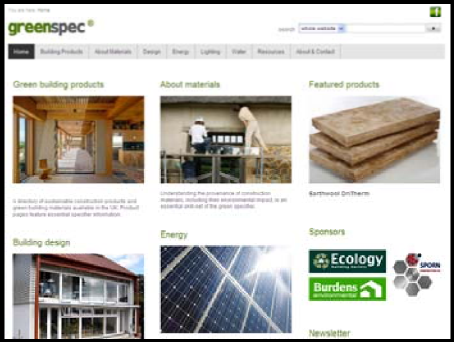

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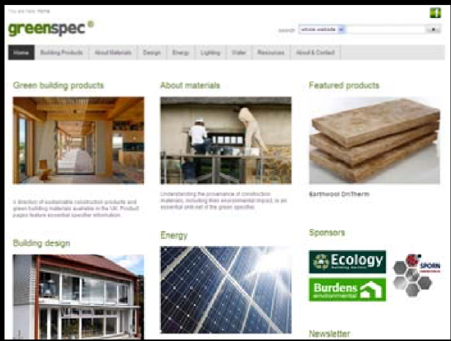
A shining example of how to communicate with Architects



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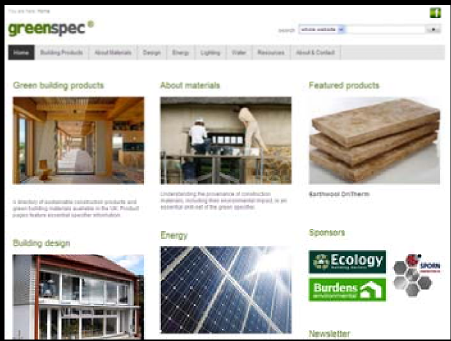
- A shining example of how to communicate with Architects

Architects Can’t/Won’t Read

- Architects choose picture books not reading books
- Illustrate your story
- A picture tells a thousand words
- A picture per paragraph
- A paragraph per picture
- Make it possible to avoid reading
- Learn all there is to learn from pictures
- Impossible, but do have a try



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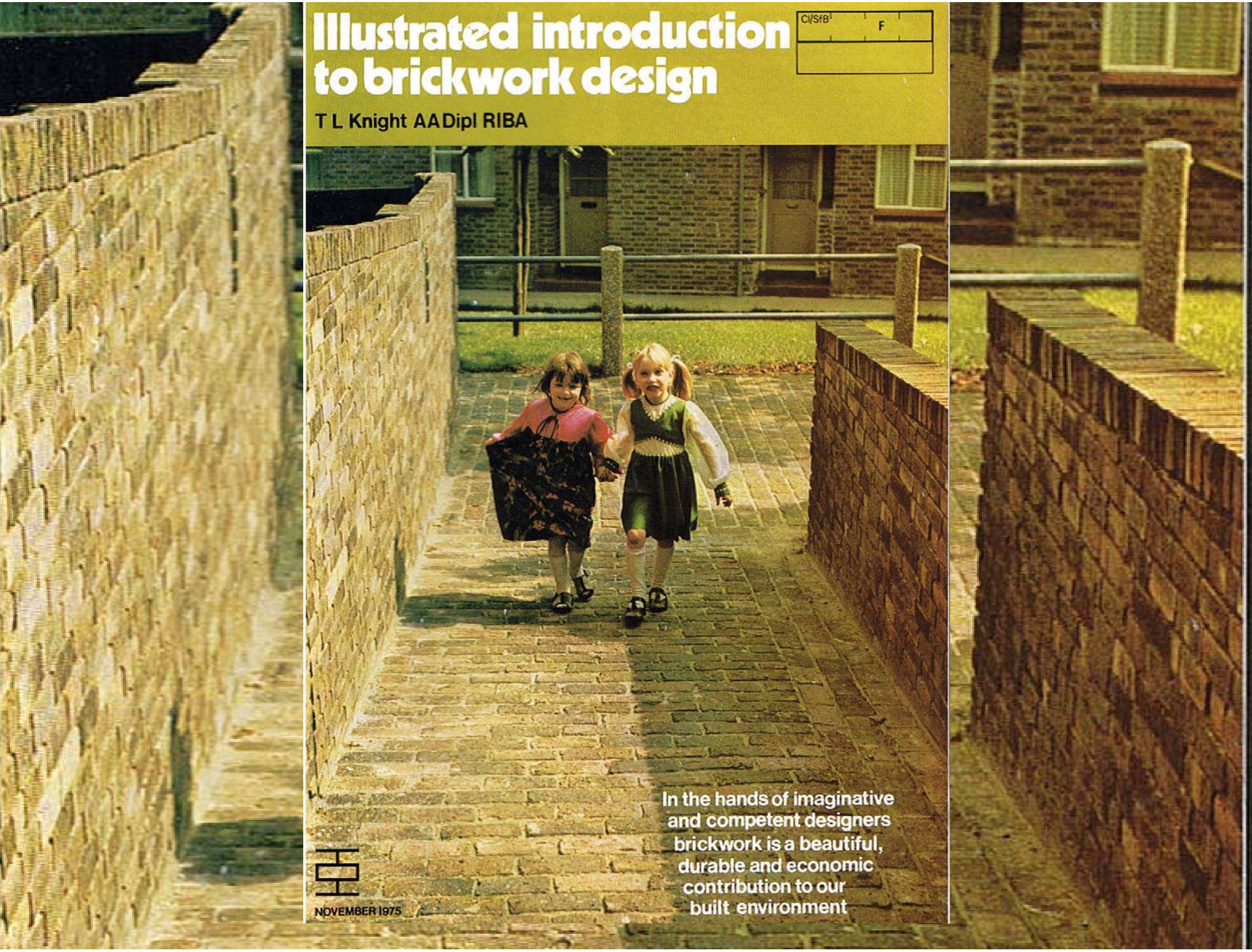
Brickwork

- Is easy to assume is easy to get right
- There are plenty of hurdles to trip over
- We need to be aware of the risks
- We need to understand a lot
- Drip feed the issues one at a time

Illustrated introduction to brickwork design

CI/SfB | F

T L Knight AA Dipl RIBA



In the hands of imaginative and competent designers brickwork is a beautiful, durable and economic contribution to our built environment

NOVEMBER 1975

The fundamental properties of bricks are well understood and documented but, sadly, a designer's intentions are sometimes frustrated by his misunderstanding of the significance of these properties.

To use brickwork successfully designers must ■ Choose bricks of appropriate quality. ■ Specify their use correctly. ■ Design appropriate details. The remaining sections contain essential information to help you to do this.

These illustrated notes have been prepared as a reminder of the basic physical properties of bricks, as a guide to applying the principles of good design to brickwork, and as a reference to the more important requirements and recommendations in the Building Regulations, British Standards, Codes of Practice and technical notes.

Most of the illustrations are taken from slides designed specifically for lectures given by the Brick Development Association and are available on application to the Association. Technical information is published frequently by the Brick Development Association and distributed with the Brick Bulletin.

STRENGTH & STABILITY

General

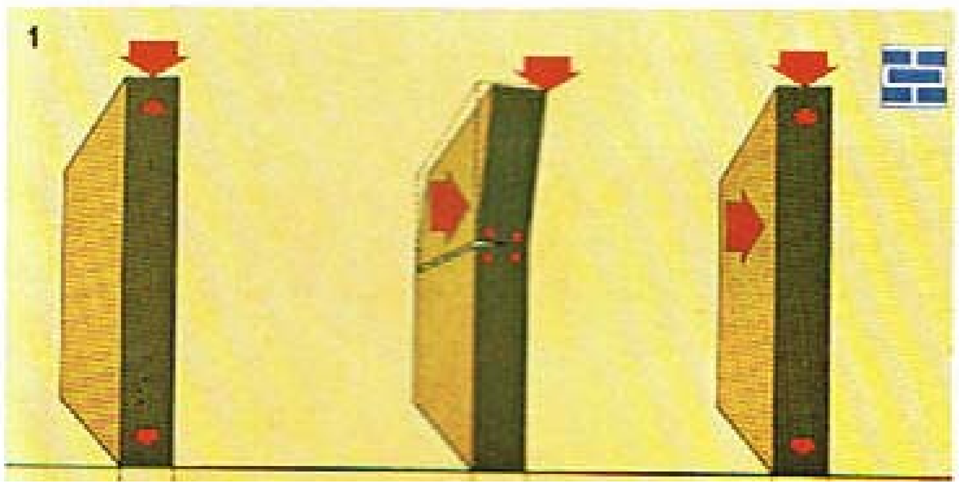
Brickwork readily resists large compressive forces induced by axial loads.

Unreinforced brickwork, using conventional mortars, is less able to resist tensile forces induced by wind or eccentric loads.

In practice, tensile forces are resisted by the compressive forces induced by the load of the structure above. The stress block diagrams illustrate this graphically.

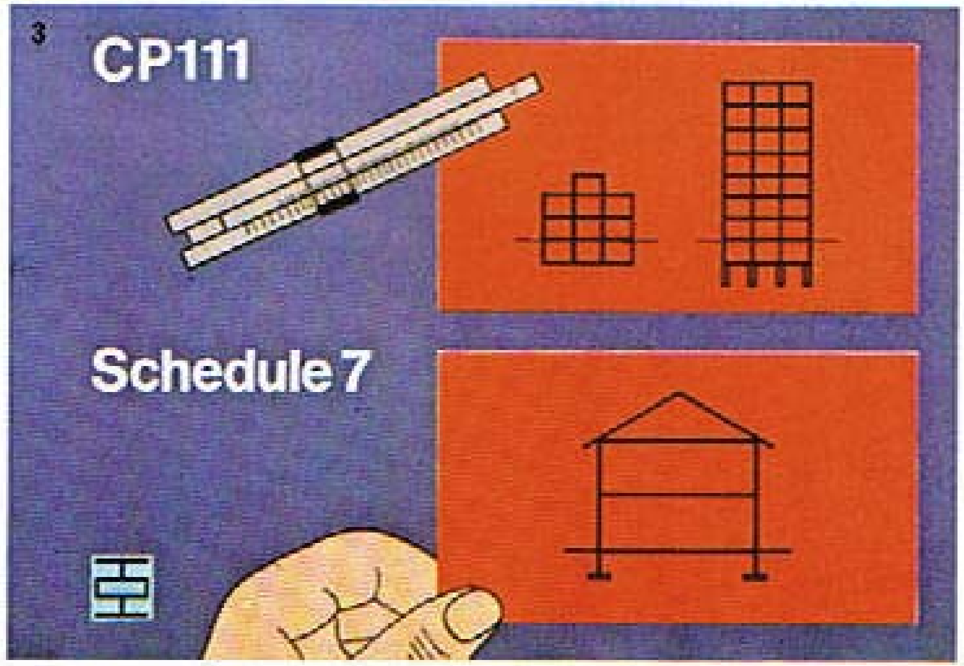
The art of designing a structure in brickwork is to exploit its inherent compressive strength, and the stability induced by pre-compression from vertical loads, while avoiding the development of tension (1).

