommendations of **5.6.4** should be followed. DPCs of clay units are unlikely to be suitable for walls of other masonry units, as differential movement can occur (see **5.4**).
B2	In external works	DPC 2 as described in BS 3921, in (i)	Not suitable	Not suitable	Not suitable	

Table 13 — Durability of masonry in finished construction *(continued)*

Masonry condition or situation		Quality of masonry units and appropriate mortar designations				Remarks
		Clay units	Calcium silicate units	Concrete bricks	Concrete blocks	
(C) Unrendered external walls (other than chimneys, cappings, copings, parapets or sills)						
C1	Low risk of saturation	FL, FN, ML or MN in (i), (ii) or (iii)	Classes 2 to 7 in (iii) or (iv) (see remarks)	⩾7 N/mm² in (iii)	Any in (iii) or (iv) (see remarks)	Walls should be protected by roof overhang and other projecting features to minimize the risk of saturation. However, weathering detail may not protect walls in conditions of Very Severe driving rain (see **5.5.4**). Certain architectural features, e.g. brick masonry below large glazed areas with flush sills, increase the risk of saturation (see **5.6.5**). Where Designation (iv) mortar is used it is essential to ensure that all masonry units, mortar and masonry under construction are protected fully from saturation and freezing (see **A.4.1.3.2** and **A.5.1.1**). Where FN clay units are used in Designation (ii) mortar for C2, sulfate-resisting cement should be used (see **5.6.4**).
C2	High risk of saturation	FL or FN in (i) or (ii) (see remarks)	Classes 2 or 7 in (iii)	⩾15 N/mm² in (iii)	Any in (iii)	
(D) Rendered external walls (other than chimneys, cappings, copings, parapets or sills)						
	Rendered external walls (other than chimneys, cappings, parapets or sills)	a) FN or MN in (i) or (ii) (see remarks); or b) FL or ML in (i), (ii) or (iii)	Classes 2 to 7 in (iii) or (iv) (see remarks)	⩾7 N/mm² in (iii)	Any in (iii) or (iv) (see remarks)	Rendered walls are usually suitable for most wind-driven rain conditions (see **5.5.4**). Where FN or MN clay units are used, sulfate-resisting cement should be used in the mortar and in the base coat of the render (see **5.6.4**). Where Designation (iv) mortar is used it is essential to ensure that all masonry units, mortar and masonry under construction are fully protected from saturation and freezing (see **A.4.1.3.2** and **A.5.1.1**).

Table 13 — Durability of masonry in finished construction *(continued)*

Masonry condition or situation		Quality of masonry units and appropriate mortar designations				Remarks
		Clay units	Calcium silicate units	Concrete bricks	Concrete blocks	
(E) Internal walls and inner leaves of cavity walls						
	Internal walls and inner leaves of cavity walls	FL, FN, ML, MN, OL or ON in (i), (ii), (iii) or (iv) (see remarks)	Classes 2 to 7 in (iii) or (iv) (see remarks)	$\geqslant$7 N/mm^2 in (iv) (see remarks)	Any in (iii) or (iv) (see remarks)	Where Designation (iv) mortar is used it is essential to ensure that all masonry units, mortar and masonry under construction are protected fully from saturation and freezing (see **A.4.1.3.2** and **A.5.1.1**)
(F) Unrendered parapets (other than cappings and copings)						
F1	Low risk of saturation, e.g. low parapets on some single storey buildings	FL, FN, ML, or MN in (i), (ii) or (iii)	Classes 3 to 7 in (iii)	$\geqslant$20 N/mm^2 in (iii)	a) of net density $\geqslant$1 500 kg/m^3; or b) made with dense aggregate conforming to BS 882 or BS 1047; or c) having a compressive strength $\geqslant$7 N/mm^2; or d) most types of autoclaved aerated block (see remarks) in (iii)	Most parapets are likely to be severely exposed irrespective of the climatic exposure of the building as a whole. Copings and DPCs should be provided wherever possible. Some types of autoclaved aerated concrete block may not be suitable. The manufacturer should be consulted. Where FN clay units are used in F2, sulfate-resisting cement should be used (see **5.6.4**).
F2	High risk of saturation, e.g. where a capping only is provided for the masonry	FL or FN in (i) or (ii)	Classes 3 to 7 in (iii)	$\geqslant$20 N/mm^2 in (iii)	As for F1 in (ii)	
(G) Rendered parapets (other than cappings and copings)						
	Rendered parapets (other than cappings and copings)	a) FN or MN in (i) or (ii) (see remarks); or b) FL or ML in (i), (ii) or (iii)	Classes 3 to 7 in (iii)	$\geqslant$7 N/mm^2 in (iii)	Any in (iii)	Single-leaf walls should be rendered only on one face, the other being left free to breathe. All parapets should be provided with a coping. Where FN or MN clay units are used, sulfate-resisting cement should be used in the mortar and in the base coat of the render (see **5.6.4**).

Table 13 — Durability of masonry in finished construction *(continued)*

Masonry condition or situation		Quality of masonry units and appropriate mortar designations: Clay units	Calcium silicate units	Concrete bricks	Concrete blocks	Remarks
(H) Chimneys						
H1	Unrendered with low risk of saturation	FL, FN, ML or MN in (i), (ii) or (iii)	Classes 3 to 7 in (iii)	$\geq$10 N/mm^2 in (iii)	Any in (iii)	Chimney stacks are normally the most exposed masonry on any building. Due to the possibility of sulfate attack from flue gases the use of sulfate-resisting cement in the mortar and in any render is strongly recommended (see **5.6.4**). Brick masonry and tile cappings cannot be relied upon to keep out moisture. The use of a coping is preferable. Some types of autoclaved aerated concrete block may not be suitable for use in H2. The manufacturer should be consulted.
H2	Unrendered with high risk of saturation	FL or FN in (i) or (ii)	Classes 3 to 7 in (iii)	$\geq$15 N/mm^2 in (iii)	a) of net density $\geq$1 500 kg/m^3; or b) made with dense aggregate conforming to BS 882 or BS 1047; or c) having a compressive strength $\geq$7 N/mm^2; or d) most types of autoclaved aerated blocks (see remarks) in (ii)	
H3	Rendered	FL or ML in (i), (ii) or (iii) or FN or MN in (i) or (ii)	Classes 3 to 7 in (iii)	$\geq$7 N/mm^2 in (iii)	Any in (iii)	
(I) Cappings, copings and sills						
	Cappings, copings and sills	FL or FN in (i)	Classes 4 to 7 in (ii)	$\geq$30 N/mm^2 in (ii)	a) of net density $\geq$1 500 kg/m^3; or b) made with dense aggregate conforming to BS 882 or BS 1047; or c) having a compressive strength $\geq$7 N/mm^2; or d) most autoclaved aerated blocks (see remarks) in (ii)	Some autoclaved aerated concrete blocks may be unsuitable for use in I. The manufacturer should be consulted. Where cappings or copings are used for chimney terminals, the use of sulfate-resisting cement is strongly recommended (see **5.6.4**). DPCs for cappings, copings and sills should be bedded in the same mortar as the masonry units.

Table 13 — Durability of masonry in finished construction *(continued)*

Masonry condition or situation		Quality of masonry units and appropriate mortar designations: Clay units	Calcium silicate units	Concrete bricks	Concrete blocks	Remarks
(J) Freestanding boundary and screen walls (other than cappings and copings)						
J1	With coping	a) FL or MN in (i) or (ii); or b) FL or ML in (i), (ii) or (iii)	Classes 3 to 7 in (iii)	⩾15 N/mm² in (iii)	Any in (iii)	Masonry in free-standing walls is likely to be severely exposed, irrespective of climatic conditions. Such walls should be protected by a coping wherever possible and DPCs should be provided under the copings and at the base of the wall (see **5.5**). Where FN or MN clay units are used for J1 in conditions of Severe driving rain (see **5.5**), the use of sulfate-resisting cement is strongly recommended (see **5.6.4**). Where Designation (iii) mortar is used for J2, the use of sulfate-resisting cement is strongly recommended (see **5.6.4**). Some types of autoclaved aerated concrete block may also be unsuitable. The manufacturer should be consulted.
J2	With capping	FL or FN in (i) or (ii) (see remarks)	Classes 3 to 7 in (iii)	⩾20 N/mm² in (iii)	a) of net density ⩾1 500 kg/m³; or b) made with dense aggregate conforming to BS 882 or BS 1047; or c) having a compressive strength ⩾7 N/mm²; or d) most types of autoclaved aerated block (see remarks) in (ii)	

Table 13 — Durability of masonry in finished construction *(continued)*

Masonry condition or situation		Quality of masonry units and appropriate mortar designations				Remarks
		Clay units	**Calcium silicate units**	**Concrete bricks**	**Concrete blocks**	
(K) Earth-retaining walls (other than cappings and copings)						
K1	With waterproofing retaining face and coping	FL, FN, ML or MN in (i) or (ii)	Classes 3 to 7 in (ii) or (iii)	⩾15 N/mm^2 in (ii)	a) of net density ⩾1 500 kg/m^3; or b) made with dense aggregate conforming to BS 882 or BS 1047; or c) having a compressive strength ⩾7 N/mm^2; or d) most types of autoclaved aerated block (see remarks) in (iii)	Because of possible contamination from the ground and saturation by ground waters, in addition to subjection to Severe climatic exposure, masonry in retaining walls is particularly prone to frost and sulfate attack. Careful choice of materials in relation to the methods for exclusion of water recommended in **5.5** is essential. It is strongly recommended that such walls be backfilled with free draining materials. The provision of an effective coping with a DPC (see **5.5**) and waterproofing of the retaining face of the wall (see **5.6.1.4**) is desirable. Where FN or MN clay masonry units are used, the use of sulfate-resisting cement may be necessary (see **5.6.4**). Some types of autoclaved aerated concrete block are not suitable for use in K1. The manufacturer should be consulted. Some concrete blocks are not suitable for use in K2. The manufacturer should be consulted.
K2	With coping or capping but no waterproofing on retaining face	FL or FN in (i)	Classes 4 to 7 in (ii)	⩾30 N/mm^2 in (i) or (ii)	As for K1 but in (i) or (ii) (see remarks)	

Table 13 — Durability of masonry in finished construction *(concluded)*

Masonry condition or situation		Quality of masonry units and appropriate mortar designations				Remarks
		Clay units	**Calcium silicate units**	**Concrete bricks**	**Concrete blocks**	
(L) Drainage and sewerage, e.g. inspection chambers, manholes						
L1	Surface water	Engineering bricks, FL, FN, ML or MN in (i) (see remarks)	Classes 3 to 7 in (ii) and (iii)	⩾20 N/mm^2 in (iii)	a) of net density ⩾1 500 kg/m^3; or b) made with dense aggregate conforming to BS 882 or BS 1047; or c) having a compressive strength ⩾7 N/mm^2; or d) most types of autoclaved aerated block (see remarks) in (iii)	Where FN or MN clay units are used, sulfate-resisting cement should be used. If sulfate ground conditions exist the recommendation in **5.6.4** should be followed. Some types of autoclaved aerated block are not suitable for use in L1. The manufacturer should be consulted. Some types of calcium silicate brick are not suitable for use in L2 or L3. The manufacturer should be consulted.
L2	Foul drainage (continuous contact with masonry)	Engineering bricks, FL, FN, ML or MN in (i)	Class 7 in (ii) (see remarks)	⩾40 N/mm^2 with cement content ⩾350 kg/m^3 in (i) or (ii)	Not suitable	
L3	Foul drainage (occasional contact with masonry)	Engineering bricks, FL, FN, ML or MN in (i)	Classes 3 to 7 in (ii) and (iii) (see remarks)	⩾40 N/mm^2 with cement content ⩾350 kg/m^3 in (i) or (ii)	Not suitable	

5.7 Mortars

5.7.1 *Types of mortar*

5.7.1.1 *General*

For building mortars, about one volume of binder should be combined with three volumes of sand to give a workable mix, but a 1:3 cement:sand mortar is stronger than is necessary for most uses.

Improved workability of mortars containing less cement can be achieved by incorporation of lime, plasticizers or entrained air or any combination of these.

In Table 14, mortar mixes are grouped in four Designations. Within each Designation, mixes produce mortars of approximately equal strength and durability. As cement content is reduced, strength is reduced, but such mortars are more able to accommodate minor movements of the masonry.

Adhesion to dry absorbent units can be considerably improved by the incorporation of a water-retaining admixture.

5.7.1.2 *Cement:lime:sand mortar*

In this type of mortar good working qualities, water retention, adhesion and early strength can be secured without the mature strength being too high. The lime used should be non-hydraulic to BS 890.

5.7.1.3 *Air-entrained cement:lime:sand mortar and air-entrained cement:sand mortar*

Mortar air-entraining agents which entrain air in a mix provide an alternative to lime for imparting improved working qualities to lean cement:sand mixes. In effect, the air bubbles serve to increase the volume of the binder paste, filling the voids in the sand, and this improves the working qualities.

The incorporation of lime and air-entraining agents in a mortar mix combines the workability benefits of the lime with the freeze-thaw durability benefit of the air-entrainment.

Alternatively, the benefits of air-entrainment can be obtained by the use of air-entrained cement:sand mixes, or by the use of mixes based on masonry cement.

All factory-made and masonry cement-based mortars are air-entrained.

Table 14 — Mortar mixes

Types of mortar		**Cement:lime:sand**[a]	**Masonry cement:sand**[a]		**Cement:sand**[a] **(plasticized)**
Binder constituents		A Portland cement and lime, with or without an air entraining additive	Masonry cement containing a Portland cement and lime in the approximate ratio 1:1, and an air entraining additive	Masonry cement containing a Portland cement and inorganic materials other than lime[b] and an air entraining additive	A Portland cement and an air entraining additive
Designation	(i)	1:0 to 0.25:3	—	—	1:3
	(ii)	1:0.5:4 to 4.5	1:3	1:2.5 to 3.5	1:3 to 4
	(iii)	1:1:5 to 6	1:3.5 to 4	1:4 to 5	1:5 to 6
	(iv)	1:2:8 to 9	1:4.5	1:5.5 to 6.5	1:7 to 8

NOTE 1 The range of sand volumes is to allow for the effects of differences in grading on the properties of the mortar. In general the lower values apply to Type G of BS 1199 and 1200:1976 and the higher values to Type S. Mortars incorporating both lime and air-entrainment can be used with any sands within the BS 1199 and 1200 gradings.

NOTE 2 Air entrainment to improve the durability and the working properties of the mortar is recommended. It may be achieved by the use of air-entrained cements, either masonry cements or improved cements, by the addition of plasticizer to the site mixer, or by the use of a factory made mortar. (Improved cements are Portland cements modified for use in masonry containing a relatively small amount of air entrainment. They are produced for use in masonry and similar applications.)

NOTE 3 BS 8221 contains recommendations for other mortar mixes that are more suitable for the repair of the masonry of historic buildings.

[a] Cements for mortar and the standards to which they should conform are listed in **5.3.1**.

[b] Where masonry cement contains less than 75 % PC, no data exists with regards to equivalence (with other mixes of that Designation) of strength and durability.

5.7.2 ***Mortar admixtures***

Mortar admixtures should conform to the appropriate British Standard (see **4.3.5**).

Although where frost conditions are anticipated there would be some advantage in accelerating the setting of mortar, in practice no suitable admixtures are known that are free from other undesirable effects. In particular, calcium chloride, or admixtures based on this salt, can lead to subsequent dampness or corrosion of embedded metals, including wall ties. Therefore, calcium chloride and admixtures containing calcium chloride should not be added to mortars.

There is little experience of the successful use of any admixture intended to provide frost protection by depressing the freezing point of the mixing water. Some substances that might be contemplated for this purpose, e.g. ethylene glycol, are known to adversely affect the hydration of cement.

Styrene butadiene rubber (SBR) admixture may be used to make special mortars with high bond properties.

Water retaining admixtures may be used for mortars where high suction masonry units are involved. They are especially useful for plasters and rendering mortars.

5.7.3 ***Selection of mortar***

The design should contain provisions which pay particular attention to local practice and to any mixes that have been designed to deal with special conditions. Where mortars are to be specified by strength or where special category construction is to be used, the proportions should be determined from tests (see BS 5628-1:1992, Annex A).

In practice, the designer has the following three options:

a) to specify the Designation and type of mortar and leave the contractor free to batch mix to obtain adequate workability;

b) to specify actual mix proportions to be used for a particular sand or provide sufficient guidance on the grading of sand to enable the contractor to determine where, within the range, the sand should be proportioned. Not all sands conforming to BS 1199 and 1200 will be suitable for conditions of Severe or Very Severe categories of exposure or where flexural strength (adhesion) is critical, owing to high fines content and/or particle distribution. In such cases, consideration should be given to using sands having a particle distribution towards the coarser end of the BS 1199 and 1200 grading envelope. Such sands can be found among those conforming to grade M of BS 882:1992;

c) to specify the lowest mix proportions for each type and Designation, e.g. specify 1:1:5 for Designation (iii) cement:lime:sand.

The mortar Designation and type should be selected by reference to structural requirements and taking into account the type of construction, position in the building, degree of exposure (see **5.6.1** and Table 13), together with the general properties of mortar given in **5.7.1.1** and Table 14.

The mortars in Table 14 have been selected to provide the most suitable mortar that will be readily workable to allow the bricklayer or blocklayer to produce satisfactory work at an economic rate, be sufficiently durable and be able to assist in accommodating the strains arising from minor movements within the wall. Where a mortar designation richer than the minimum Designation recommended for durability in Table 13 is required for structural reasons, careful consideration should be given to the accommodation of movement (see **5.4**).

Proportioning by mass will produce more consistent mortars than proportioning by volume.

5.8 Fire resistance

Masonry walls should be designed to have fire resistance appropriate to their use as detailed in Table 15. Fire resistance is the time from the start of the tests laid down in BS 476-20 to -23 inclusive, until failure occurs under any one of the listed criteria, i.e. stability, integrity and thermal insulation. This time ranges from 30 min to 6 h and is a property of the complete element of structure.

