BDA DESIGN NOTE 7

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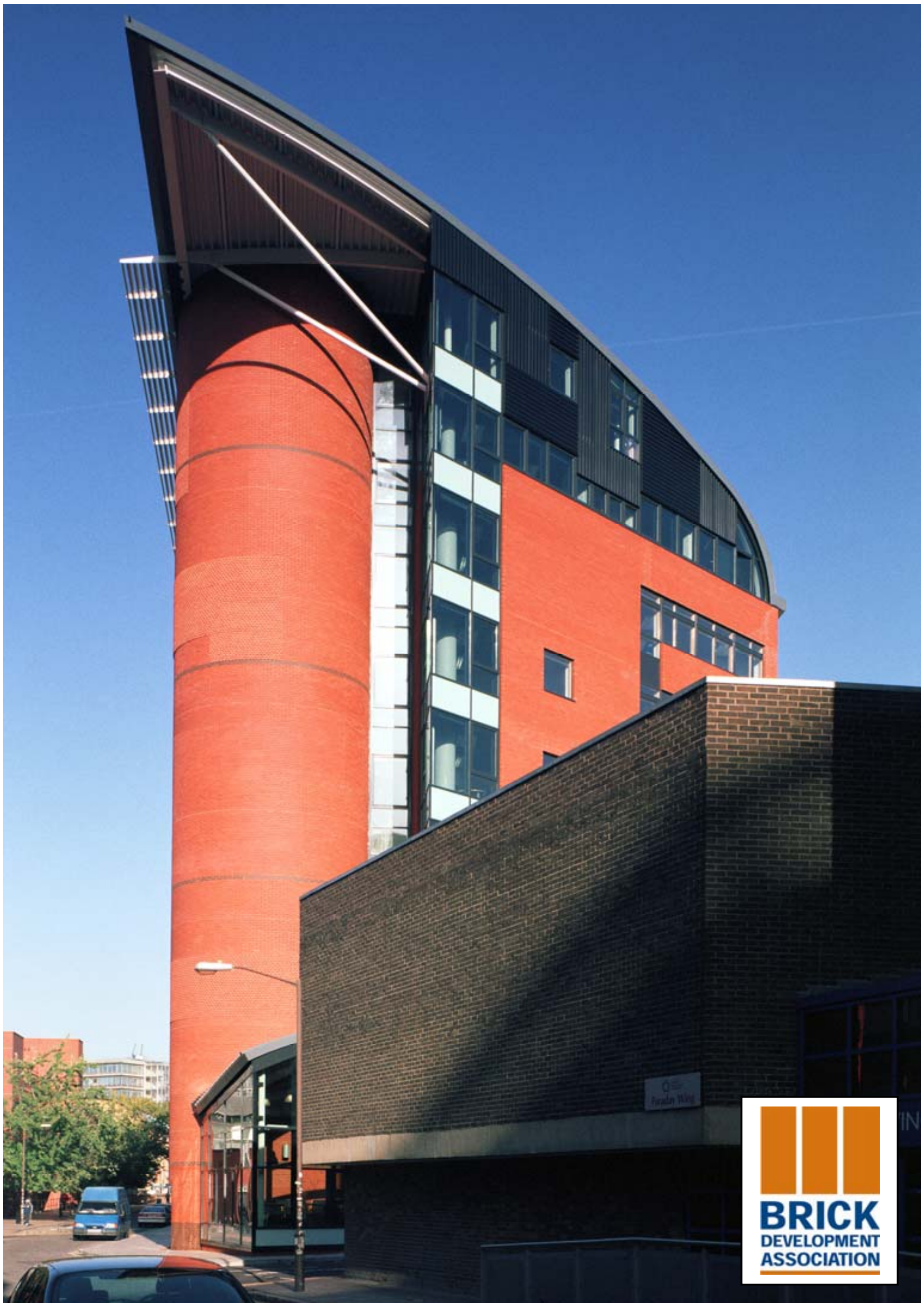
Brickwork durability



Brickwork durability

This edition of Design Note 7 replaces that issued in August 2006 and includes the recommendations of PD 6697.

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References:

1. PD 6697: 2010: **Published Document: Recommendations for the design of masonry structures to BS EN 1996-1-1 and BS EN 1996-2**
2. BS 4027:1996: **Specification for sulfate-resisting Portland cement**
3. BS 3921: 1985**: Clay bricks** (now superseded by BS EN 771-1)
4. BS EN 771-1:2003: **Specification for masonry units – Part 1: Clay masonry units.**
5. BRE Digest 250: **Concrete in sulfate-bearing soils and groundwater.**
6. BS 1200: 1976: **Building sands from natural sources.**
7. BS 4551: 1980: **Methods of testing mortars, screeds and plasters**
8. NA to BS EN 1996-1-1: **UK National Annex to Eurocode6: Design of masonry structures, Part 1-1: General rules for reinforced and unreinforced masonry structures**
9. BS EN 998-2:2003: **Specification for mortar for masonry, Part 2: Masonry mortar**
10. BDA Building Note No.1: **Bricks and brickwork on site**
11. BS 5642-1: 1978: **Specification for window sills of precast concrete, cast stone, clayware, slate and natural stone**
12. BS5642-2:1983: **Specification for coping of precast concrete, cast stone, clayware, slate and natural stone**
13. BS 4729:2005: **Clay and calcium silicate bricks of special shapes and sizes – recommendations**
14. BDA Design Guide: **Brickwork retaining walls**
15. BS 743:1970: **Materials for damp-proof courses**
16. BDA Design Guide: **Design of Free-standing Walls**
17. BS EN 12620:2002 + A1:2008: A**ggregates for concrete**
18. BS 8221-2:2000: **Code of practice for cleaning and surface repair of buildings, Part 2: Surface repair of natural stones, bricks and terracotta**