1



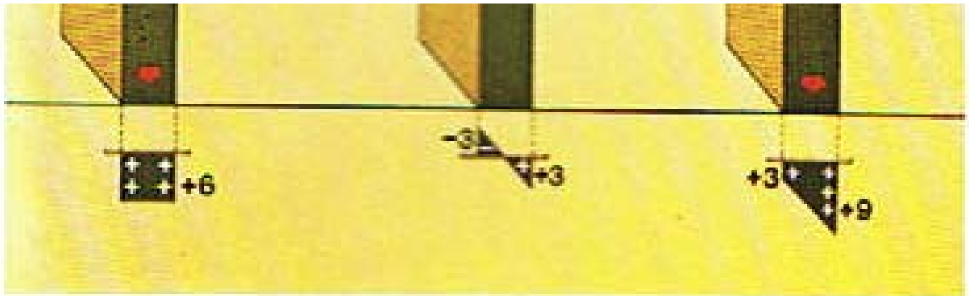
Structures must remain stable under all types of load. This is a general requirement of regulation D8 of the Building Regulations and can be satisfied in one of two ways by following the recommendations of either CP 111 or Schedule 7 of the Building Regulations *(see regulation D15 (a) & (b)).*

3

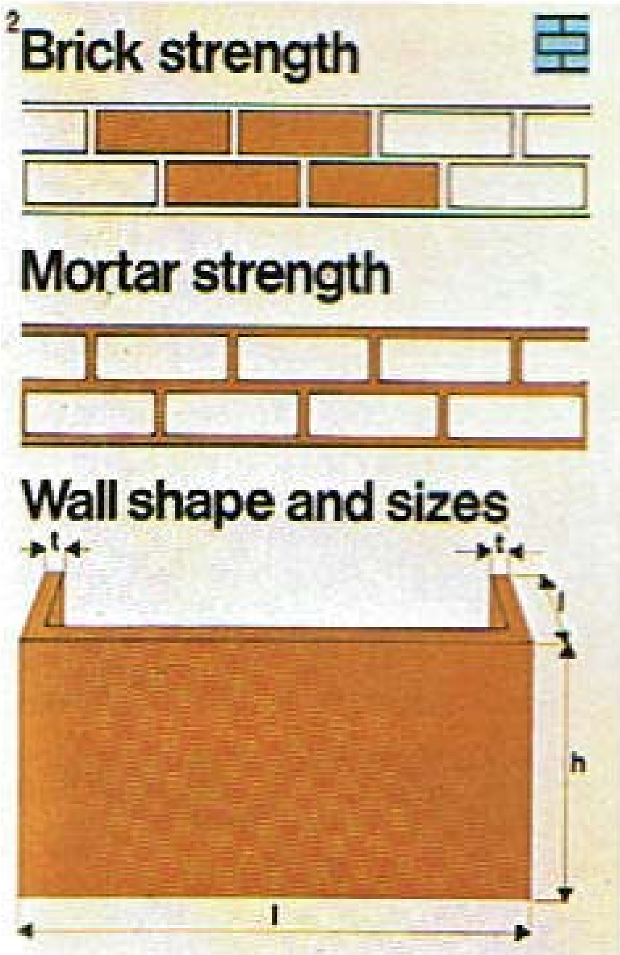


The use of CP 111 involves calculation. An architect will usually require the services of an engineer if complications arise from lateral, eccentric or concentrated loads.

Schedule 7 is intended to be a 'rule of thumb' method of design



The strength of brickwork depends on:
Brick strength
Mortar strength
Brickwork shape and sizes (2).



require the services of an engineer if complications arise from lateral, eccentric or concentrated loads.

Schedule 7 is intended to be a 'rule of thumb' method of design mainly for two-storey domestic buildings. Current revisions to the Building Regulations will define more precisely and limit the applications of Schedule 7 (3).

Note. *In Scotland the requirements differ slightly from those in England and Wales.*

Part C2 of the Building Standards (Scotland) (Consolidation) Regulations 1971 are 'deemed-to-be-satisfied' if the design is in accordance with CP 111.

An explanatory memorandum gives recommended standards but they are not 'deemed-to-satisfy' with the force of law as is Schedule 7 of the Building Regulations which are applicable in England and Wales.

Brick strength

A wide range of bricks is available in this country (4). Bricks vary greatly in compressive strength due to the differing qualities of the raw materials and the methods of firing clay bricks and of autoclaving calcium silicate bricks (5).

Note. *The compressive strength of clay bricks is not always indicative of their durability, whereas the durability of calcium silicate bricks is related to their strength (see the section on Durability).*

Modern methods of manufacture produce bricks with consistent physical qualities, but bricks are made from naturally occurring materials and the compressive strength of individual bricks in a given batch inevitably varies (6).

The compressive strength of a particular type of brick is taken as the arithmetic mean of ten bricks sampled and tested in accordance with the precise procedures defined in BS 3921 clause 31 for clay bricks and BS 187 appendix B, for calcium silicate bricks.

Compressive tests which vary from these procedures have no ability. The design recommendations of CP111 take into account the variability in the compressive strength of individual bricks.

Architects have no grounds for rejecting individual bricks because they fall below the specified compressive strength.

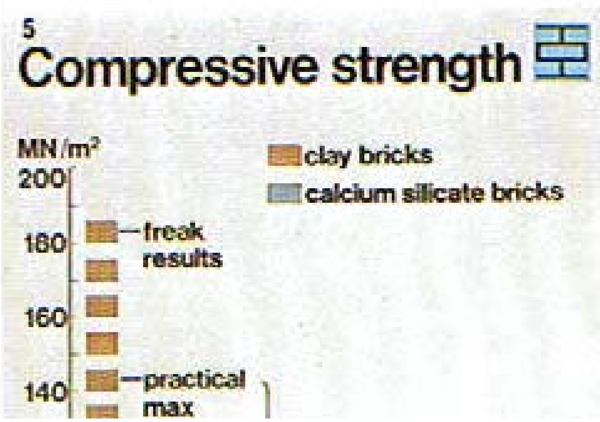
No limits are placed on the coefficient of variations in the British Standards, but manufacturers who employ quality control techniques can supply such information. Methods of quality control and of expressing the uniformity of compressive strength are given in:

BS 3921 Appendix C
BS 187 Appendix C

The compressive strength of single bricks and the mode of failure does not directly represent the strength or mode of failure of brickwork, but the compressive strength of bricks established in accordance with standard procedures does, in practice, provide basic information enabling brickwork strength to be calculated using the methods recommended in CP 111.

4

5



Mortar strength

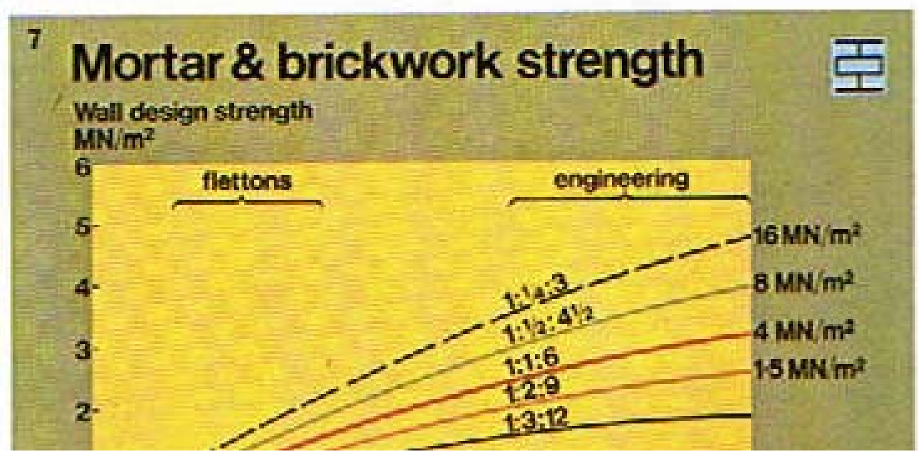
The diagram (7) shows graphically the relationship between:

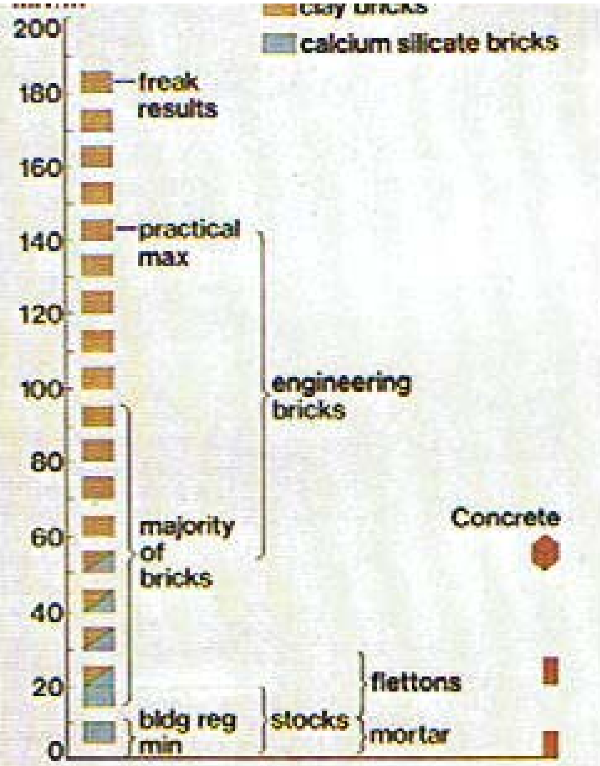
1. brick compressive strength established according to standard procedure.
2. mortar strength ie the minimum strength required from preliminary laboratory test cubes for various mortar mixes recommended in SP 56: 1973 'Model Specification for Loadbearing Clay Brickwork' Table 3. (The mortar strengths have been modified in the latest revision of SP 56 1975.).
3. The wall design strength or 'basic stress' as it is described in Table 3a of section 315 of CP 111.

Students should refer to this table and the definition of basic stress in section 315b for a fuller understanding of the meaning of the diagram.

Reference should also be made to the section on mortars in this publication.