Table 15 gives notional fire resistances of walls for various types of construction. Other forms of construction may be used, provided evidence of satisfactory performance in use, based on the results of standard fire resistance tests, is produced.

If the required fire resistance of a loadbearing cavity wall with a thickness taken from Table 15 is more than 2 h, the imposed load should be shared by both leaves; otherwise, if the imposed load is carried by the exposed leaf only, the minimum thickness of the exposed leaf should be that given for loadbearing single-leaf walls.

For panel walls which are to provide fire resistance where edge isolation is necessary, special consideration should be given to the edge details.

Where movement joints or edge clearances are required for walls designed to resist fire, they should be filled with a non-combustible material, such as mineral fibre, which still allows the movement joint to function.

Consideration should be given to non-combustible cover strips fixed to both faces of the wall on one side of the joint.

Table 15 — Notional fire resistance of walls

Material	Masonry unit type	Finish[a]		Minimum thickness of masonry[b] for notional period of fire resistance mm						
				6 h	4 h	3 h	2 h	90 min	60 min	30 min
(A) Loadbearing single-leaf walls										
Fired, brick-earth clay or shale	Brick	Solid brick (see **3.59**)	None	200	170	170	100	100	90	90[c]
			VG	170	100	100	90	90	90	90[c]
		Not less than 75 % solid, e.g. perforated	None or SC/SG	—	200	200	170	170	170	100
			VG	200	170	170	170	100	100	90
		Not less than 50 % solid	SC/SG	—	—	—	215	215	215	215
			VG	—	215	215	215	215	215	215
		Not less than 40 % solid	None or SC/SG	—	—	—	—	—	215	215
	Block (outer-web not less than 13 mm thick)	Two cells[d] not less than 50 % solid	SC/SG	—	—	—	100	100	100	100
		Three cells[d] 60 % solid	SC/SG	—	150	150	150	150	150	150
Concrete or calcium silicate	Brick	Solid brick (see **3.59**)	None	200	190	190	100	100	90	90
			VG	200	100	100	90	90	90	90
Concrete, class 1 aggregate[e]	Block	Solid brick	None	150	150	140	100	100	90	90
			VG	150	100	100	90	90	90	90
		Other, e.g. hollow	None	—	—	—	100	100	100	90
Concrete, class 2 aggregate[e]	Block	Solid brick	None or SC/SG	—	—	—	100	100	90	90
			VG	—	100	100	90	90	90	90
		Other, e.g. hollow	SC/SG	—	—	—	—	—	—	190
			VG	—	—	—	200	200	190	190
Aerated concrete, density 480 kg/m^3 to 1 200 kg/m^3	Block	Solid brick	None	215	180	140	100	100	90	90
			VG	180	150	100	100	90	90	90

NOTE Non-loadbearing walls are assumed to carry no load other than their own weight and edge restraint. Loadbearing walls may carry any load up to that which produces the maximum permissible design stresses. Interpolation between Table 15**(A)** and Table 15**(B)** or between Table 15**(C)** and Table 15**(D)** is not permitted.

[a] The finish should be not less than 13 mm plaster or rendering on each face of a single-leaf wall and on the exposed faces of a cavity wall. SC/SG is sand:cement or sand:gypsum (with or without lime). Plasterboard of an equivalent thickness may be substituted for fire resistance periods up to 2 h. VG is vermiculite:gypsum plaster (1.5:1 to 2:1 by volume). Perlite may be substituted for vermiculite for clay bricks and other materials with similar surfaces.

[b] The thickness represents either the work size of the unit, or, where applicable for solid walls, the sum of the work sizes of two units together with the work size of the joint between them.

[c] The minimum thickness given is suitable for 75 mm brick-on-edge construction with a completely solid unit with plane faces.

[d] The number of cells is that in any cross-section through the wall thickness.

[e] Class 1 aggregates for concrete blocks include limestone, air-cooled blastfurnace slag, foamed or expanded slag, crushed brick, well-burnt clinker, expanded clay or shale, sintered pulverized-fuel ash and pumice. Class 2 aggregates for concrete blocks include all gravels and crushed natural stone, except limestone.

[f] These thicknesses may be reduced to 100 mm for walls built with cellular bricks.

[g] Thicknesses given here are minimum thicknesses for each leaf in millimetres (mm).

[h] These thicknesses may be reduced to 90 mm if the load is distributed over both leaves.

Table 15 — Notional fire resistance of walls *(continued)*

Material	Masonry unit type	Finish[a]		Minimum thickness of masonry[b] for notional period of fire resistance (mm)						
				6 h	4 h	3 h	2 h	90 min	60 min	30 min
(B) Non-loadbearing single-leaf walls										
Fired brick-earth, clay or shale	Brick	Solid brick (see **3.59**)	None	200	170	170	100	90	75	75
		Not less than 75 % solid, e.g. perforated	VG	100	100	90	90	90	75	75
			None	200	200	170	170	100	100	75
			VG	170	170	100	100	90	75	75
		Not less than 50 % solid	SC/SG	—	—	—	215	215	215[f]	215[f]
			VG	—	215	215	215	215	215[f]	215[f]
		Not less than 40 % solid	None	—	—	—	—	—	215	215
	Block (outer-web not less than 13 mm thick)	One cell[d] not less than 50 % solid	SC/SG	—	—	—	—	—	100	75
		One cell[d] not less than 30 % solid	SC/SG	—	—	—	—	—	150	150
		Two cell[d] not less than 70 % solid	SC/SG	—	—	—	100	100	100	75
		Two cell[d] not less than 45 % solid	SC/SG	—	—	—	225	225	150	150
		Two cell[d] not less than 50 % solid	SC/SG	—	—	—	—	—	—	75
		Two cell[d] not less than 70 % solid	SC/SG	—	150	150	150	150	150	150
Concrete or calcium silicate	Brick	Solid brick (see **3.59**)	None	200	170	170	100	90	75	75
			VG	100	100	90	90	90	75	75

NOTE Non-loadbearing walls are assumed to carry no load other than their own weight and edge restraint. Loadbearing walls may carry any load up to that which produces the maximum permissible design stresses. Interpolation between Table 15**(A)** and Table 15**(B)** or between Table 15**(C)** and Table 15**(D)** is not permitted.

[a] The finish should be not less than 13 mm plaster or rendering on each face of a single-leaf wall and on the exposed faces of a cavity wall. SC/SG is sand:cement or sand:gypsum (with or without lime). Plasterboard of an equivalent thickness may be substituted for fire resistance periods up to 2 h. VG is vermiculite:gypsum plaster (1.5:1 to 2:1 by volume). Perlite may be substituted for vermiculite for clay bricks and other materials with similar surfaces.
[b] The thickness represents either the work size of the unit, or, where applicable for solid walls, the sum of the work sizes of two units together with the work size of the joint between them.
[c] The minimum thickness given is suitable for 75 mm brick-on-edge construction with a completely solid unit with plane faces.
[d] The number of cells is that in any cross-section through the wall thickness.
[e] Class 1 aggregates for concrete blocks include limestone, air-cooled blastfurnace slag, foamed or expanded slag, crushed brick, well-burnt clinker, expanded clay or shale, sintered pulverized-fuel ash and pumice. Class 2 aggregates for concrete blocks include all gravels and crushed natural stone, except limestone.
[f] These thicknesses may be reduced to 100 mm for walls built with cellular bricks.
[g] Thicknesses given here are minimum thicknesses for each leaf in millimetres (mm).
[h] These thicknesses may be reduced to 90 mm if the load is distributed over both leaves.

Table 15 — Notional fire resistance of walls *(continued)*

Material	Masonry unit type	Finish[a]		Minimum thickness of masonry[b] for notional period of fire resistance mm						
				6 h	**4 h**	**3 h**	**2 h**	**90 min**	**60 min**	**30 min**
(B) Non-loadbearing single-leaf walls *(continued)*										
Concrete, class 1 aggregate (see note 7)	Block	Solid brick (see **3.59**)	None	150	140	125	75	75	75	50
			SC/SG	150	100	90	75	75	75	50
			VG	100	75	75	75	63	50	50
		Other, e.g. hollow	None	225	150	140	100	90	90	75
			SC/SG	150	140	140	100	75	75	75
			VG	150	100	90	75	75	63	63
Concrete, class 2 aggregate (see note 7)	Block	Solid brick (see **3.59**)	None	200	150	140	100	90	75	50
			SC/SG	150	140	100	90	90	75	50
			VG	125	100	90	75	75	75	50
		Other, e.g. hollow	None	215	150	140	140	125	125	90
			SC/SG	150	140	140	140	125	125	90
			VG	150	125	125	100	90	90	75
Aerated concrete, density 480 kg/m³ to 1 200 kg/m³	Block	Solid brick (see **3.59**)	None	150	100	75	63	63	50	50
(C) Load-bearing cavity walls[g]										
Fired brick-earth, clay or shale, concrete or calcium silicate	Brick	Solid brick (see **3.59**)	None	100	100	100	100[h]	100[h]	90	90
Fired brick-earth, clay or shale	Block (outer-web not less than 13 mm thick)	Not less than 70 % solid e.g. perforated	SC/SG	—	150	150	100	100	100	100
		Not less than 50 % solid	SC/SG	—	—	—	100	100	100	100
Concrete, class 1 aggregate[d]	Block	Solid brick (see **3.59**)	None	100	100	100	100[h]	100	90	90
		Other, e.g. hollow	None	—	100	100	100	100	100	90

NOTE Non-loadbearing walls are assumed to carry no load other than their own weight and edge restraint. Loadbearing walls may carry any load up to that which produces the maximum permissible design stresses. Interpolation between Table 15**(A)** and Table 15**(B)** or between Table 15**(C)** and Table 15**(D)** is not permitted.

[a] The finish should be not less than 13 mm plaster or rendering on each face of a single-leaf wall and on the exposed faces of a cavity wall. SC/SG is sand:cement or sand:gypsum (with or without lime). Plasterboard of an equivalent thickness may be substituted for fire resistance periods up to 2 h. VG is vermiculite:gypsum plaster (1.5:1 to 2:1 by volume). Perlite may be substituted for vermiculite for clay bricks and other materials with similar surfaces.

[b] The thickness represents either the work size of the unit, or, where applicable for solid walls, the sum of the work sizes of two units together with the work size of the joint between them.

[c] The minimum thickness given is suitable for 75 mm brick-on-edge construction with a completely solid unit with plane faces.

[d] The number of cells is that in any cross-section through the wall thickness.

[e] Class 1 aggregates for concrete blocks include limestone, air-cooled blastfurnace slag, foamed or expanded slag, crushed brick, well-burnt clinker, expanded clay or shale, sintered pulverized-fuel ash and pumice. Class 2 aggregates for concrete blocks include all gravels and crushed natural stone, except limestone.

[f] These thicknesses may be reduced to 100 mm for walls built with cellular bricks.

[g] Thicknesses given here are minimum thicknesses for each leaf in millimetres (mm).

[h] These thicknesses may be reduced to 90 mm if the load is distributed over both leaves.

Table 15 — Notional fire resistance of walls *(concluded)*

Material	Masonry unit type	Finish[a]		Minimum thickness of masonry[b] for notional period of fire resistance (mm)						
				6 h	4 h	3 h	2 h	90 min	60 min	30 min
(C) Load-bearing cavity walls[g] *(continued)*										
Concrete, class 2 aggregate[d]	Block	Solid brick (see **3.59**)	None	—	—	—	100	100	90	90
Aerated concrete, density 480 kg/m³ to 1 200 kg/m³	Block	Solid brick (see **3.59**)	None	150	150	140	100	100	90	90
(D) Non-loadbearing cavity walls[g]										
Fired brick-earth, clay or shale, concrete or calcium silicate	Brick	Solid brick (see **3.59**)	None	100	75	75	75	75	75	75
		Not less than 50 % solid	None	—	100	90	90	90	90	90
Fired brick-earth, clay or shale	Block (outer-web not less than 13 mm thick)	Not less than 70 % solid, e.g. perforated	SC/SG	100	100	100	100	100	100	100
		Not less than 50 % solid	SC/SG	—	100	100	100	100	100	100
Concrete, class 1 aggregate[e]	Block	Solid	None	90	75	75	75	75	75	75
		Other, e.g. hollow	None	100	75	75	75	75	75	50
Concrete, class 2 aggregate[e]	Block	Solid	None	90	75	75	75	75	75	50
Aerated concrete, density 480 kg/m³ to 1 200 kg/m³	Block	Solid	None	90	75	75	63	63	50	50

NOTE Non-loadbearing walls are assumed to carry no load other than their own weight and edge restraint. Loadbearing walls may carry any load up to that which produces the maximum permissible design stresses. Interpolation between Table 15**(A)** and Table 15**(B)** or between Table 15**(C)** and Table 15**(D)** is not permitted.

[a] The finish should be not less than 13 mm plaster or rendering on each face of a single-leaf wall and on the exposed faces of a cavity wall. SC/SG is sand:cement or sand:gypsum (with or without lime). Plasterboard of an equivalent thickness may be substituted for fire resistance periods up to 2 h. VG is vermiculite:gypsum plaster (1.5:1 to 2:1 by volume). Perlite may be substituted for vermiculite for clay bricks and other materials with similar surfaces.
[b] The thickness represents either the work size of the unit, or, where applicable for solid walls, the sum of the work sizes of two units together with the work size of the joint between them.
[c] The minimum thickness given is suitable for 75 mm brick-on-edge construction with a completely solid unit with plane faces.
[d] The number of cells is that in any cross-section through the wall thickness.
[e] Class 1 aggregates for concrete blocks include limestone, air-cooled blastfurnace slag, foamed or expanded slag, crushed brick, well-burnt clinker, expanded clay or shale, sintered pulverized-fuel ash and pumice. Class 2 aggregates for concrete blocks include all gravels and crushed natural stone, except limestone.
[f] These thicknesses may be reduced to 100 mm for walls built with cellular bricks.
[g] Thicknesses given here are minimum thicknesses for each leaf in millimetres (mm).
[h] These thicknesses may be reduced to 90 mm if the load is distributed over both leaves.

5.9 Thermal performance

5.9.1 *General*

Where appropriate a wall should be designed to:

a) reduce the heat transfer through the wall in order to minimize the quantity of energy needed to establish and maintain the desired temperature of the interior of the building;

b) match the thermal response of the building with the type and pattern of heating;

c) help prevent both internal surface condensation and interstitial condensation in an unacceptable location within the structure (see **5.9.5**).

5.9.2 *Thermal conductivity*

The manufacturer's declared thermal conductivity values should be used in U-value calculations.

NOTE Where the manufacturer's values are not available, the user is referred to [7] for guidance.

5.9.3 *Thermal insulation*

The insulation value of masonry walls can be improved by adding insulation and/or selecting masonry units of high thermal resistance. Insulation may be positioned externally, internally or within any cavity. The designer should ensure that the construction selected does not conflict with other recommendations of this code.

Thermal insulation materials should be specified and installed in accordance with the relevant British Standards and the manufacturer's instructions and should be suitable for the particular category of exposure.

NOTE For guidance on the selection of insulation and the design of insulated masonry, the user is referred to [7].

5.9.4 *Cold bridges*

At points where the insulation does not continue across the entire construction for structural or other reasons, the thermal resistance is reduced. This is characterized by a drop in the internal surface temperature of the wall in the region of the "cold bridge". This can cause pattern staining and/or condensation on internal surfaces. Further information can be found in [6] and [8].

5.9.5 *Condensation*

Two types of condensation that should be considered are internal surface condensation, and interstitial condensation which occurs within a building element of construction. Detailed information is given in BS 5250.

The risk of condensation may be assessed using various calculation procedures, e.g. as described in BS 5250.

If interstitial condensation is predicted then the designer should assess the suitability of a construction by considering the position in the construction where condensation occurs, the quantity of condensate expected and the likely effect of the condensate on adjoining materials. For example, condensation on the cavity face of the external leaf of a cavity masonry wall is generally inconsequential.

5.10 Sound control

5.10.1 *Resistance to sound transmission*

5.10.1.1 *General principles*

Sound is transmitted from its source to adjacent spaces or enclosures by a multitude of routes involving airborne and structure-borne transmission. Structure borne sound can originate from impact on a surface or from airborne sound impinging on the surface of the structure. However, when designing walls, the origin is generally assumed to be airborne sound rather than impact sound.

Sound generated in the air in one room radiates to the surfaces of the enclosing structure and is transmitted through the structural elements, sound separating walls, and flanking walls and floors to an adjacent room, where the sound is normally transmitted through the air to the ear.

The sound insulation of a single-leaf masonry wall is largely related to its mass per unit area, provided that there are no direct air paths through it.

The sound insulation of a cavity wall is related to its mass per unit area, the width of the cavity, and the rigidity and spacing of any wall ties. A cavity wall, with a nominal cavity width of 50 mm and leaves connected by wire butterfly ties as recommended in **5.3.5**, may be expected to have a resistance to sound transmission similar to that of a solid masonry wall of the same surface mass. If more rigid ties are used, or a greater number of ties per square metre are used, the sound insulation of the wall is reduced.

Direct air paths around the separating wall or floor should be avoided. Window reveals should be sealed to prevent direct transmission along the cavity. Care should be taken to avoid air paths in floors which penetrate separating walls. Unplastered walls in attics or roof spaces should be well built with all bed joints and cross joints filled with mortar.

For detailed recommendations, designers are directed to BS 8233.

5.10.1.2 *Sound separating walls*

The thickness of a separating wall required for sound insulation should be maintained as far as possible where chases, recesses, chimney flues, electrical sockets, etc. are to be built into the wall.

Where joists are supported by a sound separating wall, they should be supported on joist hangers and not built into the wall. Hollow cored concrete floor units should have their voids filled at the bearings if they "face" similar units on the opposite side of the wall.

Connections between the leaves of sound separating walls of cavity construction should be kept to the minimum number consistent with structural stability.

5.10.1.3 *Flanking transmission*

Good sound separating performance depends not only on the separating wall or floor, but also on the design and construction of the external wall areas flanking the separating element, and the size and disposition of any openings in it.