1. MODERN BRICKWORK AND TRADITIONAL DURABILITY

Buildings surviving throughout the world since Roman times and before, testify to the inherent durability of brickwork. In Britain, enduring 16th century brickwork is particularly significant for designers, builders and building owners.

Until recent years, most buildings were built from a limited range of local bricks, employing traditional well-tried methods and details. Today, modern manufacturing methods and a nationwide road and rail system make available everywhere bricks from the great variety of brickmaking raw material in which this country abounds. To achieve the inherent long-term durability of brickwork in modern buildings, account must be taken of the physical properties of the bricks and mortars, as well as the degree of exposure to which parts of the building will be subjected.

Knowledge and experience of local bricks and building methods is now supplemented by the wider collective experience which has been built up over the years within the brick industry, and forms the basis of the guidance offered in this Design Note.

Saturation by water is the commonest potential enemy of brickwork, but recognition of this by appropriate design, specification and workmanship will ensure that modern brickwork will remain effectively maintenance free.

2. CAUSES & PREVENTION OF DETERIORATION

Saturation – the main cause

Saturated brickwork may deteriorate for two reasons. Firstly, both bricks and mortar may be susceptible to damage by freezing when saturated. Secondly, if brickwork remains saturated for long periods, sulfate attack may disrupt the joints unless a suitable mortar is used.

Protection from saturation by design

Brickwork is unlikely to become saturated where projecting features shed run-off water clear of the walling below. Roof overhangs or copings, projecting and throated sills at openings, bellmouths to renderings and similar features at the bottom of tile hanging and other claddings may provide such protection to wall heads. Protection is also afforded to brickwork by damp-proof courses, flashings and weatherings, as discussed in PD 6697 [1].

Exposed conditions

The frequency and extent of saturation of brickwork also depends on the degree of exposure to the weather. In areas of high exposure to driving rain, it is particularly important to give consideration to architectural features that minimise saturation and to note that elements and details in the same building may be subjected to different degrees of exposure.

Ground conditions

The presence of sulfates in soils and ground-waters can significantly affect the durability of brickwork below ground-level dpcs unless care is taken in specification.

Vulnerable details & locations

If, for functional or aesthetic reasons, protective features are omitted, particular attention should be paid to the choice of bricks and mortar.

The following are locations where brickwork is likely to remain saturated for long periods:

- Near ground level below dpc and in foundations.
- In free-standing walls, retaining walls, parapets and chimney stacks.
- In cappings, copings, sills, and chimney terminals.

Improper use of reclaimed/recycled bricks

Although use of reclaimed/recycled bricks is excellent from a sustainability point of view it is possible for non frost resistant bricks, originally used for internal brickwork, to end up being used externally. Therefore it is recommended that reclaimed/recycled bricks be used with caution.

For detailed comment on the use of recycled bricks see BDA publication *"Some Observations On The Use Of Second-hand Clay Bricks"*, which can be downloaded free from the BDA website - www.brick.org.uk .

Workmanship

The quality of workmanship, both in the preparation of the mortar as well as in bricklaying, is a vital factor in achieving the long-term durability of brickwork.

3. FROST ACTION

The mechanism

The destructive effect of frost is due to the 9% increase in volume that occurs when water at 0^oC is converted into ice at the same temperature. When bricks and mortar are saturated and frozen, expansion within the pore spaces may set up stresses that cannot be withstood. With some bricks and mortars, accessible space within the pore structure, in which expansion can take place, greatly reduces the risk of frost damage.

It is not necessarily the coldest or wettest winters that lead to frost failure, but rather recurring freeze/thaw cycles of saturated brickwork. When failure occurs, brick surfaces may flake or spall, while the mortar joints may crumble.

A manufacture must declare the frost resistant designation of its bricks and may do so based on extensive experience of their use in buildings.

TS 772-22 *'Methods of test for masonry units - Part 22: Determination of freeze/thaw resistance of clay masonry units'*, is the only test method of assessment of freeze/thaw resistance of clay bricks.

Winter construction

Brickwork is particularly at risk during winter construction. As night frosts are common, even in mild winters, it is important that bricks stored on site, as well as uncompleted and new brickwork, are adequately protected from both saturation and frost. Even correctly proportioned mortar may be damaged by frost before it has fully hardened.