7

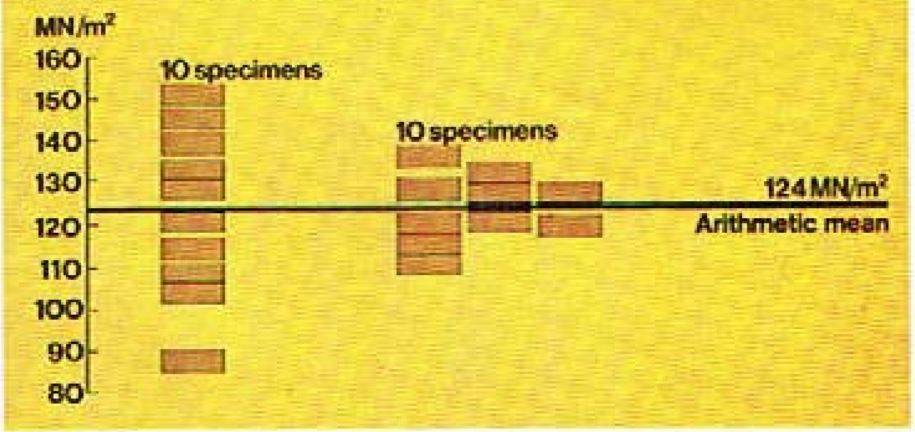


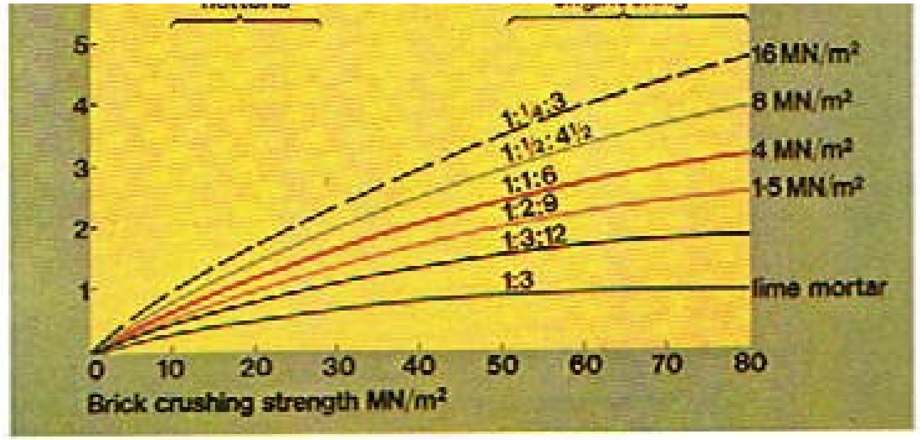


6

Compressive strength

BS3921 - Clay
BS 187 - Calcium silicate

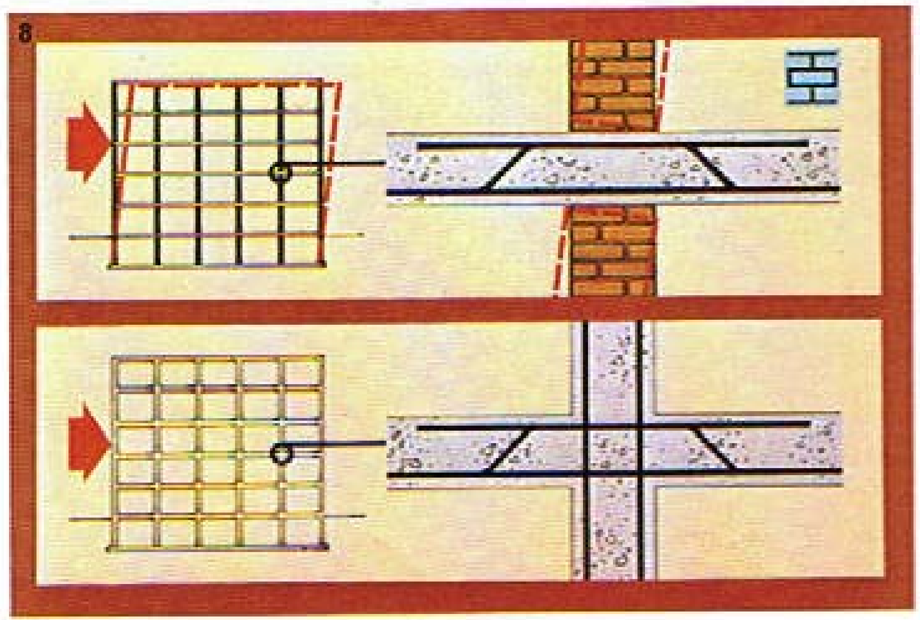


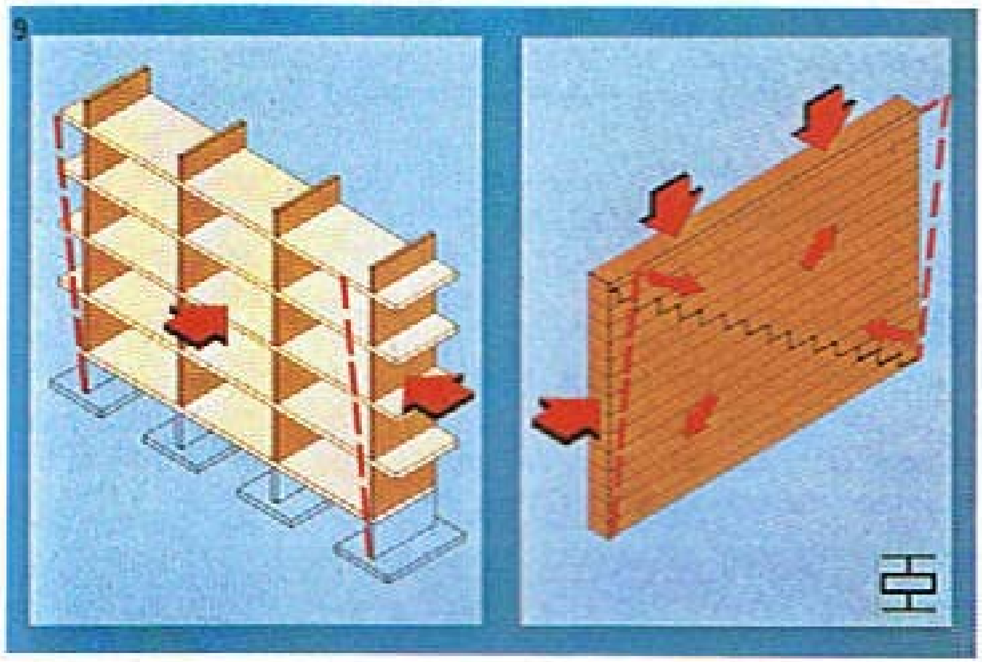


Form of building

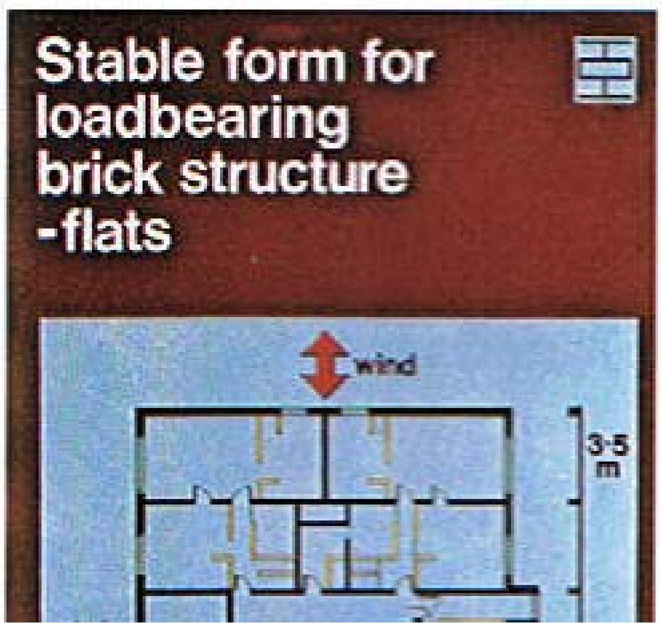
Structural stability and in particular resistance to horizontal wind loads can be most effectively achieved in brick buildings by the appropriate disposition of walls. Brick walls do not effectively resist horizontal wind loads at right angles to their longitudinal axis because it is not possible to develop rigidity at the junction of brick walls and concrete floors as it is between reinforced concrete walls and floors or columns and beams (8).

8





Brick walls successfully resist wind loads along their longitudinal axis because the high level of friction between the concrete floors and brick walls prevents the floors sliding differentially. The compressive forces from the load of the structure above the wall prevent the brick panel from distorting and failing in tension along the diagonal (9).

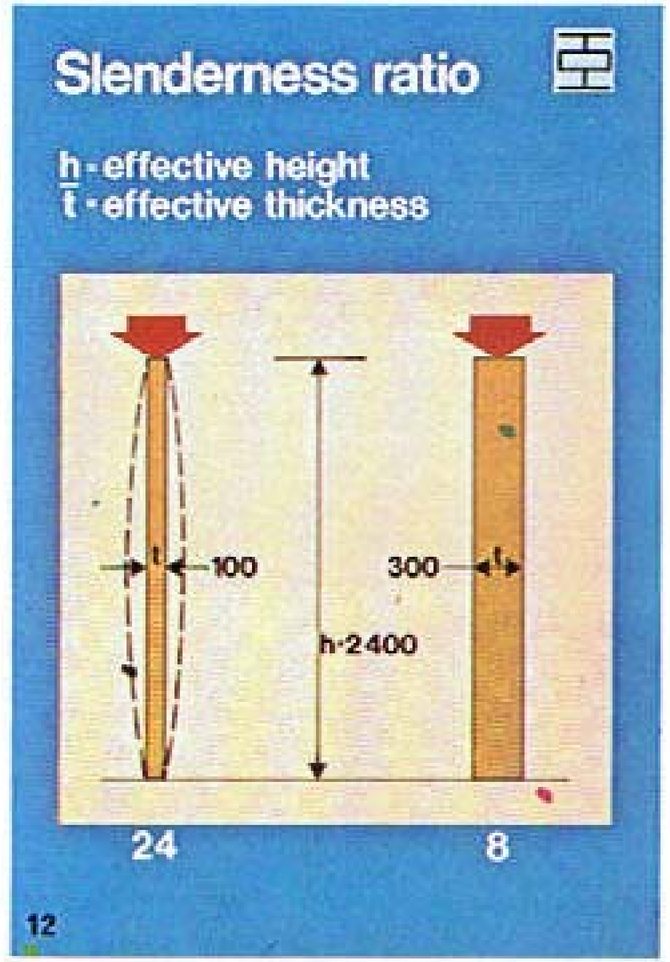


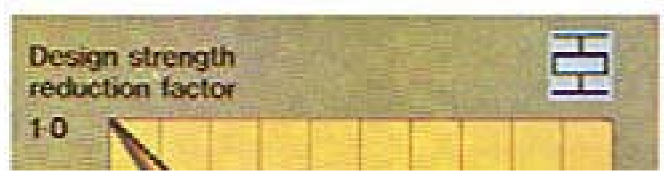
Slenderness ratio

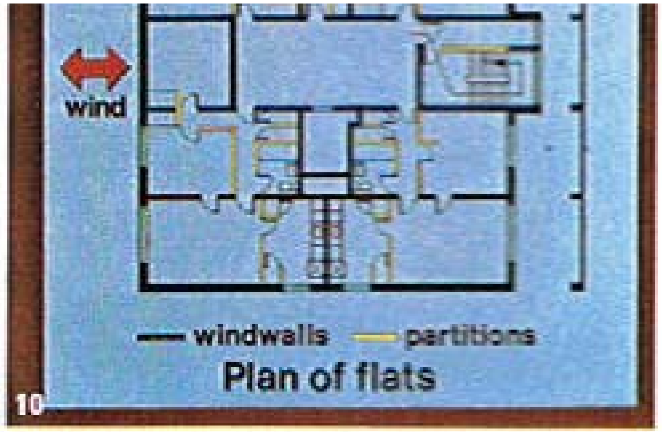
In practice the slight eccentricity of vertical loads on walls tends to induce bending. This tendency is relatively greater in thin walls. The slenderness ratio is defined as the