5.10.2 *Sound absorption*

Sound absorption should not be confused with sound insulation. Sound absorbent materials reflect only a small proportion of the incident sound energy arriving at their surface, but dissipate a substantial amount as heat. They are used to reduce the reverberation (echo or liveliness) of a space, but have little effect on the sound transmitted to an adjacent space. Sound insulating materials reflect most of the incident sound energy and so transmit little to an adjoining space, but they do not usually reduce reverberation. Sound absorbent materials are not usually good sound insulating materials.

5.11 Masonry bonds and other constructional details

5.11.1 *Masonry bonds*

5.11.1.1 *General*

The horizontal distance between cross joints in successive masonry courses should normally be not less than one-quarter of the length of the units, but in no case less than 50 mm for bricks or 75 mm for blocks. Bonds that do not conform to this criterion, e.g. stack bond, should be used only where experience or experimental data indicate that they are satisfactory for the particular construction.

In practice, a single course of soldier units as a band course, although not conforming to the minimum dimensions for overlap stated above, does not cause instability, provided that it is incorporated into conventionally bonded masonry.

The overall dimensions of walls and the positions and sizes of openings and piers should be chosen bearing in mind the dimensions of the type of unit specified and the dimensions of special units available. This keeps cutting of units to a minimum and avoids irregular or broken bonds.

5.11.1.2 *Brick masonry*

Bonds of bricks in masonry create characteristic patterns of stretchers and headers in the surface of a structure.

Bonds which have headers in the pattern are intended for work with a minimum thickness of one brick length. The headers show because some of the bricks are laid lengthways across the wall to provide the interlock of the bond.

Stretcher bond, which consists of stretchers only in each course, is normally used for brick masonry with a thickness of a half brick-length, often the outer leaf of a cavity wall. The lap is normally half the length of the brick, but quarter and third lap varieties are also used.

To match existing thicker walls, or for decorative purposes, bond patterns incorporating headers may be used for half brick leaves, but they will require the use of half-bricks, or bats, as the headers. The bats may be available from the manufacturer or they should be prepared by carefully cutting standard bricks.

5.11.1.3 *Block masonry*

A great variety of bonds for facing block masonry is possible due to the wide range of available shapes and sizes of blocks.

Hollow block masonry can be suited to the incorporation of reinforcement within the voids of the units, which are filled with concrete. Where quoin or reveal blocks are used, alternate short and long blocks should be used in successive courses to ensure that the bond within the wall is retained.

5.11.1.4 *Natural stone masonry*

5.11.1.4.1 *Solid walling*

In this more traditional type of stone walling face work of ashlar is built-up simultaneously with brick masonry or block masonry forming the balance of the thickness of the wall.

The coursing of the ashlar can be regular or random but should relate to the coursing of the backing to prevent unnecessary cutting of the backing units. If brick backing is used a greater number of bed joints compared with the bed joints in the ashlar facing is inevitable.

It is important to ensure that the ashlar is properly bonded and tied in, especially at openings and quoins, and that shear stresses are evenly distributed throughout the component materials.

5.11.1.4.2 *Rubble walling*

This type of walling is more appropriate for work of a less formal character.

There are varieties of rubble bond types which are generally characteristic of a particular region or area of the country. The varieties are determined by the type of stone available and the way in which it comes from the quarry or can be dressed:

a) *Uncoursed random rubble*

Uncoursed random rubble walling is constructed from stones as they come from the quarry. The mason selects blocks of all shapes and sizes, more or less at random, and places them in position to obtain a good bond, while restricting cutting of the stones to the removal of inconvenient corners with a walling hammer.

The bond should be transverse (across the thickness of the wall) and longitudinal (along both faces of the wall). Transverse bond is obtained by the use of bonders, of which there should be not less than one in each square metre of each wall surface. They should extend about two-thirds into the wall; headers extending through the full thickness of the wall are not recommended as they tend to permit damp-penetration.

b) *Uncoursed squared rubble*

Uncoursed squared rubble walling is constructed from stones roughly squared as jumpers (or risers) and stretchers, of various heights, and laid uncoursed. In general, the risers should be not more than 250 mm in height and stretchers should not exceed two-thirds the heights of the adjoining riser.

c) *Snecked rubble*

Snecked rubble walling consists of stones roughly squared but without the limitation of size and proportions recognized in uncoursed square rubble. The walling includes a definite proportion of small stones (snecks) that prevent the occurrence of long continuous vertical joints. These snecks are comparatively small, but should be not less that 50 mm in any dimension;

d) *Brought to courses*

Brought to courses walling consists of squared rubble of mixed sizes laid at random but periodically levelled to give continuous bed joints at intervals of 300 mm to 900 mm according to the type of stone used. The courses usually correspond with the quoin or jamb stones.

e) *Coursed squared rubble*

Coursed square rubble walling courses can vary in height from 100 mm to 300 mm, but the stones in any one course are roughly squared to the same height. A variant of this type may be formed by the introduction of pinnings, i.e. smaller stones in the same course, at intervals, producing a chequered effect.

5.11.2 ***Flue blocks***

Flue blocks, where built into a wall, should be bonded. Manufacturers' instructions regarding details of their orientation and assembly should be followed.

5.11.3 ***Architectural features***

5.11.3.1 Architectural features such as plinths, string courses and cornices may be formed of bricks, blocks or other suitable materials. Their design should involve considerations of stability, resistance to abrasion, moisture penetration (see **5.5.4.1** and **5.5.4.2.8**) and durability (see **5.6.1**), particularly where dissimilar materials are associated. Wherever possible, all features should be designed to fit with the masonry in length, height or thickness.

5.11.3.2 Features which project from the main plane of the wall should have their upper surfaces protected by flashings or weatherings from downward penetration of water. In modern cavity wall construction, projecting features cannot readily be secured in the wall by weight above as in older solid walls. It may therefore be necessary to hold them in place by other means, such as a reinforced concrete, reinforced masonry or steelwork core.

5.11.3.3 Unless bricks are selected for size, their variation in length will usually preclude the building of one brick single-leaf bonded walls having a fair face on both sides, but this can readily be achieved by using double-leaf (collar-jointed) walls instead.

5.11.3.4 Block masonry walls needing both sides fair should be built as collar-jointed walls.

5.11.4 ***Masonry slips***

The use of masonry slips to mask the edges of concrete floors or beams should be avoided because of the dangers of slips falling from buildings due to fixing failure. Experience indicates that, because of difficulties of predicting and accommodating shrinkage and creep of the concrete frame, incompatible thermal movements, inaccuracy of construction and inadequacies of fixing adhesives, dependable fixing is difficult to achieve.

Where the use of slips is unavoidable mechanical methods of securing slips should be considered as a supplement to adhesives (see also **5.4.6.4** and **5.4.6.3.2**).

5.11.5 ***Pistol units***

Pistol units can be used as an alternative to masonry slips to mask the toes of reinforced boot lintels or beams. They do not generally require adhesive fixing systems and they permit the application of damp-proof coatings to the concrete surfaces when necessary. Special corner units are supplied by some manufacturers.

Generally a "barrel" thickness of 20 mm can be achieved with most types of facing units but it is important that over-run of the horizontal cut be avoided, as this will weaken the "barrel" at what is already its weakest point.

When the bottom of the "barrel" adjoins masonry below, a compressible horizontal joint as described in **5.4.2.3.2** should be provided.

5.11.6 ***Brick arches***

BS 4729 lists a range of standard specially shaped arch bricks to suit various spans of openings in brick masonry. Non-standard arch bricks can also be manufactured to suit other spans.

A traditional alternative to specially made wedge shaped units is to use soft clay bricks known as “rubbers” which are cut and rubbed with an abrasive stone to wedge shape to suit a particular application. These may still be demanded for restoration work (see BS 8221).

Arches built with wedge shaped units are referred to as “gauged arches”.

Normal shaped bricks can be used and the mortar joints between them tapered. Arches built this way were known previously as “rough arches” and were used as backing to gauged arches, but today they are also used for facing work.

The difficulties of determining the actual loads acting on arched openings formed within brick masonry walls means that accurate structural design is unlikely to be achieved. Usually minor arches of segmental, parabolic or semi-circular form up to about 2 m span can be proportioned empirically, provided care is taken to ensure that there is an adequate amount of masonry over the arch ring and between it and any line of floor loads. Also that adequate resistance is provided at the abutments. The latter is more important in the uppermost storeys of loadbearing walls or where arched brick masonry openings are provided in any storey height of a framed structure where the brick masonry is not self-supporting.

Arch construction is less suitable for the external skins of cavity walls than for solid walling of greater thickness because of the added complication of damp-proofing the junctions between inner and outer skin. The normal cavity tray cannot readily be sloped outward and simultaneously curved to follow the outer skin unless it is in very malleable material, such as lead. Specially pre-formed arch trays suitable for cavity walling are available from some manufacturers of DPC materials.

5.11.7 ***Jointing and pointing***

Jointing is considered preferable to pointing because it leaves the bedding mortar undisturbed. Also, because it is completed in one operation, it is less expensive.

However, pointing does offer some advantages.

a) It can be carried out in one continuous operation, maintaining colour consistency.

b) Pointing mortar may be a consistent colour although the bedding mortar might vary.

c) For decorative reasons different mortars may be required in different areas of a wall in a pattern that would not make it practical to joint the work.

d) Some joint finishes such as “cut and struck” and “tuck pointing” are only practicable as pointing.

e) It improves resistance to rain penetration.

The mortar used for pointing should have similar characteristics to those used in the bedding mortar. Hard, impervious pointing mortar should not be applied to joints made with weaker, porous mortar.

Types of finish for jointing and pointing of work are described in Annex C. These should be carefully chosen in relation to colour, texture, form and durability of the units used and the conditions of exposure.

Tooling of the joints to compact the mortar helps to improve the durability of the mortar and the rain-shedding capacity of the wall (see **5.5.4.2.6**). Recessed joints should not be used where there is a danger of excessive wetting which can lead to damage by frost action or rain penetration (see **5.6.1.1** and **5.5.4.2.6**). The depth of the recess should be related to the distance of any perforation of cavity from the exposed face of the unit.

6 Workmanship

Masonry designed following the recommendations and guidance given in this standard should be constructed in conformity with the recommendations of BS 8000-3 which gives guidance on basic workmanship and covers those tasks which are frequently carried out in relation to the construction of brick and block masonry.

NOTE For the convenience of users of this standard the text of BS 8000-3 is reproduced here, in Annex A.

Annex A (normative)
BS 8000-3:2001, Workmanship on building sites — Part 3: Code of practice for masonry

A.1 Introduction

BS 8000-3 makes recommendations and gives guidance on basic workmanship for conventional types of building work. It supersedes BS 8000-3:1989 which is withdrawn. The text of BS 8000-3:2001 from clause **3** onwards is repeated in this document from **A.3** onwards. The internal references within BS 8000-3 and references to BS 5628-3 have been changed here to reflect the position in this document.

The recommendations given are not fully comprehensive as particular project documents, e.g. project specifications, may need to cover particular recommendations not dealt with by this standard. This standard may not be applicable to the use of some proprietary systems[3)].

BS 8000-3 is unique in that it draws together recommendations given in other British Standards.

The purpose of BS 8000-3 is to encourage good workmanship by providing the following.

a) The most frequently required recommendations on workmanship for building work in a readily available and convenient form to those working on site.

b) Assistance in the efficient preparation and administration of contracts.

c) Recommendations on how designers' needs for workmanship can be satisfactorily realized.

d) Guidance on good practice on building sites for supervision and for training purposes. This guidance is not intended to supplant the normal training in craft skills.

e) A reference for quality of workmanship on building sites.

f) The recognition that design, procurement and project information should be conducive to good workmanship on site.

During the preparation of BS 8000-3 the Building Industry's Co-ordinating Committee for Project Information (CCPI[4)]), produced a Common Arrangement of Work Sections (CAWS) for building work. BS 8000-3 has been drafted in accordance with this CAWS so that it can be used easily with project specifications and bills of quantities using the CAWS. Other major documents are being restructured in accordance with the CAWS.

BS 8000 is published in the following parts:

— *Part 1: Code of practice for excavation and filling*;
— *Part 2: Code of practice for concrete work*;
— *Part 3: Code of practice for masonry*;
— *Part 4: Code of practice for waterproofing*;
— *Part 5: Code of practice for carpentry, joinery and general fixings*;
— *Part 6: Code of practice for slating and tiling of roofs and claddings*;
— *Part 7: Code of practice for glazing*;
— *Part 8: Code of practice for plasterboard partitions and dry linings*;
— *Part 9: Cementitious levelling screeds and wearing screeds — Code of practice*;
— *Part 10: Code of practice for plastering and rendering*;
— *Part 11: Code of practice for wall and floor tiling*;
— *Part 12: Code of practice for decorative wallcoverings and painting*;
— *Part 13: Code of practice for above ground drainage and sanitary appliances*;
— *Part 14: Code of practice for below ground drainage*;
— *Part 15: Code of practice for hot and cold water services (domestic scale)*;
— *Part 16: Code of practice for sealing joints in buildings using sealants.*

[3)] The user's attention is drawn to the need to follow any relevant Technical Approval.
[4)] The CCPI was sponsored by the Association of Consulting Engineers, the Building Employers' Confederation, the Royal Institution of Chartered Surveyors and the Royal Institute of British Architects.

Subcommittees B/525/6, Use of masonry, B/519/2, Mortar and B/546/6, Damp-proof courses for masonry, have participated in the preparation of BS 8000-3 and its content is based on and is consistent with that of BS 5628 and BS 8215. However, BS 5628 and BS 8215 cover the subject matter more comprehensively and include design, materials and other related aspects in addition to workmanship on site. The user's attention is also drawn to [9].

In this standard a commentary on the relevant principles accompanies the recommendations that are made. The commentary is intended to provide further guidance.

NOTE Commentary text is printed in italics.

A.2 Scope

BS 8000-3 gives recommendations for basic workmanship in relation to masonry but does not specifically address health and safety issues.

For design aspects of masonry, reference should be made to BS 5628.

BS 8000-3 does not necessarily cover the use of proprietary systems. The user is referred to the particular recommendations of any technical approval in this case.

A.3 Definitions

For the purpose of this part of BS 8000, the definitions given in BS 5628-3 apply.

NOTE Other associated definitions which may be of use to the user of this standard can be found in BS 6100-1 and -5.

A.4 Materials, handling and preparation

A.4.1 *Checking, handling and site storage of materials and components*

A.4.1.1 *General*

Keep the site clean and tidy to ensure that checking, handling and storage of materials and components can be carried out speedily and effectively.

A.4.1.2 *Checking*

Check delivery tickets and certificates against the specification. Examine marks, labels and the condition of materials and components and report any discrepancies to the supplier immediately. Check masonry units that are delivered wrapped or banded, at the time of delivery.

In particular check that:

a) materials and components are clean and are not damaged or unduly wet;

b) the colour and texture of facing masonry units match the agreed reference panels;

c) that there is continuity in the supply of materials and components, and particularly of sand and cement from the same source and of materials for the approved mortar mixes and facing work;

d) sand is visually clean.

COMMENTARY. *The condition of masonry units at the time of delivery can impose requirements on site before use (see **A.4.2.2**). Testing and/or certification may be called for by the specifier.*

It is desirable that colour differences between consignments of masonry units do not result in banding or patchiness of colour in finished walling. Distributing units from different packs throughout the site helps to blend units of different colour within the consignment. Ascertaining in advance whether the manufacturer can blend the units in their factory is useful. Where several consignments will be delivered to site over a long period of time, blending on site may not solve the problem of colour variation between consignments. It is worthwhile identifying the problem before deliveries begin and consulting the manufacturer.

Sands and cement supplied from different sources can give rise to colour variations in the mortar. This can significantly affect the appearance of walling.

A.4.1.3 *Handling and site storage*

A.4.1.3.1 *General*

The manufacturers' recommendations for handling and site storage of materials should be followed.

A.4.1.3.2 *Masonry units*

Unload masonry units with care, either by machine or by hand, to minimize soiling, chipping and breakage. Handle prepacked masonry units with wrapping and banding in place unless it is not practical to do so. Use mechanical handling equipment where practicable.

Protect the stacks from rain and frost, and from soiling from the ground and passing traffic. Protect the bottom of the stack from becoming wet from ground moisture.

Stack unwrapped masonry units in such a manner as to allow free circulation of air.

COMMENTARY. *If masonry units are too wet they can be difficult to lay and the finished work can develop efflorescence or leaching from the joints causing white stains. The risk of unacceptable shrinkage cracking, particularly with concrete block masonry and calcium silicate brick masonry, is greater when units have been wetted unnecessarily because of lack of protection.*

A.4.1.3.3 *Stone*

Deliver the stone from the yard to a suitable off-loading facility on site, and in the fixing sequence. Stack clear of the ground on battens to prevent contamination from moisture and soluble salts in the earth. In wintry weather take precautions to prevent damage to the stones from the freezing of rainwater or residual quarry-sap by covering with tarpaulins or polyethylene sheet over straw, hessian or other suitable insulating materials, which contain nothing that might damage or stain the stone. Protect against staining from other building materials, particularly hardwoods, oils and fuels.

A.4.1.3.4 *Ancillary components*

Handle all ancillary components, e.g. lintels, flue linings, tiles, cavity closers and edge trims with care to avoid cracking, damage to edges, damage to surfaces and coatings, distortion and soiling.

Stack lintels and copings of precast concrete and pressed metal on level bearers so that they are clear of the ground. Cover the stacks, to protect them from staining and splashing of mud, and follow any additional advice in the manufacturer's recommendations.

Store metal and plastics components, e.g. wall ties, straps, etc. under cover and protect from damage and distortion.

A.4.1.3.5 *Bags of cement and hydrated lime and dry prepacked cementitious mortar mixes*

Where materials are to be stored for later use, store:

a) in a dry, frost-free, enclosed shed or building with a dry floor. If the floor is concrete, upon a timber platform;

b) with different materials in separate stacks;

c) with bags stacked away from walls, not more than eight high, and covered with a tarpaulin or polyethylene sheet;

d) in an arrangement so that consignments can be used in the order of delivery.