4. SULFATE ATTACK

Uncommon and slow to develop

Examples of serious deterioration of brickwork, due to sulfate attack, such as crumbling and erosion of the mortar joint or, in severe cases, expansion, bowing and disruption of the brickwork itself, are relatively uncommon because a number of conditions have to exist simultaneously for sulfate attack to occur. Where conditions for sulfate attack are present, it may take several years before it becomes apparent.

Cracking of the bed joint mortar is characteristic of sulfate attack.

The mechanism

Sulfate attack on brickwork mortars is principally caused by the reaction between sulfate in solution and the tricalcium aluminate (C_3A) constituent of Portland cement, which forms calcium sulfoaluminate (ettringite). This reaction only occurs if there is an appreciable C_3A content, found in ordinary Portland cement. The risk is greatly reduced by the use of sulfate-resisting Portland cement to BS 4027[2] where the C_3A content is limited to a maximum of 3.5%.

Sulfate attack occurs only if there is a considerable amount of water movement through the brickwork. Diffusion alone will not carry sufficient amounts of sulfate to the hydrated cement in the mortar. Water movement may occur by percolation of water through the brickwork under the action of gravity, such as in free-standing walls, or below brick sills where effective dpcs have not been provided. Movement of water may also be brought about by evaporation and capillary action, for example through retaining walls that are not waterproofed on the retaining face, or in external walls between ground level and the dpc.

Sulfates from bricks

Experience shows that the use of Category S2 clay bricks[4] reduces the risk of sulfate attack on the mortar.

Sulfates from other sources

Sulfates may be derived from ground-waters, from the soil, or from make-up fill adjacent to the brickwork. Where soil or ground-water sulfate levels are appreciable (Class 3 or higher), the use of strong mortar mixes containing sulfate-resisting Portland cement should be considered.

Dense mortars

Sulfate attack can only occur when sulfate solutions can readily penetrate the mortar itself. Strong dense mortars are relatively resistant to sulfate attack, despite their higher C_3A content per unit volume. The permeability of the mortar is also affected by the grading and clay content of the sand (see page 6).

Vulnerable situations

Parapets and free-standing walls without effective copings and dpcs, and other exposed brickwork, may remain wet long enough for sulfate attack to occur if the other conditions are present.

If dense rendering on brickwork becomes cracked, rainwater may penetrate it. Drying-out will be restricted by the render and the brickwork may remain wet long enough for severe sulfate attack and expansion to occur in the mortar joints. In all such cases, protective detailing and good specification and workmanship will minimise saturation. Additionally, the use of sulfate-resisting Portland cement should be considered for the jointing mortar and the base coat of the render, particularly if category S0 clay bricks are to be used.

5 EXCLUSION OF WATER FROM BRICKWORK

The term, exclusion of water, is generally thought of in the context of preventing rain or ground water entering the interior of the building.

The foregoing establishes that it is equally important to minimise the amount of water entering the brickwork itself. Where this is not done, for functional or aesthetic reasons, particular care must be taken with the choice of materials and details.

Methods for the exclusion of water are dealt with in detail in PD 6697[1]. The following factors are of particular importance, as far as the durability of materials is concerned.

Copings & cappings: Definitions

Copings provided at the top of chimney stacks, parapet walls, free-standing walls and retaining walls will minimise the risk of saturation of the brickwork. For the purpose of this document a coping is defined as a unit or assemblage which sheds rainwater falling on it clear of all exposed faces of the walling it is designed to protect. A capping, on the other hand, whether flush or projecting, does not incorporate a throating or similar device designed to shed water clear of the walling below. In the case of a coping, PD 6697[1] recommends that the drip edge of the throating should be at least 40mm from the face of the wall.

Clayware coping units with a suitable drip are functionally efficient and aesthetically pleasing.

An attractive wall with an effective coping

Flush cappings do not protect bricks below from saturation. Cappings and bricks must, therefore, be frost resistant.

A continuous sheet dpc should be provided beneath jointed copings and cappings, in order to prevent downwards percolation of water into the wall should the joints fail. The dpc will normally be positioned immediately underneath a copying. With a capping, in order to obtain greater mass above the dpc, it may be positioned one or more courses lower down. The risk of a coping or capping being displaced will be minimised by the use of a dpc designed to give a good bond with the mortar. Dpc may be omitted if coping is jointless.

Ground-level damp-proof courses

Dpcs are required near the base of walls to prevent rising damp. In the case of buildings, the dpc will normally be a flexible material, although slate or brick dpcs can be used.

Brick dpcs are used extensively in free-standing and retaining walls where the dpc is required to resist tension and shear. Although it is unlikely that such walls will become saturated by rising damp, the dpc does form a barrier against soluble salts from the ground and ground-waters.