$$\frac{\text{effective height}}{\text{effective thickness}} = \frac{h}{t}$$

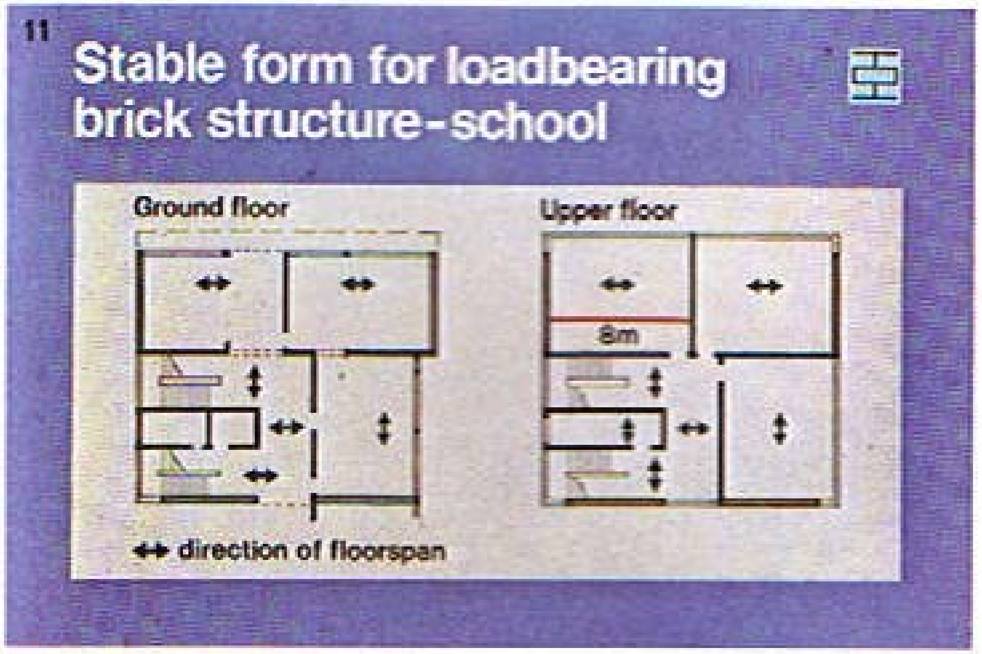
Refer to CP 111 sections 305 and 307 for a more detailed definition and diagram (12) in this publication.

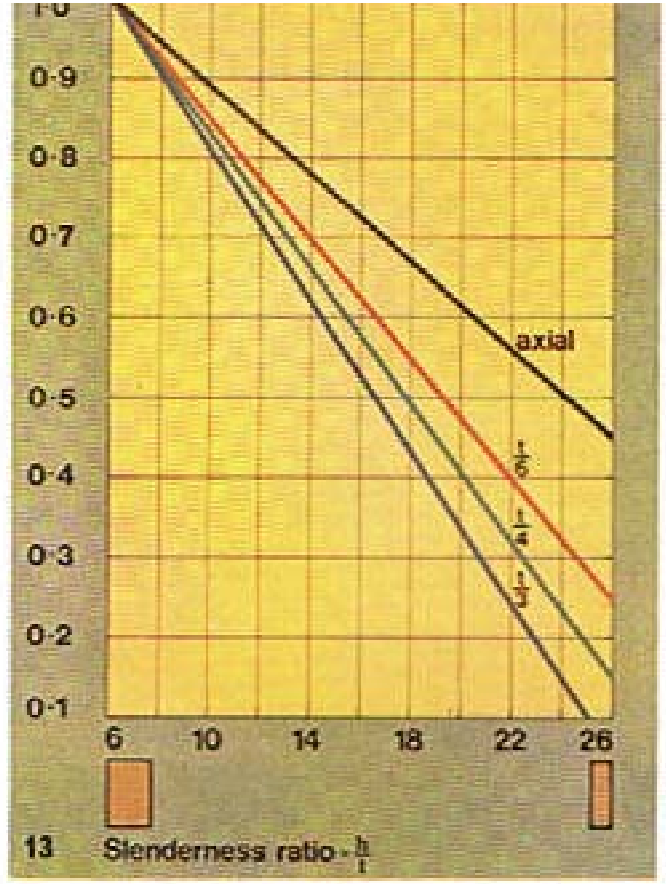






Stable brickwork structures can be designed for many building types in which walls can be placed along both main axes (10 & 11).



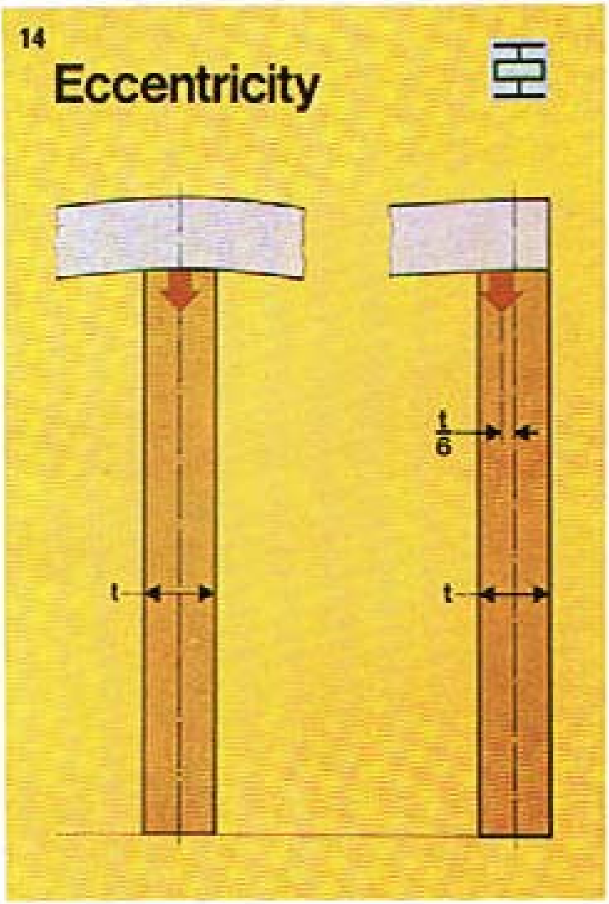


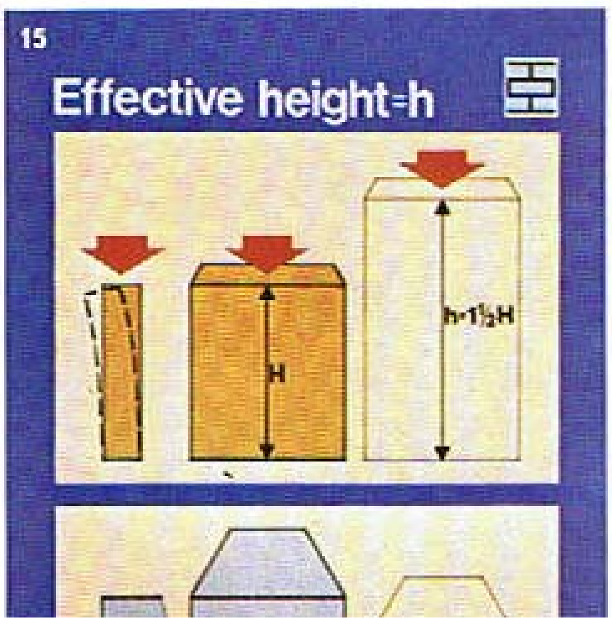
Allowances are made for the effect of the slenderness ratio by applying a stress reduction factor to the basic stress. The stress reduction factor and, consequently, the permissible stress reduce as the slenderness ratio increases. This graph is compiled from Table 4 of CP111 *(see also section 315 a, b, and c for further detailed definitions)* (13).

n addition to buildings typically using cellular plan forms such as blocks of flats, hostels and hotels, other building types which have been built from loadbearing brickwork include schools, swimming pools, libraries and offices.

Besides structural stability, brickwork achieves good sound insulation, by virtue of its mass, together with excellent fire protection.

The stress reduction factor and consequently the final permissible compressive strength will be further reduced if there is a degree of eccentricity in the application of the vertical load. In practice such eccentricity may be induced by the deflection of floor slabs and beams. The degree of eccentricity to be allowed for is a matter of engineering judgement. *(See CP 111 section 315 d.)* (14).





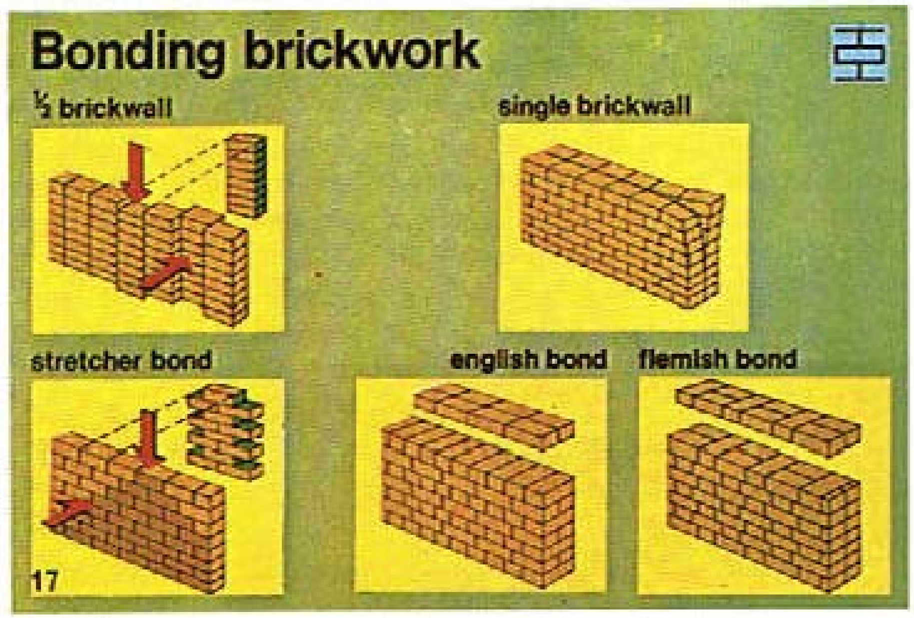
Where a concrete or timber floor spans parallel to a wall but is properly tied to it h = H *(CP 11 305a (ii) but also 304b (ii) & (iii))*

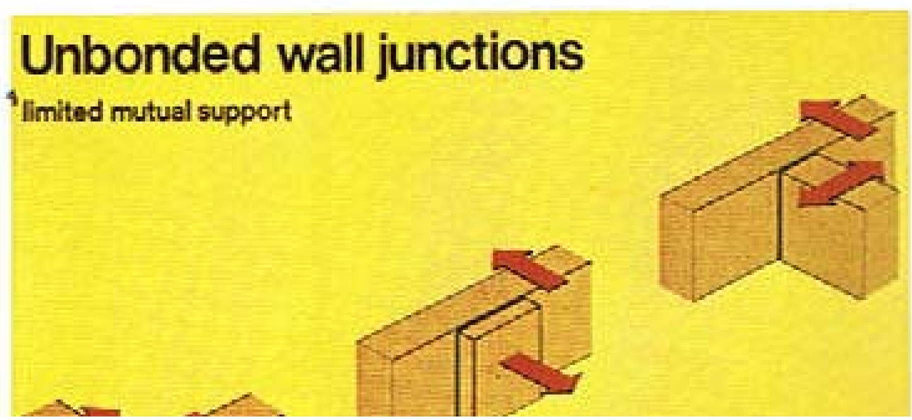
Columns, in the direction in which lateral support is provided, h = H *(CP 111 cl. 305b)*

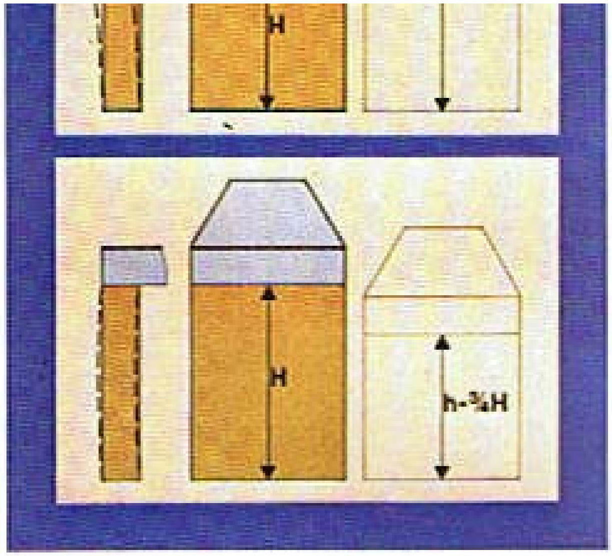
Columns, in the direction in which no lateral support is provided, h = 2H *(CP 111 cl. 305b)* (16).