Keep cement stored on site to a practical minimum. Check materials for deterioration when taken out of storage and discard if lumpy.

Stack small quantities of cement and hydrated lime intended for immediate use, if not stored in a shed or building, on a timber platform, well clear of the ground. Cover with a tarpaulin or a polyethylene sheet so that all the bags are protected from wind and rain.

Arrange deliveries so that the materials do not arrive at site too early and that excessively large quantities are not delivered at one time.

COMMENTARY. *Even if materials are protected from rain, moisture in the air will gradually cause deterioration. Even in fair weather conditions cement eventually goes lumpy and gives a lower strength.*

A.4.1.3.6 *Cement in bulk*

Store cement delivered in bulk in a proper cement silo, in accordance with BS 8000-2.

A.4.1.3.7 *Sand, aggregates and mortars*

Store different sands, aggregates and lime–sand mixes in different stockpiles on hard clean bases which permit free drainage. Avoid intermix and contamination from other building materials, debris or other deleterious material.

Store factory produced premixed lime–sand for mortars on a clean hard impervious surface and cover to prevent excessive drying out, wetting and loss of fine particles of lime and pigments.

Store factory produced ready-to-use retarded mortars in covered containers to prevent excessive drying out or wetting.

Cover all sands and mortars and protect from freezing during frosty weather.

Do not store retarded ready-to-use mortars for longer than the manufacturer's quoted periods of retardation.

A.4.1.3.8 *Damp-proof course (DPC) materials*

Store DPC materials in the dry, under cover, and protected against damage. In addition, follow these recommendations for flexible materials.

a) Stand rolls on their ends to form a stable stack not more than three packs or more than 1 m high.

b) Keep bitumen and other thermoplastic materials away from any direct heat source.

c) Store sufficient rolls for the next day's use in a warm place prior to use, since some DPC materials can become stiff in cold weather conditions.

d) Check all labels on adhesives for any particular storage recommendations, e.g. avoidance of high or low temperature, and for any hazards relating to solvent vapours.

A.4.1.3.9 *Thermal insulation materials*

Store thermal insulation materials in the dry, under cover, and protected against damage. Follow the manufacturer's recommendations for storage and handling.

A.4.2 ***Preparation of work, materials and components***

A.4.2.1 *General*

A.4.2.1.1 *Distributed components and materials*

Where materials and components are distributed to the work position ensure that:

a) neither the structure nor the access scaffolding are overloaded;

b) the components and materials are protected to prevent damage or deterioration before use.

A.4.2.1.2 *Setting out building*

Set out masonry relative to securely marked or pegged reference lines and datum levels using appropriate serviceable equipment. Squareness should be checked with diagonal measurements or a builder's square. Securely fix any datum and profile marks. Leave datum level points in position so that a gauge rod can be used for coursing other heights such as openings, storeys and string courses (see **A.5.1.2**).

A.4.2.1.3 *Horizontal setting out*

Anticipate the position of openings, etc. in the starting course prior to carrying out work to avoid unnecessary cutting and adjustment of masonry units at a later stage which can lead to incorrect or uneven bonding (see **A.5.1.3**).

A.4.2.2 *Masonry units*

A.4.2.2.1 *General*

Protect units from rain. Where appropriate allow newly manufactured units to cool before being used.

A.4.2.2.2 *Clay masonry units*

In dry warm weather wet the surfaces of very absorbent clay masonry units sufficiently to reduce suction, but without over-wetting.

COMMENTARY. *Low water absorption units such as engineering bricks should not be wetted as they can slide on the mortar. Over-wetting of any bricks can cause efflorescence or lime staining.*

A.4.2.2.3 *Calcium silicate masonry units*

To achieve better adhesion and laying of calcium silicate masonry units in dry warm weather adjust the consistency of the mortar. Alternatively, the surfaces to be bedded can be wetted just sufficiently to reduce the suction by briefly dipping in water.

COMMENTARY. *Over-wetting of calcium silicate units prior to laying should be avoided in order to minimize the shrinkage of the built masonry when it dries.*

A.4.2.2.4 *Concrete masonry units*

Do not wet concrete masonry units before laying. Where necessary adjust the consistency of the mortar to suit the suction rate of the units.

A.4.2.2.5 *Stone masonry units*

Check that stone masonry units as delivered are of proper dimensions and will work-in satisfactorily. Check the positions of the main features, such as quoins, door jambs, etc., and prepare a marked off gauge-lath, making allowance for the joints. In intricate work lay a trial assembly of stones dry for the first two courses to check bonding and jointing.

A.4.2.3 *Preparation of mortar mixes*

A.4.2.3.1 *Gauging*

When mortar is gauged by volume use a gauge box, bucket, or similar standard container for each material. Use containers of a size to be completely filled to proportion each batch. When cement is supplied in bags it is preferable to use whole bags of cement for any one mix.

COMMENTARY. *Gauging volumes by the shovelful cannot be relied upon to give sufficiently accurate mix proportions, e.g. the volume of material in a shovelful of free flowing cement is approximately half the volume of material in a shovelful of damp cohesive sand. If mortar materials are not properly proportioned, this will lead to variations in the colour, strength and durability characteristics of the mortar.*

A.4.2.3.2 *Admixtures*

Do not use admixtures except where specified by the designer. Where this is the case, follow the manufacturer's recommendations.

COMMENTARY. *Calcium chloride added to mortar can lead to corrosion of embedded metal.*

A.4.2.3.3 *Pigments*

Unless otherwise specified do not use more than 10 % pigment or not more than 3 % in the case of carbon black, of the cement mass, in coloured mortar mixes. Proportions should be consistent from batch to batch of mortar.

COMMENTARY. *It is not practicable to proportion accurately on site unless all materials are batched by weight. Inaccuracies can lead to colour variation. It is preferable to use ready-mixed pigmented material. Proportioning small quantities of mortars on site is particularly difficult.*

A.4.2.3.4 *Mixing method*

Mix mortar by machine except in the case of small quantities of mortars not containing plasticizers (see **A.4.2.3.2**). Do not load a mixer to more than its rated capacity. Hand-mix mortar on a clean watertight platform.

A.4.2.3.5 *Mixing sequence*

Where mixing by machine, load about three-quarters of the sand or premixed lime–sand mixtures and water. While mixing, gradually add lime and/or cement and continue mixing. Load the remainder of sand or pre-mixed lime-sand mixtures and further water to achieve required workability. Alternatively, add half the water to the mixer followed by all the cement and all the sand in that order. Add the final quantity of water to achieve the correct workability.

Where mixing by hand, mix the cement (and lime, if used) with sand before adding water until the colour is consistent. Add and thoroughly mix about three-quarters of the required amount of water. Then add further water and mix to achieve the required workability.

A.4.2.3.6 *Mixing time*

Continue mixing long enough to obtain a uniform consistency and colour from the ingredients.

COMMENTARY. *In general, a machine mixing time of 3 min to 5 min after all the constituents have been added should be sufficient. Wide variation in the mixing time of different batches should be avoided. Prolonged mixing where air-entraining plasticizers are used can lead to excessive air entrainment and thus to a reduction in strength, adhesion and durability.*

A.4.2.3.7 *Setting time of mortars containing cement*

Use cement based mortars, other than retarded mortars, within 2 h of mixing. Discard any unused mortar (see also **A.5.1.1.1**).

COMMENTARY. *If workability is reduced due to water loss by evaporation the mortar can be re-tempered within a maximum of 2 h by the addition of a small amount of water. Retarded mortars can be re-tempered, but only within the manufacturer's stated retardation time. In hot weather the prescribed retardation time may be shortened.*

A.4.2.3.8 *Mixing in cold weather*

Do not mix mortar when the air temperature is at or below 3 °C and falling or below 1 °C and rising. Do not use sand or lime–sand mixtures containing ice particles (see also **A.5.1.1.1**).

A.4.2.3.9 *Care of mixing plant*

Clean the mixer at least once a day and whenever mixes are changed. If the mixer has a weighing mechanism check it regularly in accordance with the manufacturer's site work instructions to ensure constant accuracy.

COMMENTARY. *Cleaning the mixer is particularly important when changing from or to coloured mortars.*

A.4.2.3.10 *Mix proportions*

Use the specified mix proportions.

COMMENTARY. *Mortar mixes may be specified by the designations given in Table A.1. Mixes of the same Designation have approximately equivalent strength and durability.*

Table A.1 — Mortar mixes

Types of mortar		Cement:lime:sand[a]	Masonry cement:sand[a]		Cement:sand[a] (plasticized)
Binder constituents		A Portland cement and lime, with or without an air entraining additive	Masonry cement containing a Portland cement and lime in the approximate ratio 1:1, and an air entraining additive	Masonry cement containing a Portland cement and inorganic materials other than lime[b] and an air entraining additive	A Portland cement and an air entraining additive
Designation	(i)	1:0 to 0.25:3	—	—	1:3
	(ii)	1:0.5:4 to 4.5	1:3	1:2.5 to 3.5	1:3 to 4
	(iii)	1:1:5 to 6	1:3.5 to 4	1:4 to 5	1:5 to 6
	(iv)	1:2:8 to 9	1:4.5	1:5.5 to 6.5	1:7 to 8

NOTE 1 The range of sand volumes is to allow for the effects of differences in grading on the properties of the mortar. In general the lower values apply to Type G of BS 1199 and 1200:1976 and the higher values to Type S. Mortars incorporating both lime and air-entrainment can be used with any sands within the BS 1199 and 1200 gradings.

NOTE 2 Air entrainment to improve the durability and the working properties of the mortar is recommended. It may be achieved by the use of air-entrained cements, either masonry cements or improved cements, by the addition of plasticizer to the site mixer, or by the use of a factory made mortar. (Improved cements are Portland cements modified for use in masonry containing a relatively small amount of air entrainment. They are produced for use in masonry and similar applications.)

NOTE 3 BS 8221 contains recommendations for other mortar mixes that are more suitable for the repair of the masonry of historic buildings.

[a] Cements for mortar and the standards to which they should conform are listed in **5.3.1**.
[b] Where masonry cement contains less than 75 % PC, no data exists with regards to equivalence (with other mixes of that Designation) of strength and durability.

A.5 Brick and/or block walling

A.5.1 *General*

A.5.1.1 *Weather conditions*

A.5.1.1.1 *Cold weather*

In cold weather do not:

— build masonry when air temperature is at or below 3 °C and falling or unless it is at least 1 °C and rising (see also **A.4.2.3.8**);

— lay mortar on frozen surfaces;

— use wet bricks or blocks when there is a danger of freezing.

A.5.1.1.2 *Frost damage*

If the mortar is susceptible to frost damage, obtain guidance and instructions before proceeding work.

A.5.1.1.3 *Protection*

Cover the tops of newly built brick and block masonry to protect it from rain and also from frost, if imminent, and at all times when work is not proceeding. If there is any danger of the work being frozen then consideration should be given to the use of insulation under the covers.

COMMENTARY. *Unless the work is protected when not proceeding there is always the risk of sudden frosts or showers causing damage. It is important to cover work at the end of each day. These covers should be kept handy for use. Wet covers can freeze in contact with the work, therefore, it may be preferable to top the wall with a clean and dry wooden plank, wider than the wall, and place polyethylene or similar sheeting over the plank, clear of the wall face, in order to provide an insulating air gap. It is important to weight the covers to prevent the wind lifting them.*

A.5.1.1.4 *Hot weather*

Protect newly-built masonry during hot weather.

COMMENTARY. *In hot, sunny weather, especially with drying winds, mortar joints can dry before the cement has set and the mortar has bonded adequately with the brick and/or block masonry units. This is more likely to happen with masonry units of high water absorbency.*

A.5.1.2 *Accuracy*

Build masonry (other than stone masonry) within the permissible deviations given in Table A.2, unless otherwise specified.

COMMENTARY. *The permissible deviations given in Table A.2 and Table A.3 are intended to provide satisfactory structural performance of the masonry. They should not be regarded as defining acceptability of appearance. Furthermore, they do not necessarily accord with standards of accuracy required for the fit of associated building components (e.g. door and window frames) or with the provision of flat backgrounds for wall finishes or linings. Higher levels of accuracy may need to be specified where such components or finishes are to be installed.*

Table A.2 — Permissible deviations in masonry (other than stone masonry)

Dimensions	Permissible deviation mm
Position in plan of any point or face in relation to the specified building reference line and/or point at the same level	±10
Straightness in any 5 m length	±5
Verticality up to 3 m height	±10
Verticality up to 7 m height	±14
Overall thickness of walls	±10
Level of bed joints up to 5 m for brick masonry	±11
Level of bed joints up to 5 m for block masonry	±13
NOTE 1 These deviations are generally derived from BS 5606:1990 and represent the level which can be reasonably expected for general brick and block masonry. NOTE 2 These deviations should be measured in accordance with the methods described in BS 5606:1990, Annex D.	

Build stone masonry within the permissible deviations given in Table A.3 unless otherwise specified.

Table A.3 — Permissible deviations in stone masonry

Dimensions	Permissible deviation mm
(A) Walls	
Overall height (up to 3 m)	±15
Verticality up to 3 m height	±6
Verticality up to 7 m height	±10
Straightness (in 5 m length)	±6
Bed joint level (in 5 m)	±6
Length along wall (in 6 m)	±15
(B) Window and door openings	
Width along wall (up to 3 m)	±6
Height (up to 3 m)	±6

A.5.1.3 *General laying*

A.5.1.3.1 *Masonry bond*

Lay using the masonry bond in accordance with that specified by the designer.

A.5.1.3.2 *Laying bricks*

Unless otherwise specified, lay bricks on a full bed of mortar, substantially fill cross joints and keep courses level and perpend joints vertically aligned. Plumb quoins and wall faces course by course as the work proceeds.

COMMENTARY. *For walling subject to exposure to wind-driven rain, and where sound insulation or fire resistance is necessary, the bricklayer should substantially fill bed and cross joints. However, in practice, some partially filled joints are unlikely to lead to a significant reduction in performance. It is not practical to vertically align every perpend joint, particularly with bricks having the maximum permissible deviation from the work sizes. It is good practice in such cases to align vertically about every fifth cross joint in each course and "even out" the size of intermediate joints. This will give a regular appearance of verticality when viewed from positions other than very close to the wall.*

BS 3921 permits variation in the dimensions of clay bricks. The tolerance is based on a measure of 24 bricks.

BS 187 for calcium silicate units and BS 6073-1 for precast concrete masonry units, give tolerances for each individual dimension.

A.5.1.3.3 *Laying single frog bricks*

Unless otherwise advised lay single frog bricks with frog uppermost and bricks with a double frog with deeper frog uppermost. Fill all frogs with mortar where advised.

COMMENTARY. *Brick walls built with frogs down and unfilled are weaker and less resistant to sound transmission. Advice should be sought as to whether bricks laid frog down are acceptable. It is not intended that the voids in perforated bricks are filled with mortar.*

A.5.1.3.4 *Laying solid and cellular blocks*

Unless otherwise specified, lay solid and cellular blocks on a full bed of mortar and substantially fill cross joints. Keep horizontal joints level and to a uniform thickness. Vertically align the perpend joints in fair faced work. Lay hollow blocks on shell bedding with the vertical joints filled.

COMMENTARY. *For walling subject to exposure to wind-driven rain, and where sound insulation or fire resistance is necessary, the blocklayer should substantially fill bed and cross joints. However, in practice, some partially filled joints are unlikely to lead to a significant reduction in performance. It is not practical to vertically align every perpend joint, particularly with bricks having the maximum permissible deviation from the work sizes. It is good practice in such cases to align vertically about every fifth cross joint in each course and "even out" the size of intermediate joints. This will give a regular appearance of verticality when viewed from positions other than very close to the wall.*

It is not practical to vertically align every perpend joint, particularly with blocks having the maximum permissible deviation from the work sizes. It is good practice in such cases to align vertically about every fifth cross joint in each course and "even out" the size of intermediate joints. This will give a regular appearance of verticality when viewed from positions other than very close to the wall.

BS 6073-1 for precast concrete masonry units, gives tolerances for each individual dimension.

A.5.1.3.5 *Make-up masonry*

Use cut or special shaped masonry units of the same type in situations such as making up courses, closing cavities, fitting around structural steel profiles, etc. Do not use materials with different physical properties, e.g. clay and concrete masonry, which have different rates of expansion.

A.5.1.3.6 *Height of lifts*

Do not rack back corners and other advanced work higher than 1.2 m above the general level.

For facing work complete the whole lift within one period of operation.

Except where permitted by a proprietary system or by the designer, do not carry up any one leaf more than 1.5 m in one day.

COMMENTARY. *If work rises more than 1.5 m in a day the mortar in the lower courses may be over-stressed as it may not have developed sufficient strength. It may be possible to safely carry lightweight masonry units higher than 1.5 m a day; conversely dense units may need to be restricted to lifts lower than 1.5 m.*

A.5.1.3.7 *Honeycomb sleeper walls*

Build half-brick sleeper walls with all vertical joints left open 65 mm to 75 mm wide (see Figure A.1).

COMMENTARY. *Leaving vertical joints open ensures a free flow of air in all directions under a ventilated floor.*

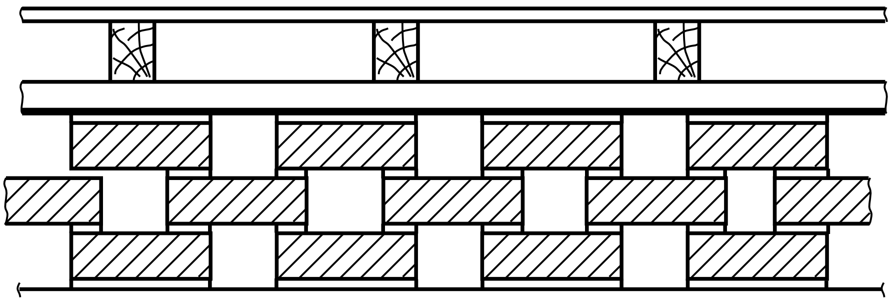


Figure A.1 — Honeycomb sleeper wall

A.5.1.3.8 *Joint reinforcement*

When installing prefabricated bed reinforcement in the joints, embed in mortar to provide a full even bed. Lay reinforcement in the mortar as follows and complete joints to the normal thickness.