Damp-proof course clay bricks are classified as DPC1 and DPC2 bricks having maximum water absorption values of 4.5% and 7.0% by mass respectively. DPC1 bricks are recommended for use in buildings, while all DPC bricks are acceptable for use in external works. They should be laid as a minimum of two bonded courses and jointed in mortar strength class M12/designation (i).

Retaining walls

Waterproofing treatments are advisable on the soil-retaining surfaces of planters and other forms of retaining wall.

Surface treatments

Clear waterproofing treatments are not usually necessary or desirable on facing brickwork. In some circumstances, e.g. where water can enter the brickwork behind the treated surface, their use can result in deterioration since drying-out of the wall will be retarded.

6 CLAY BRICKS

BS EN 771-1[4] defines clay masonry units as LD and HD units. LD units have a low gross dry density, less than or equal to 1000 kg/m^3, and are for use in protected masonry, e.g. internally or protected by impervious cladding. HD units have a high gross dry density, greater than 1000 kg/m^3, and are for use in protected as well as unprotected masonry. Furthermore the standard defines Category I masonry units as those with a probability of failure to reach their declared compressive strength not exceeding 5%. Category II units are not intended to comply with the level of confidence of Category I units.

Frost resistance

Many clay bricks are totally resistant to frost attack, while others may suffer if repeatedly frozen whilst saturated. Their resistance to frost attack cannot be reliably assessed from any of the other physical properties of the brick. Neither compressive strength nor water absorption, as was once assumed, can be taken as satisfactory indicators of frost resistance. In general there is no substitute for practical experience of the performance of a particular brick in service over a period of some years. BS EN 771-1 classifies the units into three frost resistance categories F0, F1, F2, corresponding to O, M and F in BS 3921[3], and they are defined as follows:

F2 Severe exposure

Bricks durable even when used in situations where they will be saturated and subject to repeated freezing and thawing – equivalent to the level of frost resistance achieved by the previous “frost resistant bricks” (F) in BS 3921[3].

F1 Moderate exposure

Bricks durable except in situations where they are in a saturated condition and subject to repeated freezing and thawing – equivalent to the previous frost resistant level of “moderately frost resistant bricks” (M) in BS 3921. Bricks of this category are deemed to be less durable than those of category F2, but are normally durable in the external face of a building. This pre-supposes that in such walling appropriate measures to prevent saturation have been undertaken, e.g. by provision of projecting eaves, copings and sills.

F0 Passive exposure

Bricks liable to be damaged by freezing and thawing – equivalent to the previous “not frost resistant bricks” (O) in BS 3921. Such bricks are only suitable for internal use or behind impervious cladding. During the winter they require protection from weather when stored on site or in unfinished construction..

Soluble salts

There are three categories of soluble salt content distinguished in BS EN 771-1[4].

Category S0 bricks are not subject to any limits on specified soluble radicals and are intended for use in situations where total protection against water penetration is provided.

Category S1 bricks have limits on soluble salts e.g. sodium, potassium and magnesium contents.

Category S2 bricks have lower limits than Category S1 bricks.

BS 3921 limited soluble salt contents to Normal (N) and Low (L).

Durability designations

Table NA.5 of BS EN 771-1[4] gives ‘BS3921 equivalent’ designations for all the possible combinations of categories of frost resistance and soluble salt content. PD 6697[1] prescribes the durability categories recommended in finished constructions.

Frost resistant category F1 clay bricks are suitable in the external walls of buildings where protected from saturation. If the protection is omitted, saturation and frost damage may result. (Photo Alan Blanc FRIBA)

7. MORTARS

Type and designation

Modern mortars made from suitable materials can be designed and mixed to provide a level of durability to match the bricks. The types and designations of mortars specified in Table NA.2[8] are given in Table 1. The type of mortar and designation selected for a particular element of brickwork depend upon many considerations, of which durability is but one.

Whichever type of mortar, in terms of its constituent materials, is chosen, its durability will be enhanced as the cement content is increased. In general, designation (iii), M4 mortars are likely to offer the best overall balance of properties for external walling in the UK. However, it should be noted that in conditions of severe exposure, either geographically or in the building itself, designation (ii), M6 or even (i), M12 mortars may be advisable with clay brickwork.

Semi-finished factory made and pre-batched mortars should conform to the requirements of BS EN 998-2[9]

Where pre-mixed lime-sand mortars are used, the specified addition of cement on site should be gauged.

Accuracy of batching

Because the cement content of mortar is very important, accuracy in the proportioning of mortar mixes is essential. It is recommended that use is made of a gauge box or bucket, carefully filled without compaction and struck off level.

It should be noted that damp sand is cohesive and will normally stand up on the shovel. On the other hand, cement, being a free-flowing dry powder, will occupy a considerably smaller volume on the shovel.

When the batching of mortar mixes is based on shovelfuls, the resultant mix is often considerably leaner than intended, resulting in subsequent deterioration and the need for repointing or even rebuilding.

Importance of the materials
It is also important to ensure that the raw materials used in the preparation of the mortar are satisfactory. Normally, the raw materials should comply with the relevant British Standards. It should be remembered that Portland cement may deteriorate on prolonged exposure to the atmosphere, and therefore relatively fresh material should be used.