Bonding

The bricks in a length of wall must be properly bonded in order to distribute vertical and horizontal loads over a larger area and number of bricks and so minimise the possibility of differential movement between bricks (17).





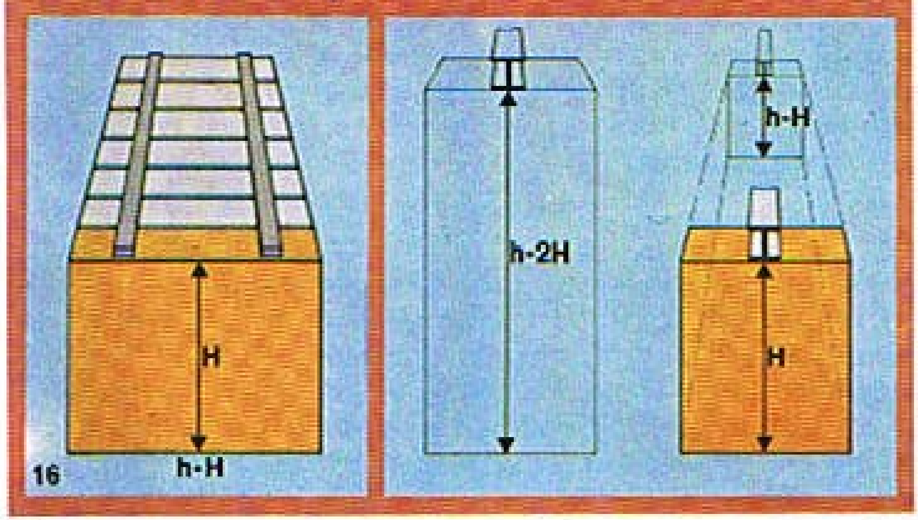


The effective height of a wall (h) will vary from the specified height (H) depending on a number of factors which may stem from the architectural design.

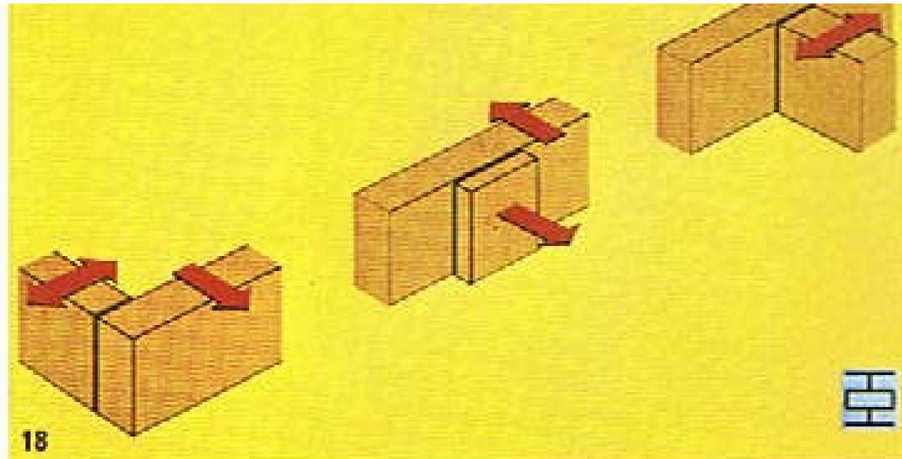
Where the wall has no lateral support at the top, h = 1½H *(CP 111 305 a (iii))*.

Where concrete floors bear on walls irrespective of the direction of span, h = ¾H *(CP 111 305a (i))* (15).

Effective height-h



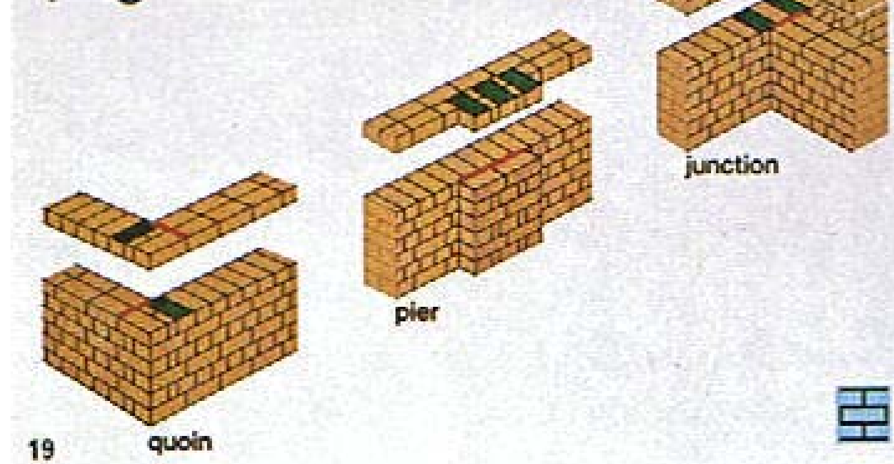
16



18

Walls give each other only limited mutual support at unbonded junctions (18).

Bonded junctions (english)



19

Properly bonded junctions provide greatly improved mutual support. Continuous vertical joints (red) are avoided by positioning tie bricks (green) over the vertical joints or 'perpends' (19).

Bonding is part of the bricklayer's skill and is not necessarily detailed by the architect, unless the construction is unusual and the architect is not confident that the bricklayers will produce work to his satisfaction without specific instructions.

Schedule 7 of the Building Regulations rule 1 (b) requires brickwork to be 'properly' bonded.

CP 111 clause 401 requires that workmanship should comply with CP 121. Appendix A (CP 121) defines 'bond' as 'A disposition of units in a wall usually designed to ensure that the cross joints in each course are not less than one-quarter of the length of the unit from those in adjacent courses.'

Various methods of bonding are used giving rise to different bond patterns which have special names. These may be referred to in good textbooks on brickwork and bricklaying eg those by W. Cutter and W. G. Nash (20, 21 & 22).

References quoted in this section and further reading:

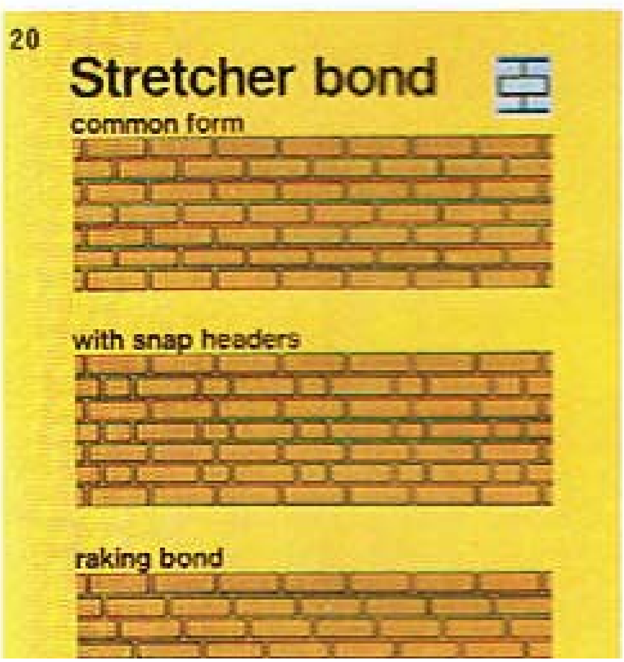
*Bricks and Brickwork by C. C. Handisyde ARIBA, AADipl and B. A. Haseltine BSc(Eng), ACGI, DIC, CEng, FICE, MConsE.

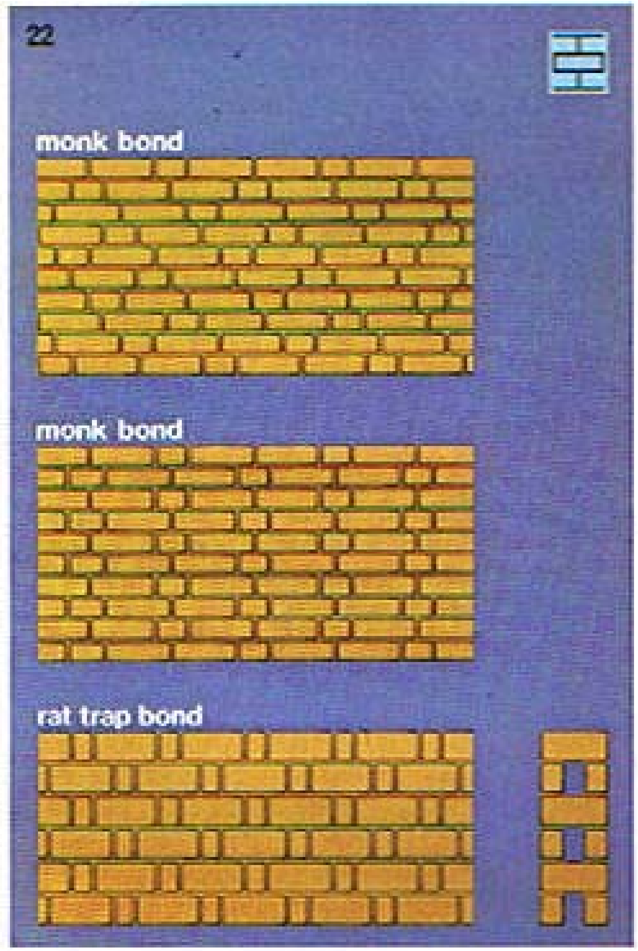
'The Building Regulations 1972' including all subsequent amendments – (First and second at the time of going to press).

'The Building Standards (Scotland) (Consolidation) Regulations 1971'.

CP 111: Part 2: 1970. 'Structural Recommendations for loadbearing walls' British Standard Code Of Practice (currently under revision).

*Obtainable from the Brick Development Association.





CP 121: Part 1: 1973. 'Walling – Brick & Block Masonry'.

*'The design of calculated loadbearing brickwork' by B. A. Haseltine BSc(Eng) ACGI DIC CEng MICE (especially pp. 3, 4 & 5).

BS 3921: 1974. 'Specification for Clay bricks and blocks'.

BS 187: Part 2: 1970. 'Specification for Calcium Silicate (Sand-lime and Flintlime bricks)'.