Keep reinforcement at least 20 mm from external mortar face and at least 12 mm from internal building faces.

Lap reinforcement a minimum of 225 mm at joints in the length and fully lapped at angles.

A.5.1.3.9 *Bedding ashlar*

To obtain a solid, even bed, use two strips of corrosion resistant metal or heavy duty plastic of the thickness of the specified joint as distance pieces, flushing all joints solidly at the time of fixing. Spread only sufficient mortar to bed one ashlar at a time.

COMMENTARY. *Uneven bedding can cause the stone to crack.*

If necessary, re-moisten the bedding mortar slightly by sprinkling with a brush immediately before laying the stone. Moisten the faces of the stones adjacent to beds and joints prior to final pointing.

The projecting members of an overhanging cornice should be hollow bedded. Take precautions to prevent overturning of projecting cornice stones, which can be unstable, pending the setting of the mortar, the fixing of dowels or cramps and the bedding of stabilizing courses.

Fit dowels and cramps as the work proceeds. Completely fill grouted joggle joints and tamp to ensure that any trapped air is expelled.

A.5.1.3.10 *Rubble walls*

Build up quoins in advance of the main body of the rubble wall to a height of approximately 1 m with the adjacent walling built or stepped down on either side.

Build the front part of the wall to a height of not more than 400 mm, raise the back part to approximately the same level using as far as possible stones that are broad on bed and which tail-in well with the front portion. At the same time, fill any spaces left between the stones of the two wall faces with core stones carefully chosen to bond in with the remainder. Fill all voids.

Build in bonders, one to each superficial metre in each face in random work, and at approximately 1 m vertical and horizontal intervals in coursed work, staggering the stones between the two faces.

COMMENTARY. *Bonders should have a height of not less than one-third their length and should extend through two-thirds of the wall thickness.*

A.5.1.3.11 *Plumbing of stone walls*

To ensure that rough-faced stone masonry is plumb, erect temporary but rigid vertical forms or battens at the building angles, approximately 300 mm away from the wall face, from which a constant distance should be maintained when forming the bed joints of the quoins. Lines should then be stretched either from the laid quoin stones or from the battens which will indicate the face of the bed joints in the intermediate walling.

COMMENTARY. *When a wall is to be built to a batter or slope, the battens should be erected at the desired angle from the vertical, and measurements taken as before.*

A.5.1.3.12 *Quoins and jambs*

Unless otherwise specified, use selected large stones for quoins and jambs. These should be more regular in shape and more carefully dressed than stones for the main walling, and should be selected and set out on the ground beforehand. The use of these stones at the angles will give greater strength and stability to the wall, and enable the mason to course and plumb the wall as the work advances.

A.5.2 ***Jointing and pointing***

A.5.2.1 *Jointing*

A.5.2.1.1 *General*

Finish facing work and fair faced work joints to the specified profile as the work proceeds.

A.5.2.1.2 *Unexposed joints*

As the work proceeds, use a trowel to strike off any joints which are not to be exposed to view in the finished work, e.g. in roof spaces.

A.5.2.1.3 *Masonry to be plastered or rendered*

Unless units have a suitable texture or purpose-made key unit or metal-lathing is used, rake out joints approximately 15 mm deep, as work proceeds, on all those faces to be plastered or rendered.

COMMENTARY. *Raking out joints gives a good key for the coating.*

A.5.2.2 *Pointing*

If pointing is specified do not use mortar stronger than that used when constructing the wall.

If pointing is specified, rake out the joints to a depth of between 10 mm and 15 mm as the work proceeds, to give an adequate key. Brush out the joints to remove dust and loose material and then lightly wet using a brush. Carry out pointing from the top of the wall downwards.

COMMENTARY. *It is important that the specified depth of raking out is achieved throughout the wall, checked with a suitable depth gauge.*

A.5.3 ***Laying DPCs***

A.5.3.1 *General*

A.5.3.1.1 *Warming DPC rolls*

Warm DPC rolls in cold weather to avoid cracking.

A.5.3.1.2 *Junction with damp-proof membrane*

Ensure that care is taken to follow the detail and specification in order to achieve continuity of the DPC at ground level with the damp-proof membrane.

A.5.3.1.3 *Sealing junctions*

Where flexible DPCs are to resist the downward movement of moisture within walls, seal the lap joints and all junctions, e.g. at columns. Also follow these recommendations.

a) For bitumen DPC materials, lap at least 100 mm and seal together with cold applied roofing felt adhesive.

b) For pitch polymer and bitumen polymer materials, lap at least 100 mm and seal joints with adhesive in accordance with the manufacturer's instructions.

c) For polyethylene, seal joints with double-sided adhesive tape.

d) For joints in lead, form the seals with 100 mm passing lap and interlocking upstands.

e) For joints in copper, form seals by welding or welting.

COMMENTARY. *If joints and junctions are not sealed, the flow of water from above can penetrate through the joints and give rise to costly and inconvenient remedial work. Examples requiring particular attention are parapet walls and wall panel and floor junctions with concrete frames (see also* ***A.5.4.1.4****).*

A.5.3.1.4 *Stepping DPCs*

Where a DPC is used in an external wall on a sloping site, ensure the DPC is never less than 150 mm above the finished ground level (see Figure A.2).

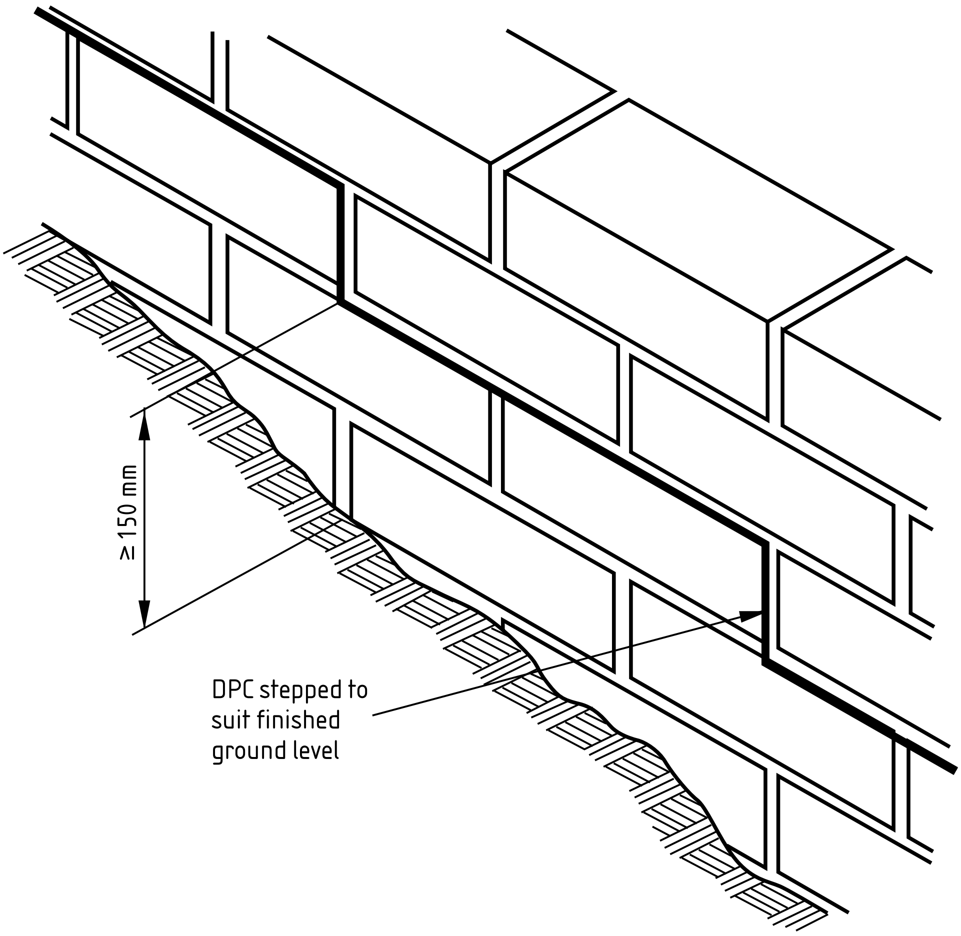


Figure A.2 — Stepping DPC above ground

A.5.3.2 *Horizontal DPCs*

A.5.3.2.1 *Flexible horizontal DPCs*

Bed DPCs on mortar. Lay DPCs in continuous lengths for the full width of the leaf, with 100 mm minimum laps in runs and with full laps at angles. Bed at least one further course of units on mortar on the DPC.

COMMENTARY. *The weight of the course above the DPC, if laid immediately after the DPC, will help to develop good adhesion between the masonry units, the mortar and the DPC.*

A.5.3.2.2 *Slate horizontal DPCs*

Lay two courses of slate with joints staggered, and fully bed each course in the Designation (i) mortar (see Table A.1). The total thickness of joint should be not more than 40 mm.

A.5.3.2.3 *Brick horizontal DPCs*

Form a DPC of brick masonry with not less than two courses of DPC category bricks laid in Designation (i) mortar (see Table A.1) with all the bed joints and perpend joints filled solid with mortar.

A.5.3.2.4 *DPCs at base of wall*

Where there are separate DPCs in each leaf, ensure edges do not project into the cavity. Do not cover edges of the DPC with mortar.

COMMENTARY. *DPCs projecting into cavities provide a place for debris to lodge. DPCs should cover the full width of the wall if they are to prevent the passage of moisture effectively (see Figure A.3).*

Dimensions in millimetres

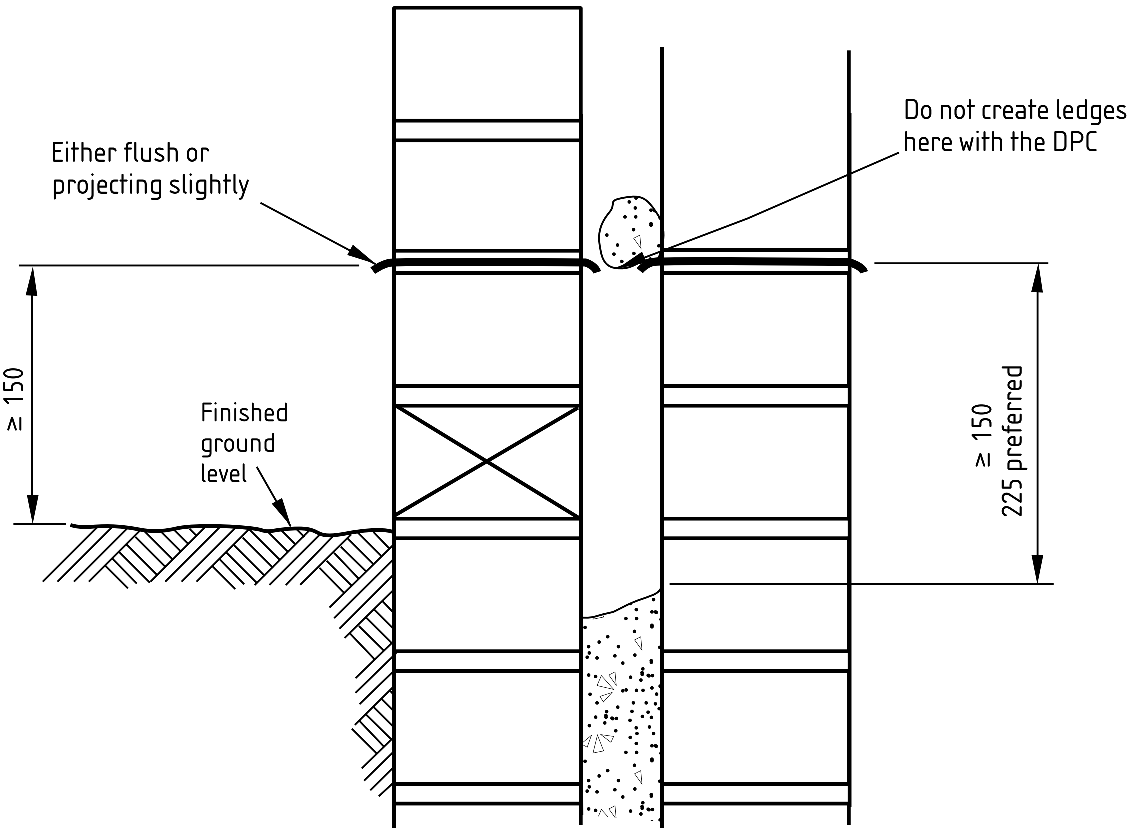


Figure A.3 — DPC at base of wall

A.5.3.2.5 *Horizontal DPCs under sills*

With jointed, pervious, or timber sills, turn up the DPC underneath at the rear face to prevent moisture coming into contact with inner leaf or finishings. Allow the leading edge of the DPC to project 5 mm from the wall face below sill.

COMMENTARY. *The joints in a sill are a source of weakness. Water running off the window on to the sill can cause moisture to penetrate through the sill or joints and back, to any part of the inner leaf or finishes in contact with the sill without an adequate DPC (see **A.5.3.3.6**).*

A.5.3.3 *DPCs in cavity work*

A.5.3.3.1 *Cavity trays over cavity bridges*

Where flexible DPCs span cavity bridges, e.g. over door and window openings, ducts and horizontal cavity barriers:

a) use cavity trays, wherever possible, in continuous lengths. If a joint cannot be avoided, use a rigid support of suitable material at the position of the joint to ensure solid bonding is provided. Overlap joints in DPCs to a minimum of 100 mm and seal with an appropriate jointing compound;

b) securely fix trays across the cavity, stepping up towards the inner leaf. Prevent sagging by providing support where necessary;

c) ensure that trays cover the full extent of any lintels or other cavity bridgings;

d) ensure that trays with stop ends to direct water flow to weepholes are provided.

See also **A.5.4.1.4** and **A.5.3.2.4**.

COMMENTARY. *Cavity trays provide a watertight barrier which discharges water to the outside.*

A.5.3.3.2 *Cavity trays at roof abutments*

Where pitched roofs abutt cavity walls, build-in cavity trays to ensure effective drainage of water through weepholes in the external leaf of the wall. Where a roof abutts a horizontal cavity, install a cavity tray above roof level. Where the junction between a pitched roof and a cavity wall forms a sloping abutment, install a system of stepped cavity trays.

A.5.3.3.3 *Trays and flashings in chimneys*

Where a tray is necessary, at one or two levels where a chimney penetrates a roof surface, extend the trays across the total area of the chimney and into the flue liner. The trays should have an upstand at the rear and to the sides of the chimney and be dressed down at the front edge. At least two weepholes above the tray at the front edge should be provided.

A.5.3.3.4 *Cavity trays above insulation*

If cavity insulation is terminated below the highest level of the wall, protect the top edge of the insulation by a cavity tray. Provide weepholes at centres not exceeding 1 m to provide adequate drainage from the cavity tray.

A.5.3.3.5 *Cavity trays to exclude soil gas*

Support any tray designed to prevent soil gases, e.g. radon and methane, from entering the building, across the cavity and seal all laps.

A.5.3.3.6 *Jambs in cavity walls*

Build in flexible DPCs at jambs of all openings unless a proprietary closer is used. Lap a vertical DPC under the DPC at the head, and lap in front of the DPC at sill level. Ensure DPCs are in close contact with frames and properly held in position to prevent sagging. Project the jamb DPC at least 25 mm into the cavity area.

COMMENTARY. *It is essential that continuity of all the DPC at the corners of all openings is maintained to prevent rain penetration.*

A.5.4 ***Cavity walling***

A.5.4.1 *Cavities*

A.5.4.1.1 *Forming a cavity wall*

Form the cavity wall to the specified overall thickness and with the specified cavity width. Clean off any surplus mortar from joints on the cavity faces as the work proceeds. Keep the cavity and ties free from mortar and debris.

COMMENTARY. *Draw battens should be used as a means of keeping the cavity clear of mortar and debris since anything that bridges the cavity can lead to damp patches appearing on the inner face of the wall. The battens should be drawn up and cleaned regularly, particularly at the end of the day's work.*

Cavities at the base of the wall should be kept clear. If cleaning becomes necessary take care not to damage the DPCs.

A.5.4.1.2 *Filling the bottoms of cavities*

Unless otherwise specified, fill cavities below ground level with concrete to a level 75 mm below finished ground level (see Figure A.3).

COMMENTARY. *Filling cavities below ground level stabilizes the two leaves and prevents the bottom of the wall filling with water. Any water reaching the bottom of the cavity is drained away through weepholes left in the base of the wall (see* ***A.5.4.1.4****).*

A.5.4.1.3 *Cavity bridges*

Where the tops of cavities are to be spanned with in situ concrete, use a rigid durable material to serve as formwork.

A.5.4.1.4 *Weepholes*

Where specified provide weepholes in the external leaf at centres not exceeding 1 m at the locations and in the form specified. If weepholes are not specified obtain instructions.

COMMENTARY. *It should be assumed that moisture runs down the inner face of the external leaf of all cavities. Where the cavity is bridged by an extensive barrier, e.g. lintels, floor slabs, concrete frame members or at the location of a horizontal cavity fire barrier, a cavity tray and weepholes are necessary (see also* ***A.5.4.1.2****).*

Normally in brick masonry, open cross joints (perpend joints) or, in block masonry, part open cross joints (perpend joints) serve as weepholes.

A.5.4.2 *Cavity wall ties*

A.5.4.2.1 *Bedding*

Except for proprietary systems, bed ties at least 50 mm into masonry leaves, and level or slope slightly downwards towards the outer leaf. Ensure that the drips point downwards. It is also important that proprietary wall ties are laid the right way up.

Build ties in as the work proceeds and do not push ties into joints after the joints have been completed. Do not bend ties or move after installation.