Excessive clay mineral content in the sand may interfere with the development of strength in the mortar. Sands with fine and relatively single-sized particle size grading may produce rather porous and permeable mortars. In either case, durability will be impaired. Sand should comply with BS 1200[6] in order to avoid such difficulties. Where the brickwork is severely exposed, it may be advisable to select a sand with a grading of that specified for Type S sands in BS 1200[6] or even for grade M sands in BS 882[17].

In some areas, sands fully complying with BS 1200 in all respects may be difficult to obtain – in which case it is essential to ascertain local experience of the way alternative sands perform in use. Where unfamiliar sands are to be specified for the first time, or where there may be some doubt as to the suitability of a sand from the viewpoint of mortar durability, it is recommended that trial mixes be prepared and mortar cube strength tests carried out, using the methods specified in BS 4551[7].

If the 28 day compressive strengths obtained meet the generally accepted minimum values quoted in various specifications satisfactory long term durability may reasonably be presumed.

Frost action
Mortars at an early age are particularly vulnerable to frost damage. The use of air-entraining agents generally improves, to a limited extent, the frost resistance of mortars in newly erected brickwork, although it is important that such admixtures are used strictly in accordance with the manufacturers' instructions regarding dosage and mixing time.

However, even when air-entraining agents are used, it is still necessary to provide frost protection in winter because the mortar may still become frozen.

'Anti-freeze' admixtures
There appear to be no satisfactory admixtures available for use in mortars that will act as anti-freeze agents in the commonly accepted sense. Admixtures intended to provide protection by increasing the rate of liberation of the heat of hydration from the setting of the cement in the mortar are ineffective because of the small mass of cement in a given volume of masonry relative to the thermal capacity of that masonry.

Although, under threatened frost conditions, there would, in principle, be some advantage in accelerating the setting of the mortar, in practice no suitable admixtures are known that do not have other undesirable effects. In particular, calcium chloride, or admixtures based on this salt, may lead to subsequent dampness of the wall or corrosion of embedded metals, including wall ties, and should not, therefore, be used

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 the cement.

Bricks in a stack protected from saturation. They should preferably be stacked on boards or pallets and protected from splashes by vehicles.

The protection of new brickwork and materials minimises damage due to saturation.

Mortar joints
Bucket-handle or struck and weathered joints contribute to brickwork durability, as the tooling of the joints reduces the permeability of the mortar surface and improves the seal between the bricks and the mortar, thereby enhancing the wall's resistance to rain penetration.

Recessed joint profiles in external brickwork will increase the level of saturation along the upper arrises of the bricks, with a consequent risk of frost damage. Such joints should only be used with frost resistant clay bricks, and the depth of the recess should take into account the proximity to the exposed face of the brickwork of perforations in the brick.

8 SITE PRACTICE

Protecting materials

To ensure durability of the brickwork, it is essential to prevent the materials and work-in-progress from becoming saturated during construction. Bricks should be stored on a prepared hardstanding and covered with well secured polythene sheeting or tarpaulins. Cement and lime should be stored off the ground and under cover. Sand and ready-mixed lime:sand stockpiles should be placed on an impermeable base and be protected from excessive wetting or drying out, preferably by the use of polythene or similar sheeting.

Protecting new brickwork

Newly erected brickwork should be protected by covering the wall heads at the end of the working day, or during other breaks in construction, when rain is likely. Even the use of scaffold boards or flexible dpc material simply held on the wall head may provide substantial protection. Inner scaffold boards should be turned up to prevent splashing, and covers should be propped away from the brickwork so that rain is shed clear, but allowing air circulation to occur to assist drying out. When frost is likely, additional sheeting should be used to cover all freshly erected work, and dry hessian or similar insulating material placed beneath the waterproof top covering. More detailed advice on site practice is available in 'Bricks & Brickwork on Site'[10]

Mortar preparation & bricklaying

Accuracy in proportioning mortar mixes is important, and good supervision is necessary to ensure that mortars are not under-gauged with cement. The quality of workmanship in bricklaying may influence the life of the masonry. All joints should be properly formed. Although bed joints are usually adequately filled, the common practice of 'topping and tailing' headers is to be deprecated, as it can lead to insufficiently filled perpendicular joints and an increased risk of water penetration, saturation, and deterioration of the brickwork and compromising sound insulation. All joints should be finished by tooling, when so specified, in order to improve the weather resistance of the joint.

Factory finished retarded mortars and silo mortars should be used strictly in accordance with the supplier's/ manufacturer's instructions.

9 SELECTION OF BRICKS & MORTARS FOR DURABILITY

At the design stage, the weather conditions at the time of construction will rarely be known, and indeed, building may continue through more than one winter period. The guidance notes, therefore, relate to cold weather working when night frost is expected, unless otherwise indicated. Even so, it is essential that bricks and brickwork under construction are fully protected from saturation and freezing.