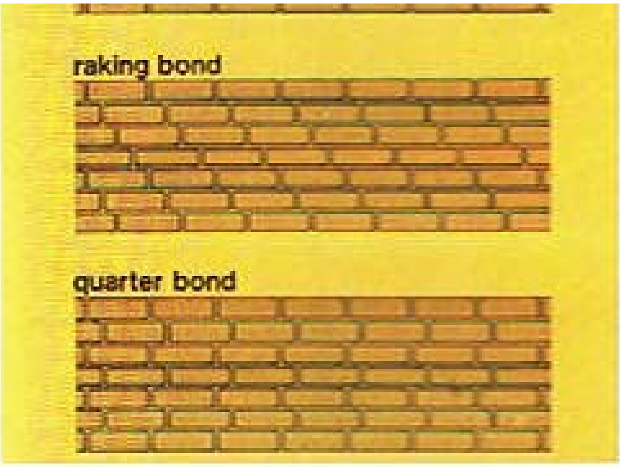
*SP 56: 1975 'Model Specification for loadbearing clay brickwork', The British Ceramic Research Association.

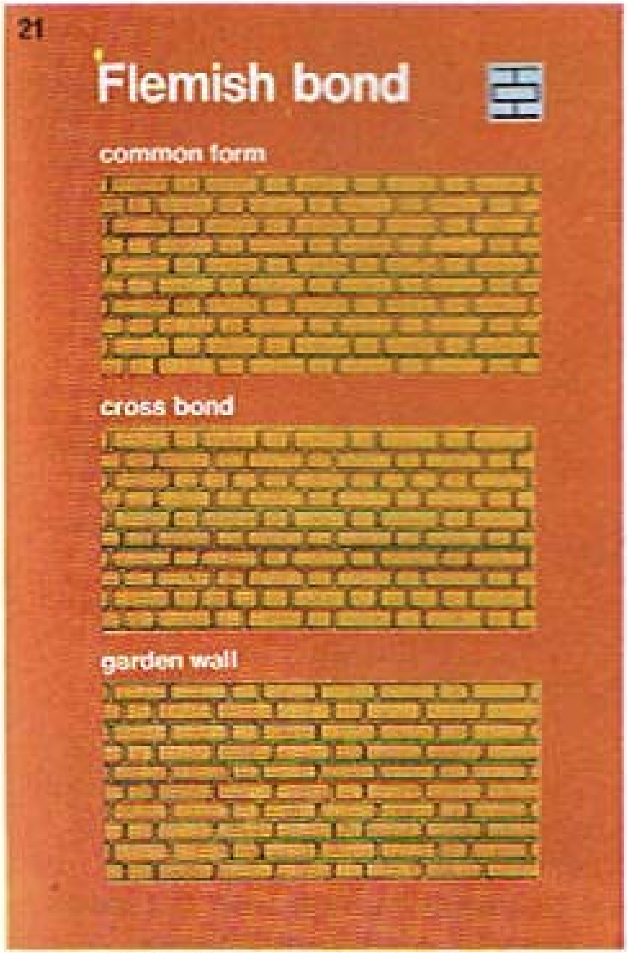
'Brickwork', (4 vols), W. Cutter, Cassell.

'Brickwork', (3 vols), W. G. Nash, Hutchinson.

*Obtainable from Brick Development Association.

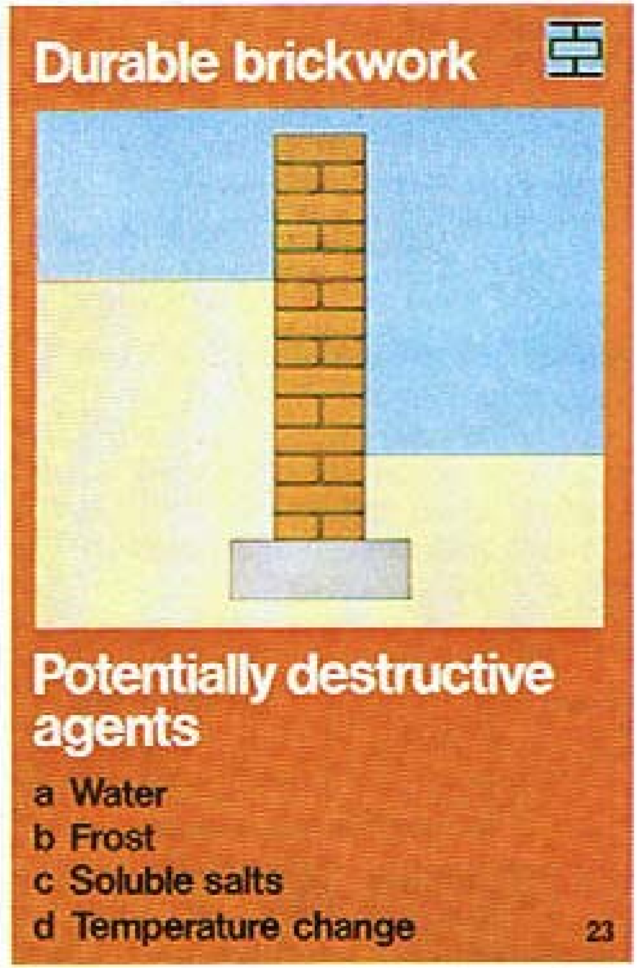
DURABILITY





*Obtainable from Brick Development Association.

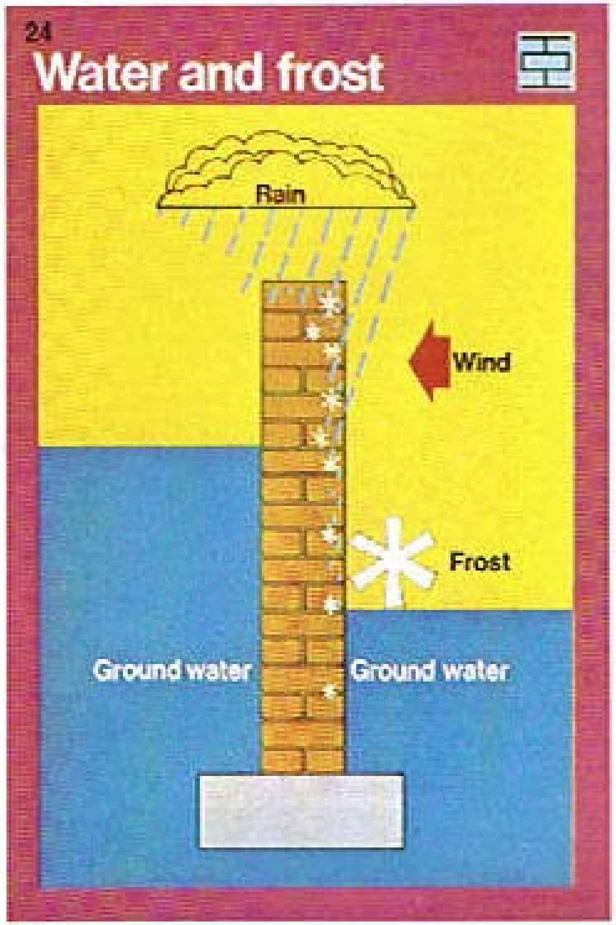
DURABILITY



Brick is the most durable building material readily and economically available for many building purposes in this country today.

Designers who understand the ways that potentially destructive agents act upon brickwork can specify appropriate bricks and design details to produce brickwork which will endure indefinitely and mellow with age. Failure to take note of simple principles and to apply well established knowledge may lead to disappointment and unnecessary remedial costs (23).

Frost attack



Brickwork absorbs water falling as rain and washing over the surface. Some parts will absorb more water than others, notably horizontal and inclined surfaces and parts in contact with the soil, and may be potentially at risk from frost attack (24).

All bricks made in this country, except those designated 'internal quality', will withstand frost attack when used in the external walls of buildings provided that the detailed design prevents prolonged saturation of the brickwork.

Many bricks will withstand constant soaking and freezing in the most exposed conditions while others rapidly deteriorate under such circumstances.

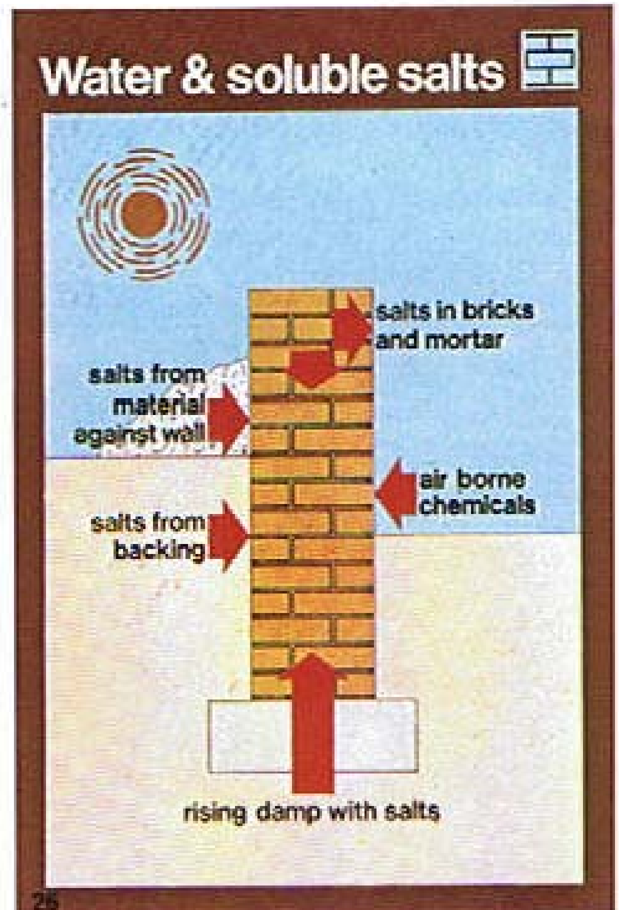
High compressive strength and low water absorption are properties which give a general guide to good frost resistance of

In a cavity wall of a building, the outer leaf seldom becomes frozen right through and the pressure of expanding ice is relieved internally. The same bricks in a free-standing wall, especially those at the top, may often be saturated and frozen (25).

A brick should not be rejected for general use merely because it fails in conditions of severe exposure. When in doubt consult the manufacturer.

When using calcium silicate (sandlime or flintlime) bricks in conditions of severe exposure, specify at least class 3 or 4. *(See BS 187 Appendix E 1.1. for further information).*

Salts



There are many possible sources of soluble salts but the most common are in the clay, or in the sand used for mortar (26).

walls of buildings provided that the detailed design prevents prolonged saturation of the brickwork.

Many bricks will withstand constant soaking and freezing in the most exposed conditions while others rapidly deteriorate under such circumstances.

High compressive strength and low water absorption are properties which give a general guide to good frost resistance of clay bricks. BUT some of low compressive strength and very high absorption are extremely frost resistant.