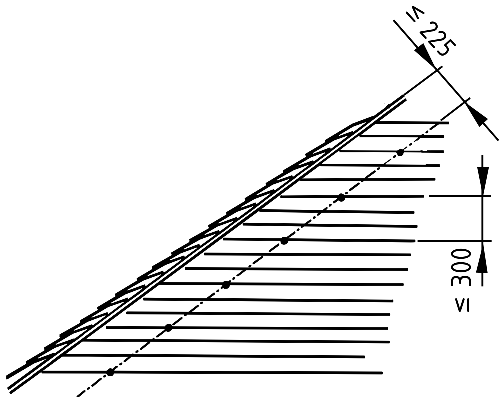
A.5.4.2.2 *Spacing for masonry cavity walls*

Stagger ties in alternate courses at the spacings given in Table A.4, unless otherwise specified.

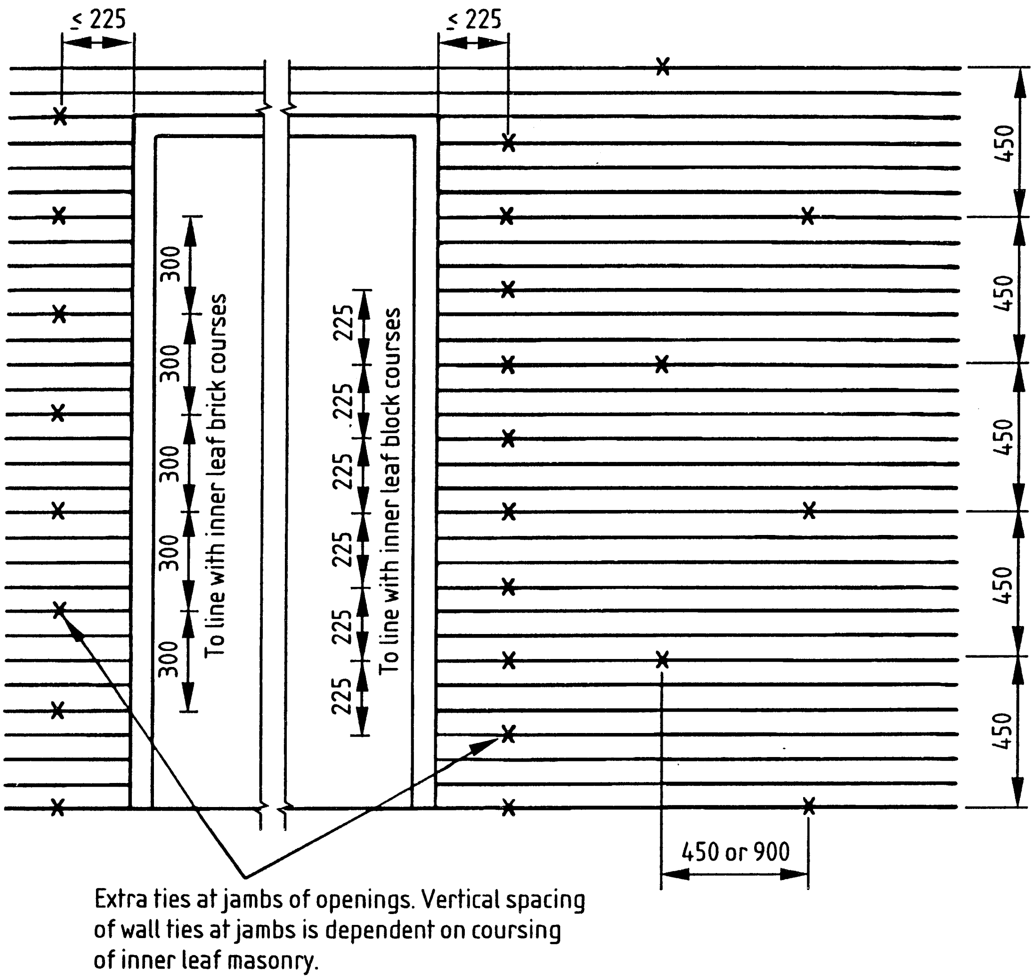
Provide additional ties at sides of openings at every block course or every fourth brick course (see Figure A.4).

COMMENTARY. *Ties should be of sufficient length to ensure that the 50 mm minimum bedding is achieved in both leaves.*

Dimensions in millimetres



a) At gable verges



b) At openings

NOTE This figure is based on the recommendations of BS 5628-3. The Approved Documents to the Building Regulations recommend the extra ties at jambs of openings to be within 150 mm of the opening.

Figure A.4 — Spacing of ties

A.5.4.2.3 *Spacing for timber frame/masonry walls*

Fix wall ties to stud members at the following maximum spacing (or equivalent in area cover):

a) at vertical spacings of 375 mm for studs at 600 mm centres;

b) at vertical spacings of 525 mm for studs at 400 mm centres;

c) at jambs vertically, not more than 225 mm from the brick reveal and at 300 mm maximum centres.

A.5.4.2.4 *Spacing for light steel frame/masonry walls*

Fix wall ties for stud members at full maximum spacing (or equivalent in area cover):

a) at vertical spacings of 375 mm for studs at 600 mm centres;

b) at vertical spacings of 450 mm for studs at 400 mm centres;

c) at jambs vertically, not more than 225 mm from the brick reveal and at 300 mm maximum centres.

A.5.4.3 *Alignment*

Where vertical twist ties are used do not build one leaf above the other leaf by more than the vertical spacing between consecutive rows of ties.

COMMENTARY. *It is difficult to ensure that the bed joints stay in alignment if the two leaves are not raised together.*

Table A.4 — Spacing of wall ties

Least leaf thickness (one or both)	Cavity width	Equivalent number of ties	Approximate spacing of ties	
			Horizontal	Vertical
mm	mm	/m^2	mm	mm
65 to 90	50 to 75	4.9	450	450
Not less than 90	50 to 300	2.5	900	450

A.5.4.4 *Installing insulation (see Figure A.5)*

A.5.4.4.1 *Partial cavity fill*

Fix insulation boards or insulation slabs carefully in accordance with the manufacturer's instructions. Construct walls in accordance with the following recommendations.

a) Close butt boards and slabs at both horizontal and vertical joints and at closures.

b) Keep joints between boards and slabs clean and free from mortar droppings.

c) Securely fix boards and slabs to be backed to one leaf by a method approved in the design, only as specified, so as not to form ledges which can collect mortar or moisture.

d) Do not block or bridge air spaces, either by mortar or off-cuts of insulation.

e) Strike mortar joints flush within the cavity and keep inner faces of the masonry clean.

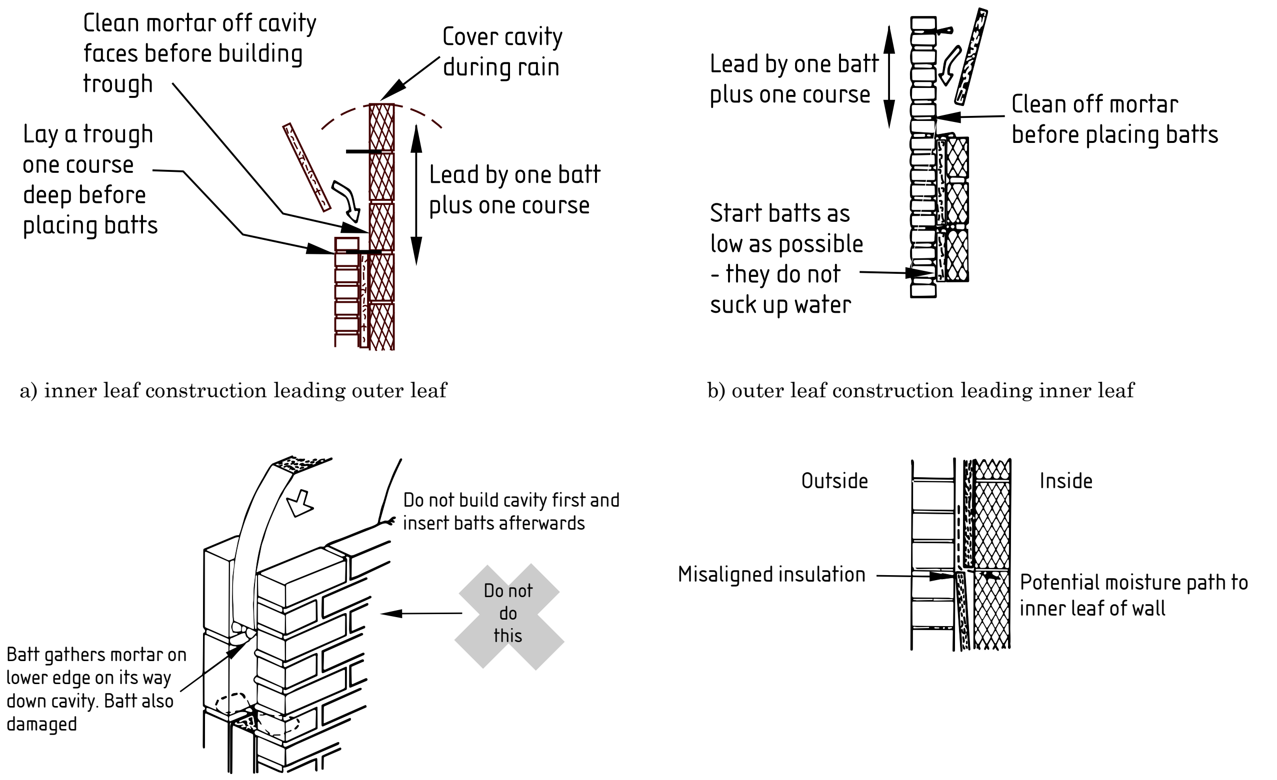
f) Do not leave gaps in the insulation.

g) Leave mortar joints open as weepholes in the outer leaf as recommended (see **A.5.4.1.4**).

h) Ensure that horizontal joints of insulation correspond with horizontal rows of ties.

i) Do not use recessed mortar joints unless specified by the designer.

COMMENTARY. *The risk of moisture penetration is increased unless the recommendations for workmanship are adhered to carefully. If moisture penetration does occur, the fault cannot be traced easily.*



a) inner leaf construction leading outer leaf

b) outer leaf construction leading inner leaf

c) faulty technique: build-in batts as wall is built — do not slide batts into cavity

d) faulty technique: align and securely fix partial-fill slabs or boards

Figure A.5 — Insulation in cavity walls

A.5.4.4.2 *Built-in cavity fill*

Fit insulation slabs carefully in accordance with the manufacturer's recommendations. Construct walls in accordance with the following recommendations.

a) Ensure that the insulation slabs are of a thickness appropriate to the cavity width so as to fill the cavity.

b) Close butt insulation slabs at both horizontal and vertical joints and at closures, and install them with staggered vertical joints.

c) Keep joints between insulation slabs clean and free from mortar droppings.

d) Strike mortar joints flush within the cavity and keep inner faces of the masonry clean.

e) Do not leave gaps in the insulation.

f) Do not place any small off-cuts with the cut edge against the wall surface.

g) Leave mortar joints open as weepholes in the outer leaf as specified (see **A.5.4.1.4**).

h) Ensure that insulation slabs are built into, and are not pushed into the cavity.

i) Ensure that horizontal joints of insulation correspond with horizontal rows of ties;

j) Where additional wall ties are required, cut insulation slabs neatly to accommodate them.

k) Do not use recessed mortar joints unless specified by the designer.

COMMENTARY. *The risk of moisture penetration is increased unless the recommendations for workmanship are carried out carefully, and if moisture penetration does occur the fault cannot be traced easily. Recessed joints also increase this risk as they increase the amount of water reaching the cavity. Further guidance is given in BS 6676-2.*

A.5.4.4.3 *Blown or injected cavity fill*

Blowing or injecting insulation should be carried out by appropriately qualified personnel.

Inspect cavity walls prior to the blowing or injecting of insulation and build in accordance with the following recommendations.

a) Strike mortar joints flush within the cavity and keep inner faces of the masonry clean.

b) Minimize mortar droppings into the footings.

c) Keep cavities free from obstructions such as lumps of mortar and parts of bricks.

d) Fully fill all putlog holes with mortar on removal of scaffolding.

e) Do not use recessed mortar joints unless specified by the designer.

COMMENTARY. *Independent attestation of conformity schemes for this process are in existence. The risk of moisture penetration is increased unless the walls are built correctly and cavities kept clean. Recessed joints also increase this risk as they increase the amount of water reaching the cavity.*

A.5.5 ***Fair faced masonry***

A.5.5.1 *General*

A.5.5.1.1 *Blending*

Before laying, blend units so that the overall appearance of the finished work is uniform and without patches or bands of colour (see also **A.4.1.2**).

COMMENTARY. *To achieve a good blend, units should be loaded out from at least three packs. It is advisable to draw from the packs in vertical rather than horizontal slices. BS 3921:1985, Annex F and BS 5628-3, Annex D describe a detailed method of assessing the visual acceptability of clay facing bricks using reference and sample panels. In general, bricks should be reasonably free from deep and extensive cracks and from damage to edges and corners and from the inclusion of pebbles and expansive particles of lime.*

A.5.5.1.2 *Selection*

Select units needed for special situations (e.g. soldier course or narrow piers) for consistency of size.

A.5.5.2 *Fair faced work*

Lay masonry units with care so that the finished work has a clean and even surface with the joints consistent in width and profile and with the perpend joints in vertical alignment (see **A.5.1.3.2** and **A.5.1.3.3**). Construct in accordance with the following recommendations.

a) Only cut masonry units where necessary for the correct bond.

b) Make good any holes, such as those for putlog scaffold members and cavity cleaning, with matching mortar and matching masonry units.

c) Keep face work clean and free from staining at all times. Protect masonry adjacent to scaffold boards from rain splashes.

d) Provide temporary protection for projecting bands and plinths while the remainder of the wall above is completed.

e) Protect built-in windows and doors from mortar staining by mortar droppings.

f) Provide protection where in situ concrete work is being executed in close proximity to finished facing work.

COMMENTARY. *The type of scaffold (putlog or independent) is to be agreed. Putlog scaffolding, which is supported by the wall as it rises, will leave holes which should be made good with matching mortar at completion. There is a risk of damage as putlogs are removed.*

A.5.6 ***Construction details***

A.5.6.1 *Sills, copings and cappings*

A.5.6.1.1 *Masonry sills, copings and cappings*

Set bricks, coping or capping units or blocks as specified on a bedding of the specified mortar mix. Fill all joints and keep the units true to line (see also **A.5.3** and **A.5.6.1.6**).

A.5.6.1.2 *Brick and tile sills, copings and cappings*

Form brick masonry as specified on a creasing course of two tiles thickness laid with joints staggered and bedded in mortar of the specified mix. Set tiles to over-sailing if specified and keep all arises true to line. Fill all joints and finish exposed joints flush with adjoining surfaces (see also **A.5.3**, **A.5.3.1.3** and **A.5.6.1.5**).

A.5.6.1.3 *Stone or precast concrete copings and cappings*

Bed stone or concrete copings and cappings in mortar. Set the coping to over-sailing correctly and to a true line. Excluding movement joints, fill joints with mortar and finish flush with the surface. Point or joint stone copings and cappings with suitable materials and to the specified profile.

A.5.6.1.4 *Stone or precast concrete sills and thresholds*

Bed only the ends of one-piece stone or concrete sills or thresholds in mortar. Leave the joint below open and at completion of the brick or block masonry seal the joint with a flexible material.

COMMENTARY. *If one-piece sills are bedded solidly in mortar there is an increased risk of fracture in the event of thermal movement or differential settlement.*

A.5.6.1.5 *DPCs under copings and cappings*

Provide DPCs below jointed or pervious copings and cappings. Lay the DPC and coping or capping units on fresh beds of mortar. Ensure the leading edge of the DPC projects 5 mm from the wall face below the coping. Beneath brick-on-edge cappings the DPC may be cut flush with the brick masonry. Provide a rigid support for the DPC in cavity walls.

COMMENTARY. *The joints in a coping or capping are a potential route for moisture penetration. A continuous DPC underneath will prevent moisture penetrating into the main portion of the wall. The DPC should be bedded in fresh mortar and the coping or capping immediately laid above in fresh mortar in order to maximize the bond between the coping or capping and the wall beneath.*

A.5.6.1.6 *Coping and capping cramps*

Ensure that non-ferrous or rustproof steel cramps are used, and build-in upstand legs tight to the face of the unit.

A.5.6.2 *Padstones*

Build in padstones to receive the ends of structural members and bed solidly in the specified mortar mix and ensure the top surface is accurately positioned in level, to provide an effective bearing area.

A.5.6.3 *Lintels*

A.5.6.3.1 *Lintel bearings*

Ensure that:

a) there is a full masonry unit immediately below lintel ends. Do not use off-cuts of bricks or blocks as they can permit local movement;

b) the lintel is of sufficient length to provide the specified bearing at each end;

c) the length of the brick or block is greater than the bearing length;

d) the lintel is level and is bedded in mortar.

It may be necessary to fill hollow and/or cellular blocks under lintel bearings with mortar.

COMMENTARY. *Lintels need to have a firm seating under each end that will not move under load.*

It may be necessary to prop long, heavy, precast lintels until the mortar has set under the bearings.

Lintel bearings length should be not less than 100 mm. The bearings length for pressed steel and boot lintels should be not less than 150 mm. The bearings length of proprietary lintels should be in accordance with the manufacturer’s instructions (see also **A.5.3.3.1**).

A.5.6.3.2 *Prestressed and reinforced concrete lintels*

Build in lintels with the correct side uppermost in relation to the position of reinforcement.

Prop prestressed composite lintels at centres not exceeding 1.2 m during the construction of masonry above and retain props in position for at least 14 days. Follow the requirements in the manufacturer's sitework instructions for installation.

COMMENTARY. *Ends of lintels should be bedded to allow for long term shrinkage of the concrete at one or both ends. When using composite lintels of prestressed concrete with masonry, the masonry should be carefully built with solidly filled joints. No holes for services should be made nor should anything be built into the masonry part except the edge of a DPC, which should not intrude more than one-quarter width of the bed joint or 30 mm, whichever is the less. In cold weather when mortar gains strength more slowly, the period of propping may need to be extended. Professional advice should be sought in these situations.*

A.5.6.3.3 *Concrete block lintels*

Form reinforced concrete filled block lintels as follows.

a) Provide adequate temporary support to retain the blocks in position until the lintel develops full strength.

b) Bed the end blocks in mortar and build the outer casing with the lintel blocks jointed in mortar.

c) Lay reinforcement on suitable spacers to provide the required cover, fill the whole lintel, tamp well and trowel the top smooth.

d) Follow any additional requirements in the block manufacturer's sitework instructions.