Table 1 – Mortar Mixes

	BS5628 Mortar Designation	BS EN 998-2 Comp. Strength Class[a]	Prescribed mortars (proportions of materials by volume) (see notes)				Compressive strength at 28 days
			Cement[b]:lime:sand with or without air entrainment	Cement[b]:sand with or without air entrainment	masonry cement[c]:sand	masonry cement[d]:sand	N/mm^2
Increasing ability to accommodate movements due to temperature and moisture change ↓	(i)	M12	1:0 to 1/4: :3	1:3	Not suitable	Not suitable	12
	(ii)	M6	1: ½ :4 to 4 ½	1:3 to 4	1:2 ½ to 3 ½	1:3	6
	(iii)	M4	1:1:5 to 6	1:5 to 6	1:4 to 5	1:3 ½ to 4	4
	(iv)	M2	1:2:8 to 9	1:7 to 8	1:5 ½ to 6 ½	1:4 ½	2

[a] The number after the letter M is the compressive strength for the class at 28 days in N/mm^2
[b] Cement or combinations of cements in accordance with Clause NA.2.3.2[8], except masonry cements
[c] Masonry cement in accordance with NA.2.3.2[8] (inorganic filler other than lime)
[d] Masonry cement in accordance with Clause NA.2.3.2[8] (lime)

NOTES:

1. Propotioning by mass will provide a more consistent mortar than proportioning by volume.
2. The range of sand volumes noted for mixes in this table is to allow for effects of differences in grading on the properties of the mortar. The lower figure should be used with sands containing a higher proportion of fines.
3. Strength class M12, M6 and M4 mortars are not generally considered suitable for the repair and maintenance of old masonry jointed with traditional lime mortars.
4. BS 8221[18] contains recommendations for other mortar mixes that are more suitable for the repair of masonry of historic buildings.
5. The different types of mortar that comprise any one designation are approximately equivalent in compressive strength and do not generally differ greatly in their other properties.

Work below or within 150mm above ground level

Brickwork near external ground level is vulnerable to frost action and sulfate attack, particularly one course (75mm) below and two courses (150mm) above ground level. In this area, brickwork will become wet and remain so for long periods. The degree of saturation will mainly depend on the climatic exposure of the building, the nature of the soil, and site drainage. Care should be taken to ensure that paved surrounds are held back from face of bricks in order to avoid splash back and channelling water into brickwork.

	Suitable Categories of bricks	**Suitable Mortar Strength Class [1] /designation**
Low risk of saturation -well drained site	F1/F2, S1/S2	M12 (i), M6 (ii), M4[2] (iii)
High risk of saturation -poorly drained site: -without freezing[3]	F1/F2, S1[4]/S2	M12 (i), M6 (ii)
High risk of saturation -poorly drained site: with freezing	F2, S1[4]/S2	M12 (i), M6 (ii)

Notes:

1 If sulfate conditions exist, the use of sulfate-resisting Portland cement is recommended.
2 Strict supervision of batching is particularly important to ensure that the requisite amount of cement is incorporated in mortar strength class M4.
3 Where brickwork is (at least 150mm) below finished external ground level, most category F1 clay bricks will be suitable, although the manufacturers' recommendations should be sought.
4 Where S1 units are used in class M6 mortar sulfate resisting Portland cement should be used in the mortar.

If there is a break in the construction programme during the winter period, unfinished masonry may be exposed to saturation and freezing for a considerable period of time. Even on well-drained sites, saturation can occur if, for example, water is allowed to run off concrete slabs on to unprotected brickwork. Footings are particularly difficult to protect. Adequate protection is difficult but essential.

On sloping sites where there is more than 150mm of masonry exposed between dpc and finished external ground level, the inner leaf may be earth-retaining. Considerable quantities of water may be transferred from the retained earth into the walling, thus increasing the risk of frost and sulfate attack, efflorescence, lime leaching and staining of the outer leaf. The application of a waterproofing treatment and provision of drainage should obviate such problems.

Clay brick damp-proof courses

Certain low water absorption clay bricks with good frost resistance properties may be used for the construction of damp-proof courses. Such dpcs can resist rising damp, although they will not resist water percolating downwards. They are particularly appropriate in positions where the dpc is required to transmit flexural tension, e.g., free-standing and retaining walls.

Guidance on the laying of brick damp-proof courses is given in BS 743[15]. Two categories of damp-proof course bricks for use in buildings and external works are now specified in BS EN 771-1[4]. The manufacturer declares a water absorption and the National Annex to BS EN 771-1[4] relates the numbers to traditional applications.

	Suitable Categories of bricks[1]	Maximum water Absorption % by mass[2]	Suitable Mortar Strength Class[3] /designation
Damp-proof courses In buildings	DPC1	4.5	M12 (i)
Damp-proof courses In external works	DPC1 DPC2	4.5 7.0	M12 (i) M12 (i)

Notes:
1 See BS EN 771-1[4]:2003, Table NA.6.
2 5-hour boil method.
3 If sulfate conditions exist, the use of sulfate-resisting Portland cement is recommended.