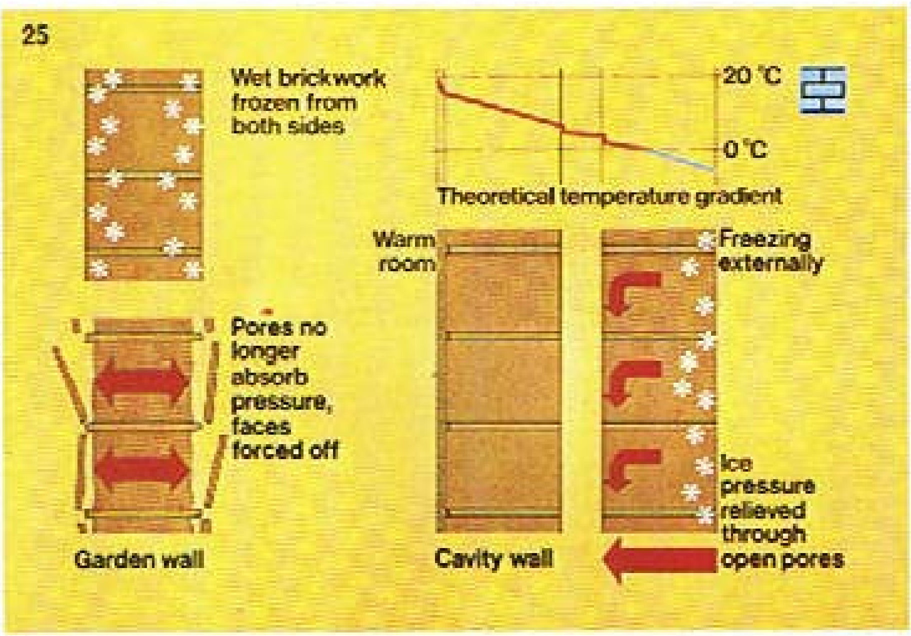
There is no known laboratory test which will satisfactorily predict the frost resistance of a clay brick. Architects having no personal experience of a particular brick should consult the manufacturer who may be asked to give evidence of:

The use of the brick in the locality in a similar degree of exposure.

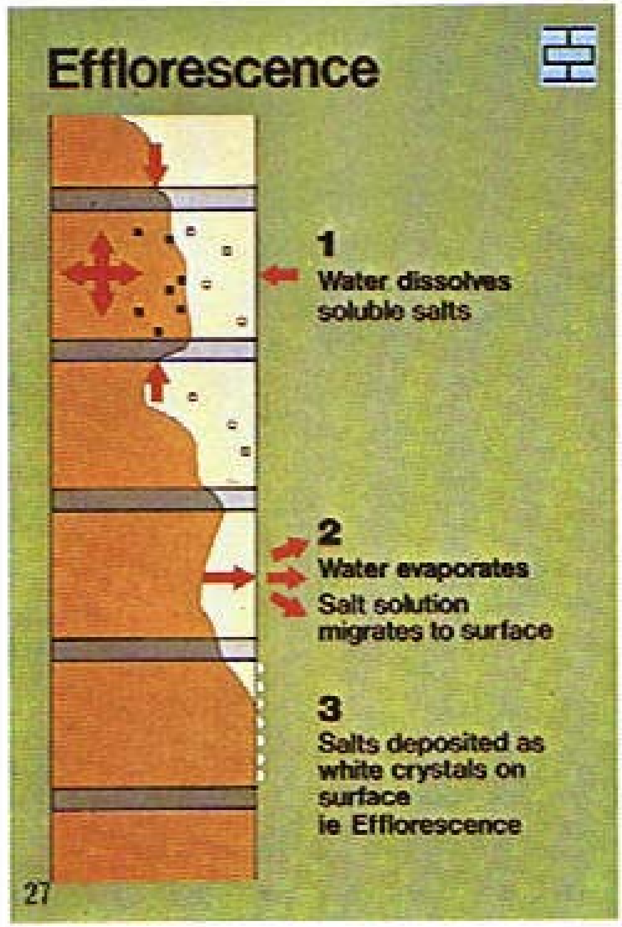
A specimen wall on an exposure site supervised by an independent authority.

Failing such evidence, clay bricks having a minimum strength of 48.5 MN/m² or a maximum water absorption of 7 % may be considered frost resistant.

(See BS 3921: clause 12.5 for further detailed information and the section under classification in this publication.).



There are many possible sources of soluble salts but the most common are in the clay, or in the sand used for mortar (26).



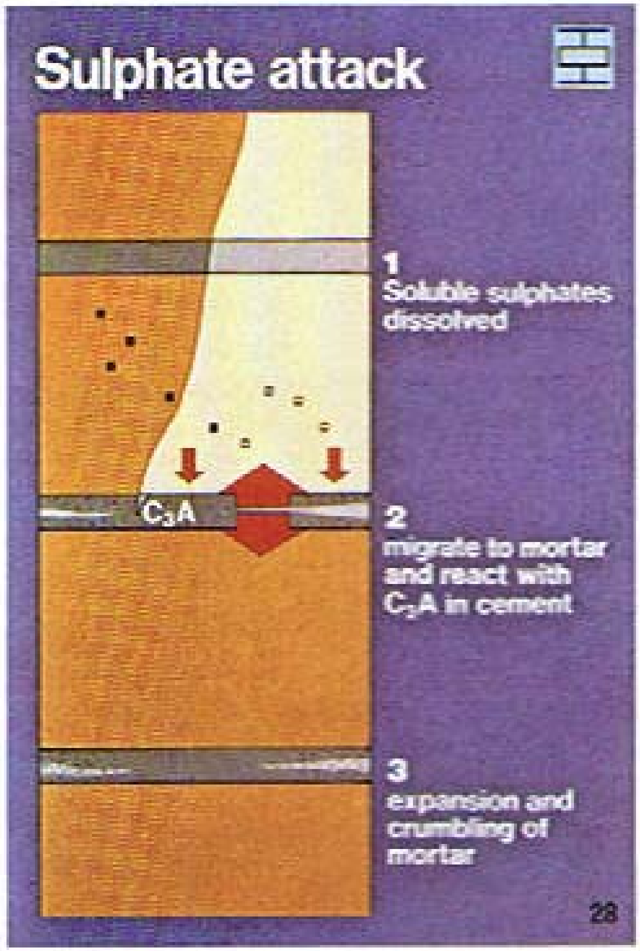
Efflorescence

Efflorescence is a harmless and usually temporary phenomenon. Brickwork is wettest and absorbs most salts immediately after being laid. It drys out most rapidly usually in the following spring when the salts migrate to the surface with the water and are left as a surface deposit when the water evaporates. It is best to allow subsequent rain to dissolve and wash away the salts. The use of metal brushes may damage the face of the brickwork, use bristle if necessary (27).

Designers consulting manufacturers on the efflorescence liability should first acquaint themselves with the standard test as described in BS 3921 clause 34.

Calcium silicate bricks are not subject to efflorescence unless salts are introduced from external sources *eg the ground, or materials stacked against the wall.*

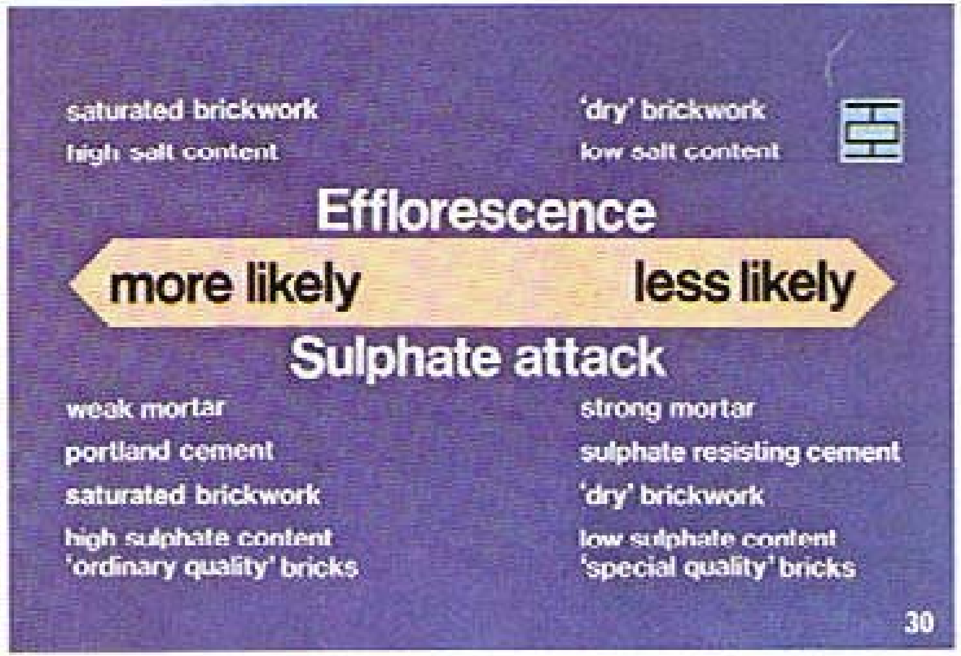
Efflorescence will persist from year to year only if the detailed design of the building allows a constant flow of water through the brickwork to dissolve fresh salts.



Sulphate attack

Sulphate attack is rare and is serious only when the design detail remains dry *ie not saturated*. Normal wetting of vertical surfaces by rain seldom saturates brickwork (29).

Faulty dpcs flashings, copings and cills may cause parts of the brickwork to remain saturated for long periods.



Other factors which must be considered are listed in the diagram (30).

All design is a matter for careful compromise. The adoption of all the factors on the right of the diagram would ensure success but be unnecessarily expensive and limit the choice of brick.

On the other hand, if one design incorporated all the factors on the left, failure would be almost certain.

Judgement and experience, guided by this check list, will minimise the chances of failure.

Notes on the diagram. *'Saturated' brickwork, usually resulting from design or construction faults, may in turn lead to the dissolving of excessive quantities of salts.*

The salt content of bricks can be obtained from manufacturers.

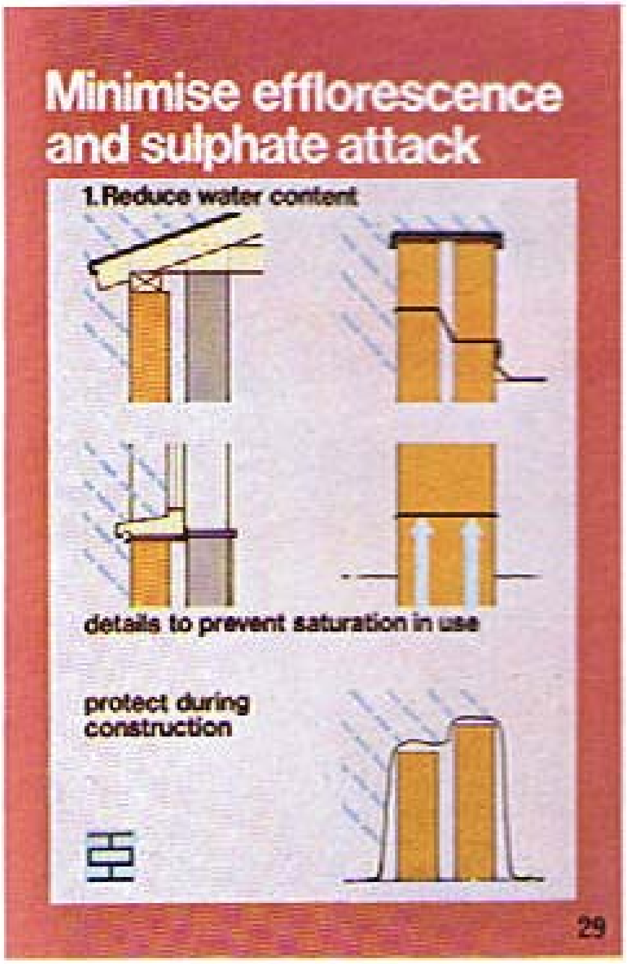
Strong mortars, rich in cement, minimise the amount of water penetrating the mortar bed and the risk of sulphate action. BUT, note that strong mortar may be undesirable in other aspects – (see the

28

Sulphate attack

Sulphate attack is rare and is serious only when the design detail ensures the continuing saturation of the brickwork, *eg under faulty copings or cills or in unprotected retaining walls*, releasing large quantities of sulphates.