A.5.6.3.4 *Steel lintels*

Where steel lintels have a drip nosing, ensure this is positioned clear of the frame head.

A.5.6.3.5 *Timber lintels*

Ensure timber lintels are not twisted or warped. If they have been cut from longer lengths on site, liberally treat the cut ends with two coats of preservative compounds (see BS 5268-5).

A.5.6.3.6 *Arches in fair faced work*

Unless preformed arch units are specified, form arches on temporary centres using masonry units. Fully fill joints with mortar. Leave the centre in position until the mortar has set. When the centre is removed, finish soffit joints to match the face joints.

A.5.6.4 *Junctions*

A.5.6.4.1 *Angles and intersections in brick or block walls*

When movement joints are not specified, bond or tie all wall junctions in accordance with the following recommendations.

a) Fully bond the two walls at angles.

b) Bond or tie intersecting walls as specified. Obtain instruction if no requirement is specified.

COMMENTARY. *Strip metal ties, cramps, expanded metal or proprietary systems can be used for jointing. The construction should follow the recommendations of the designer.*

A.5.6.4.2 *Junctions between walls and joists or rafters*

Lay wall plates true to level on a solid bed of mortar.

If a filling is advised between the joists or rafters, build in and keep the filling 12 mm below the tops of timber joists. Lay the filling as soon as is practicable after placing members to avoid displacement and distortion (see Figure A.6).

On concrete floors tightly fit the horizontal straps and attach to both the blocks and the floor beams. Provide a full bed of mortar around the strap in the wall.

COMMENTARY. *The masonry filling can provide lateral firm support to the members, whether of steel, concrete or timber. The 12 mm gap shown in Figure A.8 allows for the shrinkage of timber joists. The gap may need closing with a compressible filler depending on circumstances. The ends of members embedded in the wall should be protected against moisture.*

A.5.6.5 *Joist hangers*

Ensure joist hangers are of the type specified. Fit them securely and tightly to the wall without gaps at the contact faces (see Figure A.7).

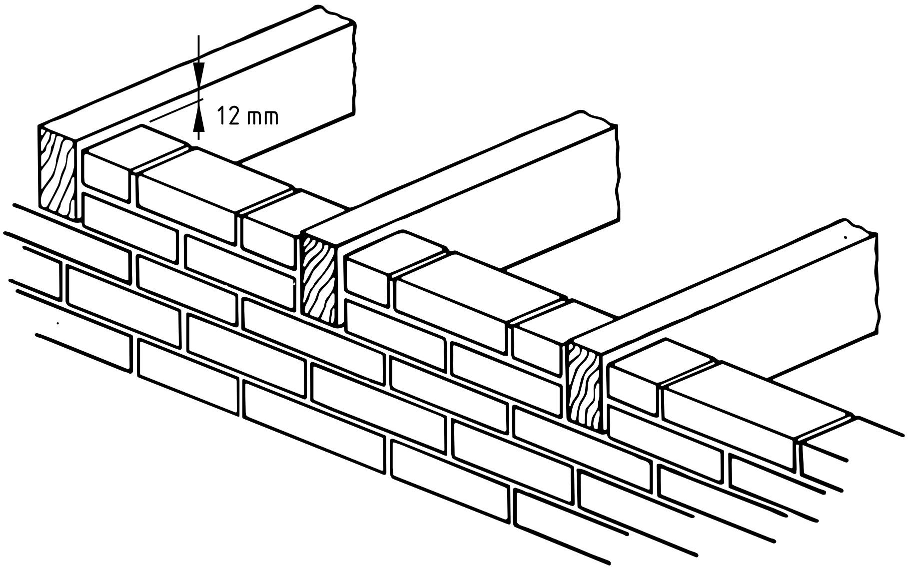


Figure A.6 — Junctions between walls and joists/rafters

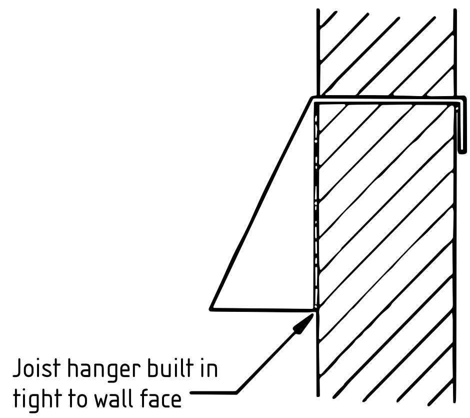


Figure A.7 — DPC tray extended through the liner into the flue

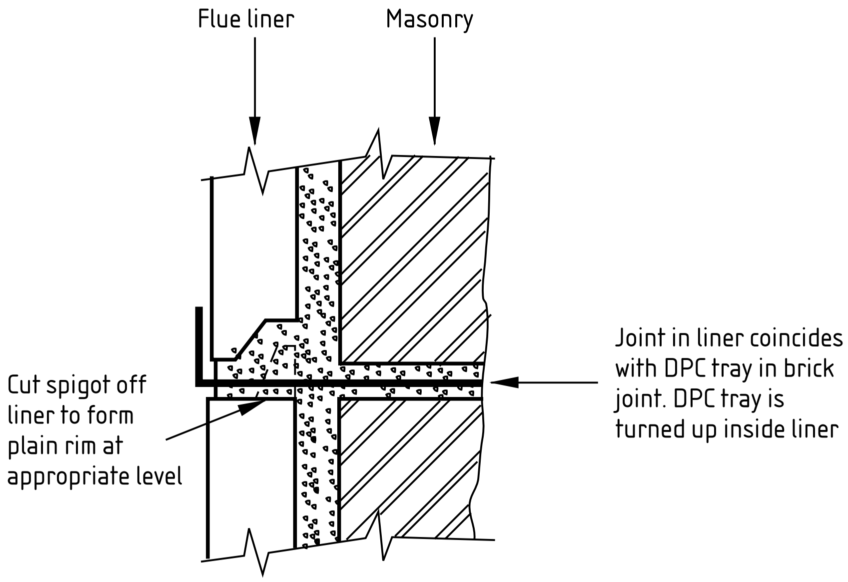


Figure A.8 — Typical joist hanger built into masonry

A.5.6.6 *Straps and metal ties*

Ensure all straps and metal ties are of the size and type specified. Fully bed in the mortar joint and fit tightly against the masonry face where specified.

It is essential that blocking be used between the joist or rafters and the parallel wall below all horizontal strapping positions

A.5.6.7 *Movement joints*

Form movement joints and build in the specified joint filler or provide a clear gap in the masonry of a size suitable for the installation of the filler.

When a filler is installed as the work proceeds locate the filler material vertically and firmly fix at the specified position. Where necessary leave a gap at the front and/or rear of the wall to allow for the installation of the sealant.

To form an open joint, locate a temporary spacer vertically and firmly fix in position. Keep the open joint clear of mortar and debris.

In all cases form a full bed to the face of the joint. Ensure the joint is vertical and of constant width. Bed joints each side of the movement joint should be at the same level.

COMMENTARY. *Any temporary spacer should be of a material which can easily be removed without damaging the face of the masonry.*

A.5.6.8 *Fixing frames*

A.5.6.8.1 *Forming openings for doors and windows*

Where doors or windows are not built-in as the work proceeds form the openings accurately in the walls by using templates. Correctly position frame fixings and securely fix to the walls.

A.5.6.8.2 *Building-in doors and windows as the work proceeds*

Fix door and window frames as the work proceeds and ensure the frames are square and positioned correctly in relation to the DPCs to prevent moisture bypassing the junction between the DPCs and the frames.

A.5.6.9 *Service entries*

At service entries allow a minimum gap of 20 mm around the service entry to allow sealing later, by following trades, in accordance with the specification.

Obtain instructions where service entries need to be sealed later, by following trades, against ingress of ground water.

A.5.6.10 *Chases and holes*

The number and position of chases and holes should be in accordance with the specification. Chases and holes for services should be cut neatly. Follow the recommendations below, but if they conflict with either the specification or with the size limits set by the masonry unit manufacturer then obtain the necessary instructions.

a) Do not cut chases in any block masonry that is less than 75 mm thick.

b) Maintain a minimum of 15 mm thickness between the bottom of the chase and the void for hollow units, unless otherwise recommended by the manufacturer.

c) Do not cut horizontal or raking chases in solid walls to a depth greater than one-sixth of the thickness of the leaf.

d) Do not cut vertical chases to a depth exceeding one-third the thickness of the single leaf in solid walls.

e) Offset chases on either side of a wall by a distance at least equal to the wall thickness. Ensure that chases back-to-back in line do not exceed the dimensional restrictions in b) and c).

f) Do not cut holes exceeding 300 mm wide in walls unless a suitable lintel has been specified.

COMMENTARY. *Mechanical rotary cutters should be used, particularly when it is necessary to avoid heavy impacts and vibration. Inappropriate chasing carried out not in accordance with the specification might adversely affect one or more of the functional requirements of the wall, e.g. its loadbearing capacity.*

A.5.7 ***Flues and linings***

A.5.7.1 *General*

Ensure that throat units, linings and terminals are built in accordance with the following recommendations.

a) Fill all joints with jointing and caulking materials in accordance with the manufacturer's sitework instructions.

b) Build socketed flue liners with the inner surface of the lining smooth at the joints and socket ends uppermost. If necessary, core the lining as work proceeds.

c) Fill the void between brick chimneys and clay or concrete flue liners with lightweight concrete or weak mortar.

d) Do not use cracked or broken liner sections. Form bends with purpose made fittings.

e) Extend DPC trays through the liner into the flue and turn upwards (see Figure A.8).

COMMENTARY. *The socket ends uppermost retain any condensation moisture within the flue.*

A.5.7.2 *Proprietary flue blocks*

Ensure proprietary flue blocks are coursed with the block masonry walls and build in accordance with the manufacturer's recommendations.

A.5.7.3 *Refractory brick flue linings*

Construct brick flue linings very carefully and ensure that:

a) only the special mortar mixed in accordance with the brick manufacturer's sitework instructions is used;

b) all joints, vertically and horizontally, are completely filled, finished flush with the face of the bricks, and kept to the thickness required by the manufacturer's sitework instructions;

c) the lining is bonded to the main brick masonry with refractory bricks in accordance with the manufacturer's sitework instructions.

COMMENTARY. *The quality of the workmanship is important as any flues contain large quantities of very hot gases.*

Annex B (informative) Determination of movement in masonry

B.1 General

This annex gives information on the various movements that can occur in masonry. It is extremely difficult, if not impossible, to predict with any degree of certainty the movement that will actually occur. This movement is a complex combination of movements caused by such factors as temperature and moisture variations (see **B.2**). Furthermore, each movement is controlled to some extent by the degree of restraint to which the masonry is subjected. To complicate matters further, the actual effect on movements of the same basic restraint can vary according to the general shape of the building and in many cases cannot be quantified.

The determination of movement is thus a complex problem which cannot be solved simply by adding or subtracting individual values for thermal movement, moisture movement, creep, deflection, etc. The various individual movements are treated separately in **B.4**, **B.5** and **B.6**.

Any estimation of movement has to rely to a great extent on engineering judgement, since many factors, such as the temperature and moisture content of the material at the time of construction, weather conditions and degree of restraint, are unpredictable.

B.2 Determination of total movement within a wall

B.2.1 *General*

To determine the movement that is likely to take place within an actual wall, the individual movements described in **B.4**, **B.5** and **B.6** should be considered in combination.

An estimate of the total movement may be made by summing all the potential free movements. However, thermal and moisture movements are not directly additive. For example, a wall which expands due to thermal or moisture action alone generally becomes cooler when wetted by rain. The exact effect of such a combination is in practice extremely difficult to determine. All that can be said is that the maximum thermal and moisture movements should not be added together to arrive at the total effective free movement.

B.2.2 *Total effective free movement for clay masonry*

For clay masonry where the ambient temperature remains reasonably constant, e.g. for internal walls, the long term or time dependent movement described in **B.5.2.2** predominates. Since this is an expansive movement, the masonry is unlikely to develop tensile cracks, except in short returns of less than 1 m in length. External masonry of clay masonry units will be subjected to the effects of thermal expansion superimposed on the long term movement.

B.2.3 *Total effective free movement for concrete and calcium silicate masonry*

Owing to the number of factors involved, it has not been found practicable to recommend coefficients for total effective free movement of concrete and calcium silicate masonry. However, where joints are provided in accordance with **5.4.2.3.5** and **5.4.2.3.6**, the total effective free movement will be small and detailed calculations are unnecessary.

B.3 Determination of spacing and widths of movement joints

There is no convenient mathematical expression for determining the position of movement joints in masonry. However, the basic principle is that the distance between joints should be such that the longitudinal strain induced in the wall is no greater than the strain capacity of the wall. Owing to the difficulty of computing joint spacings on this basis, recommended spacings based on practical experience have been given in **5.4**. It is essential that the maximum movement in the masonry should be no greater than the maximum recommended movement in the joint sealant.

The product of the length of the masonry and the effective strain in the wall should be less than the product of the width of the joint and the permitted strain in the sealant.

B.4 Thermal movement

The theoretical free movement due to thermal effects, which is reversible, is equal to the temperature range multiplied by the appropriate coefficient of linear thermal expansion and the length (see Figure B.1). However, the movement that actually occurs within a wall after construction depends not only on the range of temperature but also on the initial temperature of the masonry units when laid. This will vary according to the time of year and the exact conditions during the construction period and, in some cases, how soon after manufacture the masonry units are used, i.e. when they come straight from the kiln or curing chamber. Thus, in order to determine the potential free movement that could occur in a wall, some estimate of the initial temperature and the likely range of temperature should be made.

This potential free movement then needs to be modified, to allow for the effect of restraints.

Table B.1 indicates typical ranges for coefficients of linear thermal expansion. Some estimate of the actual value for the particular material being used should be made. In many instances, this information can be obtained from the manufacturers.

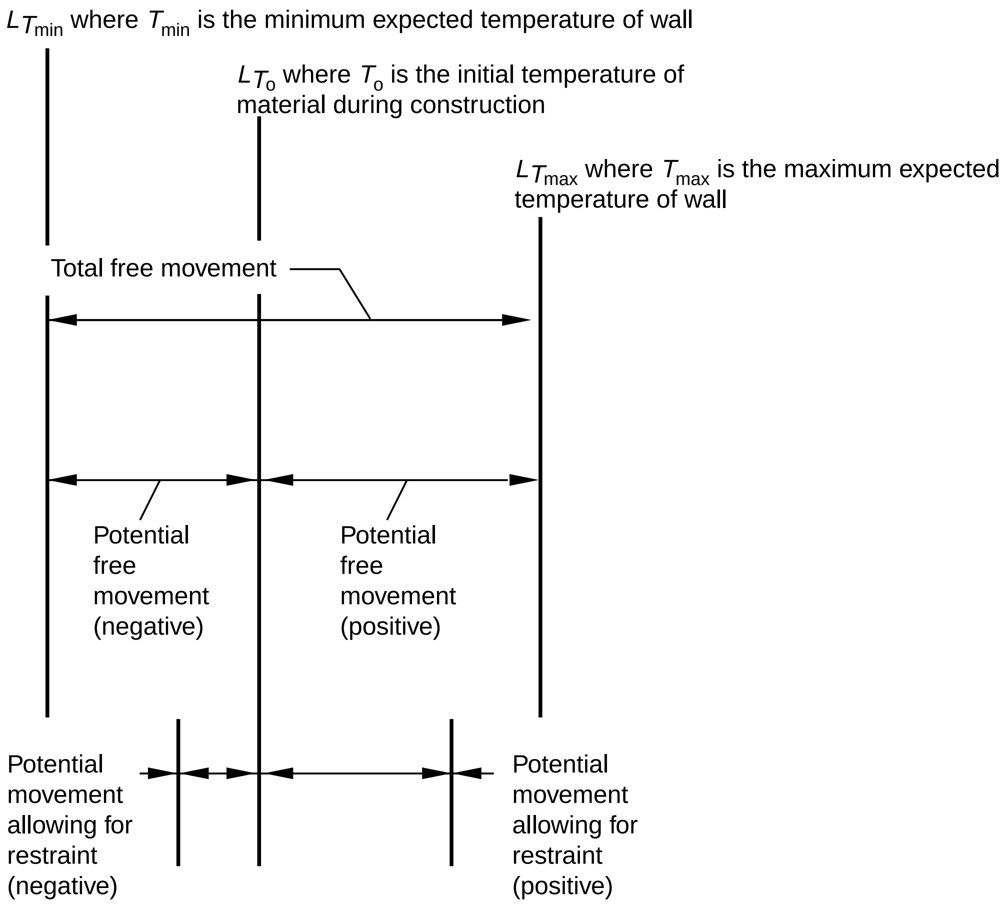


Figure B.1 — Thermal movement

Table B.1 — Coefficient of linear thermal expansion of masonry units and mortar

Material	Coefficient of linear thermal expansion 10^{-6} K^{-1}
Clay masonry units[a]	4 to 8
Concrete masonry units[b]	7 to 14
Calcium silicate masonry units	11 to 15
Mortars	11 to 13
Natural limestone masonry units[c]	3 to 10
Natural sandstone masonry units[c]	5 to 12
Natural granite masonry units[c]	5 to 10

[a] Thermal movement of clay masonry units depends on the type of clay.
[b] Thermal movement of concrete masonry units depends on the type of material and the mix proportions.
[c] Thermal movement of natural stone masonry units depends on the type of stone.

The longitudinal coefficient of linear thermal expansion of masonry may be taken to be the same as that of the constituent masonry units.

Expansion in the vertical direction may be determined by summing the values obtained by multiplying the dimensions of the masonry units and the mortar by the respective coefficients of linear thermal expansion. It should be borne in mind that the magnitude of movement in the horizontal and vertical directions will differ where:

— the coefficients for mortar and masonry units are not the same; and

— the height and length of the masonry units are unequal.