Unrendered external walls of buildings more than 150 mm above ground level (other than parapet walls & chimney stacks, and excluding brickwork sills, copings and cappings).

The risk of saturation of walls will be greatly reduced by roof overhangs and by other projecting features that incorporate a drip groove. However, these details may not give adequate protection from saturation in some exposed buildings where there are exceptional driving rain conditions.

The omission of protective features may consequently increase the risk of frost damage.

Examples of detailing that affords little protection to the brickwork in the wall include:

- Window sills that have no drip or throating. The greater the height of window above the sill, the greater will be the volume of water run-off to saturate the brickwork.
- Large areas of impermeable cladding with no effective detail at the base to shed water run-off clear of the walling below.
- Vertical tile-hanging, the lower edge of which finishes virtually flush with the walling below.
- Inadequate or non-existent roof overhang at gables.

	Suitable Categories of bricks	Suitable Mortar Strength Class /designation
Low risk of saturation Walling well protected by roof overhangs, sills and cladding designed to shed water clear of brickwork	F1/F2, S1/S2	M12 (i), M6 (ii), M4 (iii)
High risk of saturation. Brickwork inadequately protected and saturated by water run-off.	F2, S1 F2, S2	M12 (i), M6 (ii)[1] M12 (i), M6 (ii)

Notes:
1 The use of sulfate-resisting Portland cement is recommended with mortar strength class M6

Rendered external walls of buildings (other than parapet walls & chimney stacks, and excluding brickwork sills, copings and cappings)

	Suitable Categories of bricks	Suitable Mortar Strength Class /designation
All exposures	F1/F2,S1 F1/F2,S2	(M12 (i),M6 (ii),M4 (iii))[1] M12 (i),M6 (ii),M4 (iii)

Notes:
1 It is recommended that sulfate resisting Portland cement is used in the mortar, and in areas of severe exposure in the render undercoat as well.

Internal walls (including the inner leaf of cavity walls)

Suitable Categories of bricks[1]	Suitable Mortar Class [2] /designation
F1/F2, S0/S1/S2	M12 (i), M6(ii), M4 (iii)

Notes:

1 Where there is no possibility of the units or brickwork becoming saturated and frozen during site storage or construction, F0,S0/S1/S2 will be adequate. *2 Where it is known that there will be no risk of frost damage during construction, mortar strength class M2 may be used.*	

Unrendered parapets (excluding the coping or capping)

Irrespective of the climatic exposure of the building as a whole, the brickwork in parapets is likely to be severely exposed, particularly if the parapet has no coping.

There has been an increasing tendency in recent years to use flush cappings at the head of brickwork parapet walling, in the form of brick-on-edge, brick-on-end, bonded brickwork or a purpose-made capping unit. Such cappings give relatively little protection to the brickwork beneath, which may become saturated for several courses below the capping level.

Serious consideration should be given to the protection of parapets by adequate copings and dpcs. If, for aesthetic or other reasons, this is unacceptable, the choice of bricks and mortar for the parapet becomes critical and may, of course, govern the choice for the whole building.

	Suitable Qualities of bricks	**Suitable Mortar Strength Class /designation**
Effective coping used	F1/F2, S1/S2	M12 (i), M6 (ii), M4 (iii)
. Flush capping used	F2, S1 F2, S2	(M12 (i), M6 (ii))[1] M12 (i), M6 (ii)

Notes:
1 The use of sulfate-resisting Portland cement is recommended.

Rendered parapets[1]

	Suitable Categories of bricks	**Suitable Mortar Strength Class /designation**
All exposures	F1/F2,S1 F1/F2,S2	(M12 (i),M6 (ii))[2] M12 (i),M6 (ii)

Notes:
1 Parapet walls should be rendered on one face only, and coped (see Section 5, page 4). It is recommended that the rendering undercoat should contain sulfate-resisting Portland cement, and it is preferable if keyed bricks are used.
2It is recommended that sulfate-resisting Portland cement is used.

Unrendered chimneys (excluding capping or terminal)

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 the building, especially when an effective coping has not been provided at the terminal.

Cappings of brickwork and tile creasing, even though flaunched with mortar, cannot be relied upon to keep out moisture indefinitely and require an effective dpc beneath them. Where possible, a precast concrete coping in one piece, with a weathered top, ample overhang and properly throated, is preferred.

	Suitable Qualities of bricks	**Suitable Mortar Strength Class [1] /designation**
Effective coping used	F1/F2, S1/S2	M12 (i), M6 (ii), M4 (iii)
. Flush capping used	F2, S1/S2	M12 (i), M6 (ii)

Notes:
1 Owing to the possibility of sulfate attack from flue gases, the use of sulfate-resisting Portland cement should be considered..

Rendered chimneys (excluding the capping or terminal)

Some authorities advise against the practice of rendering chimneys. Where rendering is to be undertaken, it is essential to minimise the risk of water entering the brickwork of the chimney and, therefore, such chimneys should always have a coping. (see Section 5).