B.5 Moisture movement

B.5.1 *General*

The moisture movement of clay masonry units and calcium silicate or concrete masonry units differ in magnitude and in kind. They have therefore been dealt with separately in **B.5.2** and **B.5.3**.

B.5.2 *Clay masonry units*

B.5.2.1 *Wetting movement*

It has been shown that clay masonry units can exhibit small reversible dimensional changes due to changes in moisture content. The effective movement that occurs within a wall is similar to that of thermal movement, but controlled by the minimum, initial and maximum moisture content. The actual movement is modified by the effect of any restraints. The typical range of movement to be expected is generally less than 0.02 %, which is comparatively insignificant.

B.5.2.2 *Long term expansion*

Although it is found that the general wetting movement is extremely small in clay masonry units, there is an irreversible expansion which occurs as a result of adsorbing[5)] moisture from the atmosphere. This occurs in both internal and external walls but can take place slightly more quickly in the latter. The rate of expansion is at its greatest just after the masonry units have cooled and decreases thereafter. The amount of expansion depends on the type of clay and the degree of firing. The actual movement within a wall depends on the degree of restraint and the amount of creep that has taken place in the mortar.

B.5.3 *Concrete and calcium silicate masonry units*

The potential free movement that can occur in concrete and calcium silicate masonry units depends on the minimum, initial and maximum moisture contents (see Figure B.2). In Figure B.2 an additional range is shown which represents the limits for compliance for drying shrinkage in BS 187 and BS 6073-1. However, the drying shrinkage test described in BS 187 and BS 6073-1 determines the shrinkage of units between saturated and oven dry states, whereas in practice a wall is seldom totally saturated. Thus the free movement may be expected to be less than the movement encountered during a drying shrinkage test.

[5)] Adsorption is the term used to describe the bonding of water molecules to the surface of the masonry material. It should not be confused with absorption, which refers to the entry of water molecules into the pores of the masonry.

In considering Figure B.2, it can be seen that the potential free movement within a wall is related to the moisture content at the time of laying. Since concrete and calcium silicate masonry units have a general tendency to shrink as they dry out, it is clear that keeping these masonry units as dry as practicable before and during construction reduces any subsequent movement. Also, the expected movement can be less for walls built under cover than external walls, subject to the relative humidity.

The potential free movement may be modified by restraints. It should be noted that such restraints, particularly at the end of a wall, are likely to increase the tensile stresses in the wall.

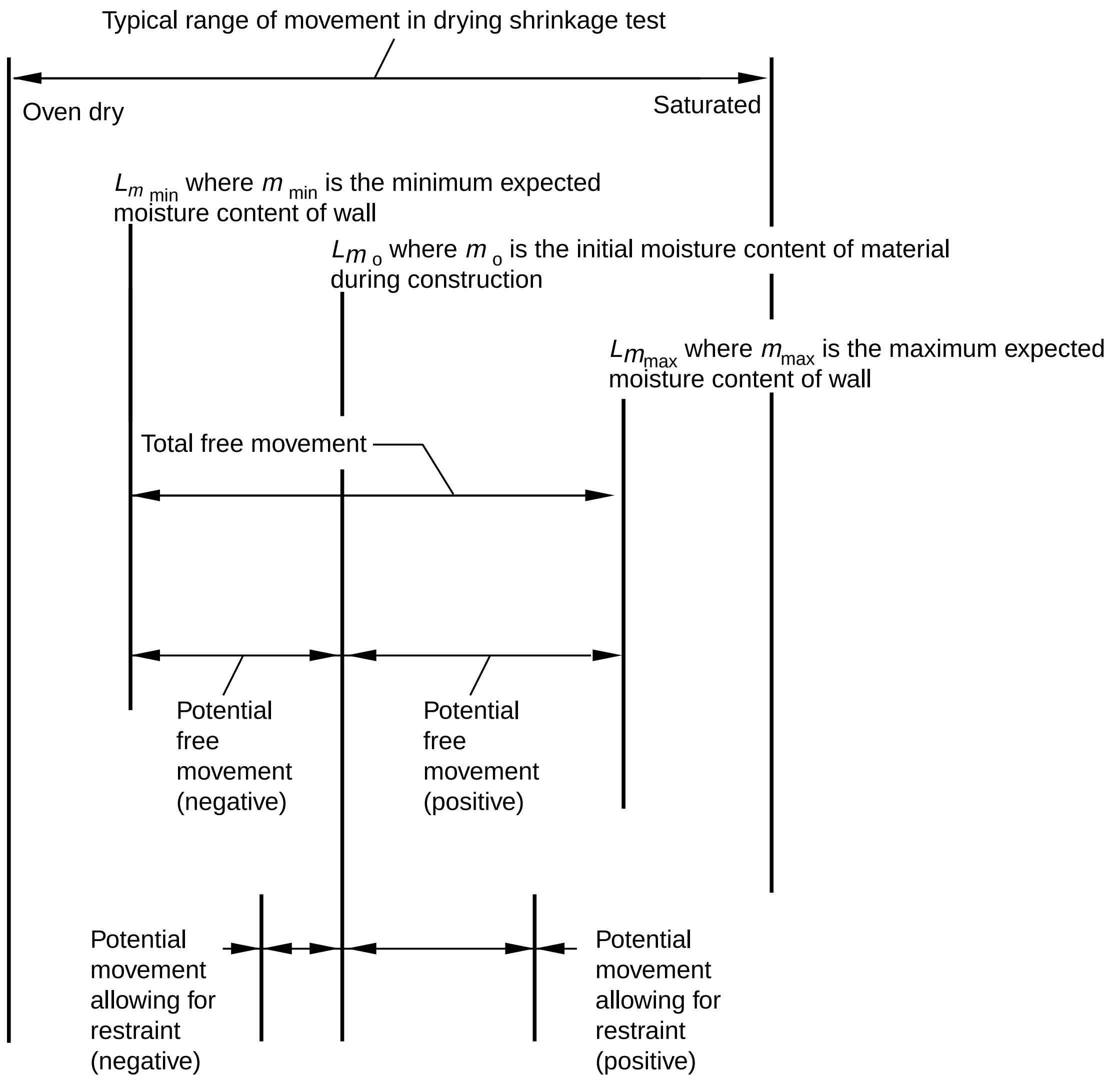


Figure B.2 — Moisture movement of concrete and calcium silicate masonry units

Table B.2 indicates the range of drying shrinkage for various masonry units. The higher figures are the limits specified in the appropriate British Standards for quality control purposes and should not be taken to represent the movement of units in a wall.

Table B.2 — Moisture movement of concrete and calcium silicate masonry units

Material	Shrinkage (as percentage of original dry length) %
Autoclaved aerated concrete masonry units	0.04 to 0.09
Aggregate concrete masonry units	0.02 to 0.06
Calcium silicate brick masonry units	0.01 to 0.04
NOTE These figures are obtained from tests carried out as described in BS 1881-5:1970.	

B.5.4 ***Natural stone masonry units***

Movement with changes in moisture content in natural stone masonry units depends on the type of stone. Some sandstone can exhibit noticeable movements with changes in moisture content, but limestones and igneous rocks only respond an insignificant amount.

Moisture movement can contribute to the opening of coping joints, and cracking at the ends of sandstone sills and lintels built into brick masonry. This has been known to occur in circumstances that suggest shrinkage of the component on drying may be the cause.

B.5.5 ***Mortar***

The free moisture movement of mortar is similar to that of aggregate concrete masonry units, although the potential free movement is likely to be greater, since initial moisture loss does not take place before construction (see Figure B.3). The effect of mortar on longitudinal movement may be neglected.

Typical shrinkage values for mortars are given in Table B.3. The actual values will depend on the constituents of the mortar, the proportions of the mix and the ambient relative humidity. For convenience, however, the lower values in the table may be taken to apply to mortars in external walls and the higher values to mortars in internal walls. The resulting movement of internal walls may generally be neglected, since they are unlikely to become wet after drying out initially.

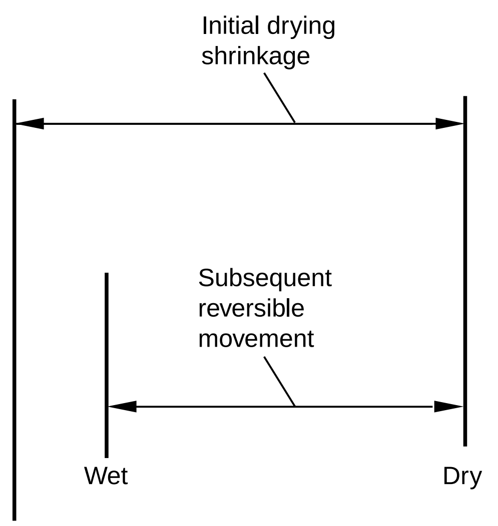


Figure B.3 — Moisture movement of mortars

Table B.3 — Shrinkage of mortars due to change in moisture content

Stage	Shrinkage %
Initial drying	0.04 to 0.10
Subsequent reversible movement	0.03 to 0.06

It should be noted that the values given in Table B.3 relate to unrestrained mortar. In practice, movement in a horizontal direction will largely be controlled by the surrounding masonry. However, for clay masonry, the effect of the mortar shrinkage can counteract the long term expansion described in **B.5.2.2**. Movement in the vertical direction will usually be unrestrained and will thus contribute to the total movement of the masonry in that direction.

B.6 Movement due to carbonation

An additional shrinkage of concrete masonry units and mortar can occur as a result of carbonation of the cement by atmospheric carbon dioxide. The extent of carbonation and the subsequent movement depends on the permeability of the concrete and on the ambient relative humidity. In dense masonry units and in autoclaved masonry units, the magnitude of this movement is extremely small and may be neglected. In unprotected open textured masonry units and mortar, the shrinkage due to carbonation can be between 20 % and 30 % of the initial free moisture movement.

Annex C (informative) Joint finishes

The principal types of joint finish used for brick and block masonry are shown in Figure C.1. They do not include the many varieties to be seen in historical examples of brick masonry.

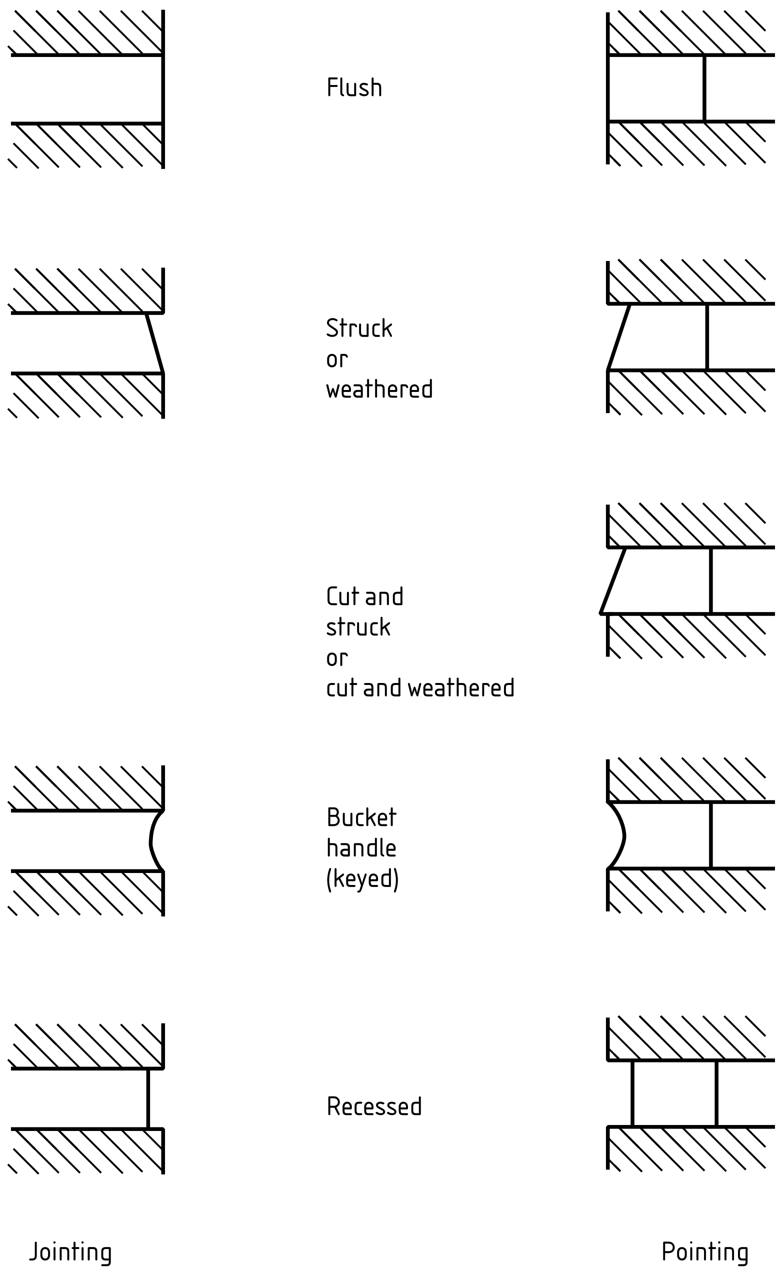


Figure C.1 — Joint finishes

Annex D (informative) Appearance of bricks, and of facing brick and block masonry

D.1 General guidance on the appearance of bricks

The appearance of bricks is always a matter of agreement between the specifier or user and the manufacturer or supplier. The requirement will vary according to the use to which the bricks are to be put, and the inherent characteristics of the bricks, e.g. common, facing, handmade, stock, need to be taken into account. As a guide, bricks need to be reasonably free from deep or extensive cracks and from damage to edges and corners, from pebbles and from expansive particles of lime.

D.2 Assessment of the visual acceptability of facing bricks

D.2.1 *Introduction*

This annex describes one way of assessing the acceptability of minor defects such as cracks, chips, surface blemishes or irregularity of shapes of facing bricks when delivered to site, which cannot be judged by examining individual bricks. Sample panels from the brick deliveries are compared with a previously constructed reference panel which is representative of what may reasonably be expected to be delivered and is large enough to encompass known and acceptable variations in bricks.

This method cannot cover possible future visual defects, e.g. due to lime bloom or frost attack. It may be used to assess consistency of supply in respect of colour and texture; however, the actual colour and texture has to be agreed between the supplier and the specifier.

When making an assessment, it is essential to recognize that different types of brick, e.g. handmade, stock, machine made, textured faced, smooth faced, etc. will have different acceptance criteria.

D.2.2 *Construction of the reference panel*

The reference panel needs to be erected on a level firm foundation in a dry location, having good natural daylight. It needs to be so sited that it can be retained for further inspection and reference and needs to be, therefore, protected from damage and the weather. If necessary, provision needs to be made for ensuring lateral stability.

The reference panel needs to be constructed to expose not less than 100 brick faces, selected as follows:

a) supplied by the manufacturer or supplier so that they are reasonably representative of the average quality of the whole order to be delivered; or

b) randomly sampled in accordance with BS 3921:1985, clause **9**.

It is essential to build the reference panel so that it reasonably represents the finished work and exposes for assessment those faces which will be visible in the finished work. In particular, bricks need to be laid in the bond selected for the finished work, using mortar of the same class and colour. If colour and textures are to be included in the assessment, the joints need to be tooled in the same manner as the finished work.

D.2.3 *Construction of the sample panels*

Sample panels representing individual batches need to be constructed in the same way as the reference panel (see **D.2.2**).

The 100 bricks used for each panel should be randomly sampled from the batch delivered to the site in accordance with BS 3921:1985, clause **9** prior to subsequent handling on site.

D.2.4 *Assessment*

Inspection needs to be carried out at any time prior to subsequent handling on site. When the sample panel is viewed at the same distance as the reference panel, without close scrutiny of individual bricks, the two panels should not differ significantly.

NOTE A viewing distance of 3 m is normally satisfactory for the purposes of this assessment. This distance may be varied by prior agreement between the supplier and the specifier.

There can be differences in the incidence of minor visual defects in any one batch when compared with the reference panel but the reference panel should be indicative of the average quality of the bricks.

D.3 Assessment of the visual acceptability of aggregate concrete block masonry

D.3.1 ***Introduction***

For close textured (paint grade), facing and architectural aggregate block masonry, a reference panel representative of blocks and mortar (when relevant) to agree texture, colour (when relevant), appearance and standards of workmanship should be constructed on site and approved by all parties as being the reference against which all quality assessments need to be based for the duration of the contract.

Reference panels need to be protected from the weather, dust, dirt and damage.

D.3.2 ***Assessment***

Consignments of blocks and mortar (when relevant) should be assessed for consistency with the reference panel.

The workmanship of built block masonry should be compared with the reference panel.

Annex E (informative)
Checklist for ordering clay and calcium silicate bricks

When enquiring about or ordering bricks, specifiers need to consider carefully which of the physical properties will be of significance in the finished brick masonry and specify only these. Specification of qualities which are not essential can restrict the choice of bricks offered. In using the following checklist specifiers need to pay particular attention to the referenced clauses in order to assess the significance of each property and the need to specify it.

a) Type of brick.

b) Durability requirements (see **5.6** and BS 3921:1985, clause **5**).

c) Requirements for structural use.

1) Compressive strength (see BS 3921:1985, clause **7**, BS 187, clause **9** and BS 5628-1 or -2).

2) Water absorption (see BS 3921:1985, clause **8** and BS 5628-1 or -2).

3) Category of manufacturing control (see BS 3921:1985, Appendix J, BS 187:1978 and BS 5628-1).

d) Any special requirements for tolerances (see BS 3921:1987, **0.3**).

e) Any additional requirements not covered by BS 3921 or BS 187, e.g. colour, texture, acid resistance.

f) Quantity, including type and number of special bricks.

g) Handling requirements, e.g. pallet-loading, strapping, mechanical off-loading.

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BS 6477, *Specification for water repellents for masonry surfaces*.

BS 6925, *Specification for mastic asphalt for building and civil engineering (limestone aggregate).*

BS 8104, *Code of practice for assessing exposure of walls to wind-driven rain*.

BS 8215, *Code of practice for design and installation of damp-proof courses in masonry construction*.

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