	Suitable Categories of bricks	**Suitable Mortar Strength Class [1] /designation**
	F1/F2 ,S1 F1/F2,S2	M12 (i), M6 (ii), M12 (i), M6 (ii), M4 (iii)

Notes:
1 Owing to the possibility of sulfate attack from flue gases, as well as the high degree of exposure, the use of sulfate-resisting Portland cement in the mortar and in the render undercoat is recommended.

Free-standing walls (excluding the coping or capping)

Free-standing walls[16] are likely to be severely exposed, irrespective of climatic conditions, and an effective coping as described in Section 5, will protect the brickwork from saturation.

	Suitable Categories of bricks	**Suitable Mortar Strength Class [1] /designation**
Effective coping used	F1/F2, S1 F1/F2,S2	M12 (i), M6 (ii) M12 (i), M6 (ii), M4(iii)
. Flush capping used	F2, S1 F2, S2	M12 (i), M6[2] (ii) M12 (i), M6 (ii)

Notes:
1 In areas of severe driving rain, class M12 and M6 mortars are preferred and, if class M6 is specified with (F1/F2, S1) clay bricks, the use of sulfate-resisting Portland cement should be considered.
2 Sulfate-resisting Portland cement is recommended with class M6 mortar. .

Earth-retaining walls (excluding the coping or capping)

Because of the possibility of contamination from the ground and saturation by ground waters, in addition to severe climatic exposure, these walls are particularly prone to frost and sulfate attack, if not protected as previously described (see Section 5 and also 'Brickwork Retaining Walls[14]). It is strongly recommended that such walls are back-filled with free-draining material to prevent a build–up of water pressure, and are water-proofed on the retaining face.

	Suitable Categories of bricks [1]	**Suitable Mortar Strength Class /designation**
Waterproofed retaining face Effective coping.	F1/F2, S1/S2	M12 (i), M6 (ii)
. Waterproofed retaining face	F2, S1 F2/S2	M12[2] (i) M12 (i)
No waterproofing of retaining face.[3]	F2/S2	M12 (i)

Notes:
1 Clay engineering bricks are often used in this application.
2 Sulfate-resisting Portland cement is recommended.
3.Some staining may occur if waterproofing is omitted.

Facing brickwork to concrete retaining walls

	Suitable Categories of bricks	Suitable Mortar Strength Class /designation
Low risk of saturation	F1/ F2 ,S1 F1/F2,S2	(M12 (i), M6 (ii))[1], M12 (i),M6 (ii)
High risk of saturation	F2, S1 F2, S2	M12 (i), M6[1] (ii) M12 (i), M6 (ii)

Notes:
1 Sulfate-resisting Portland cement is recommended.
2 For work above the dpc near to ground level, mortar strength class M2 may be used when it is known that there is no risk of frost during construction.

Sills, copings and cappings

Purpose-made sill and coping units to BS 5642: Part 1[11] and Part 2[12] may be preferred, but their specification and use are outside the scope of this Design Note. The requirements for brick-on-edge and similar cappings of clay bricks are as follows:

	Suitable Qualities of bricks	Suitable Mortar Strength Class[1] /designation
Standard format bricks and standard[3] and purpose-made special shapes	F2, S1/S2	M12 (i)

Notes:
1 Mortar strength class M12 should be used for bedding associated dpcs in clay brickwork.
2 When used in chimney cappings, sulfate-resisting Portland cement is recommended.
3 To BS 4729[13].

Drainage & sewerage manholes

Where the brickwork is wholly below ground, the risk of frost attack is minimal. However, where the brickwork is at or above ground-level, there is a risk of frost attack since it is also likely to be saturated during winter months. Clay engineering bricks are traditionally used for foul drainage works, but some clay common bricks may also be suitable. In general, clay brickwork in drainage works should not be rendered internally because experience has shown that, after extended periods of service, the render may fall away giving rise to blockages.

	Suitable Categories of bricks	Suitable Mortar Strength Class[1] /designation
Within 150 mm of ground level	F2, S1 F2, S2	M12[2] (i) M12 (i)
More than 150 mm below ground level	F2,S1/S2 F1,S1/S2[3]	M12[2] (i)

Notes:
1 If sulfate ground conditions exist, the use of sulfate-resisting Portland cement is recommended.
2 When F2, S1 or F1,S1 clay bricks are used, the use of sulfate-resisting Portland cement is recommended.
3 Some common F1,S2 and F1,S1 clay bricks are known to be satisfactory when used at depths greater than 150mm below ground level. Consult the manufacturer.

Planting boxes

Planting boxes should be waterproofed on the inner face for the full depth of earth fill, and be provided with drainage.

	Suitable Categories of bricks	**Suitable Mortar Strength Class /designation**
	F2 ,S1	M12[1] (i)
	F2,S2	M12 (i)

Notes:

1 Sulfate-resisting Portland cement is recommended.

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