Sulphates in the brick are dissolved and migrate to the mortar joint combining with tri-calcium aluminate (C_3A), a constituent of Portland cement. Expansion of the mortar joint may result possibly causing further deterioration by frost attack (28).



29

Minimising the risk of efflorescence & sulphate attack

The most important factor is to design the brickwork so that it

Strong mortars, rich in cement, minimise the amount of water penetrating the mortar bed and the risk of sulphate action. BUT, note that strong mortar may be undesirable in other aspects – (see the section on mortar).

Sulphate resisting cement has a lower C_3A content than Portland cement and virtually eliminates the possibility of reaction with the sulphates.

Special quality bricks have a limited sulphate content, again minimising the risk of attack.

References quoted in this section and further reading:

CP 121: Pt 1: 1973. Walling – Brick & Block Masonry. Section 3.6 – Durability.

BS 3921: 1974. 'Specification for Clay Bricks and Blocks'.

BS 187: Pt 2: 1970. 'Calcium Silicate (Sandlime and Flintlime) Bricks'.

SCP tn3. 'Brickwork: Durability'. Structural Clay Products Ltd., 230 High Street, Potters Bar, Herts. March 1971 50 p.

SCP5 'Brickwork Efflorescence' (as above). January 1974, 50 p.

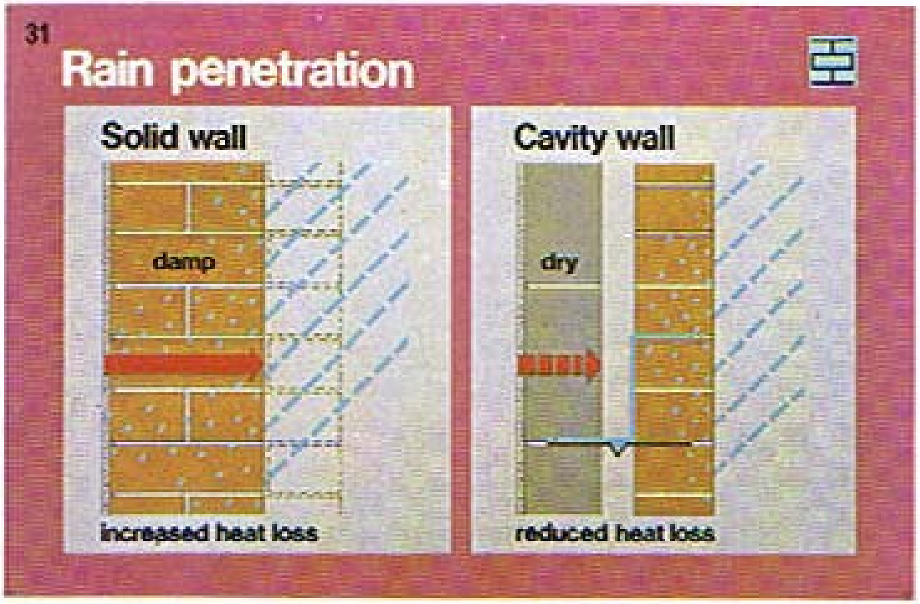
EXCLUSION OF WATER

Traditionally, solid brick walls, single or one and half bricks thick, were considered sufficiently rain resistant in many areas of the country. In coastal and other severely exposed areas, brickwork was often rendered or tile hung for additional protection.

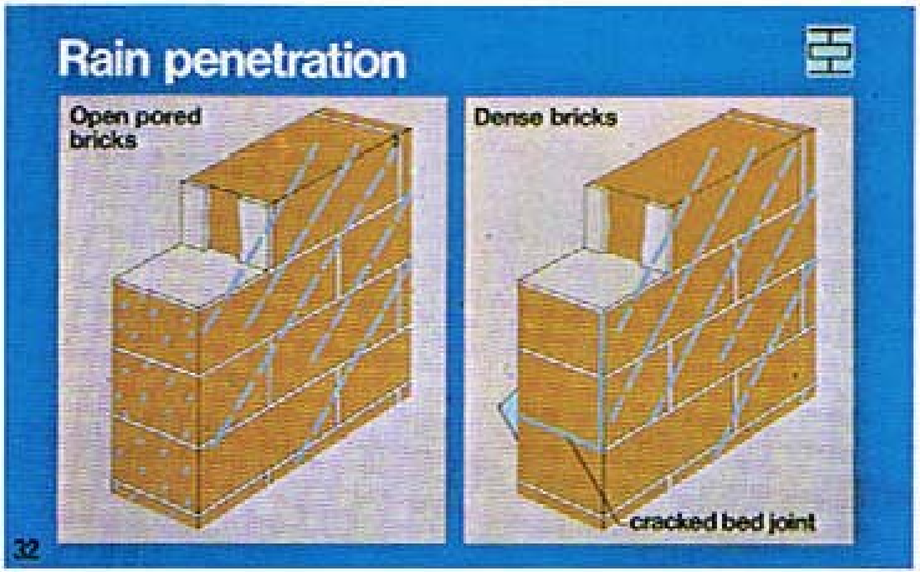
Cavity walls have become increasingly used during the last fifty years as a more certain protection against rain penetration. In addition, the dry inner leaf offers better thermal insulation.

A cavity wall is usually designed on the assumption that water

31



will eventually penetrate the outer leaf of brickwork (102.5 mm thick). Precautions must be taken to ensure that moisture will not transfer to the inner leaf at the various points where the cavity is bridged, *eg by ties, lintels, cills floors or beams* (31).



32

Outer leaves of open-pored bricks having a high rate of absorption will absorb water washing over the surface. In conditions of severe exposure and continuous driving rain, water will eventually reach the inner face through the pore structure, first as dampness and

assumed that water will eventually penetrate to the inner surface, especially in exposed situations. The water should be prevented from penetrating inside the building by careful attention to the design of dpcs, flashings and weep holes (33).

The water resistance of a building depends on appropriate detailed design rather than the choice of brick type.

Further reading to this section:

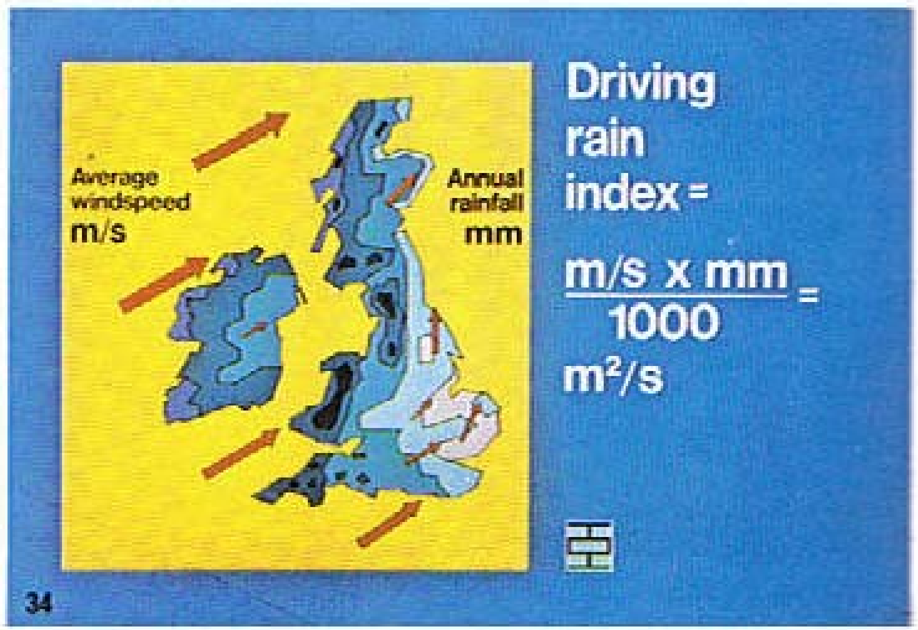
SCP tn5 'Brickwork: Resistance to Rain', Structural Clay Products Ltd, 230 High St, Potters Bar, Herts, July 1973, 50 p.

*BDA Practical Note No 6, January 1975 'Damproofing courses & flashings with brickwork and blockwork'.

CP 121: Pt. 1: 1973. 'Walling – Brick & Block Masonry' Section 3.5, Design – exclusion of rain.

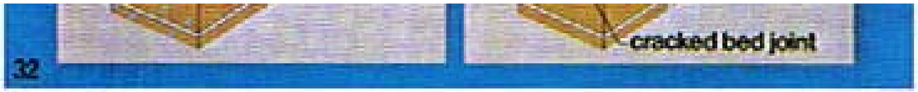
*Obtainable from The Brick Development Association.

EXPOSURE



34

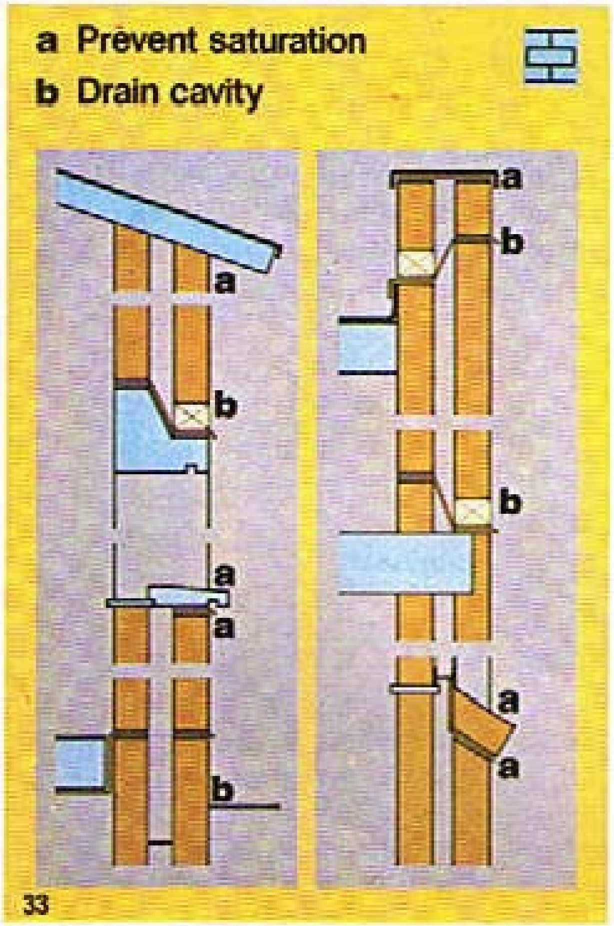
The amount of rain penetrating a building depends partly on the quantity of rain which falls, and partly on the force and duration of



32

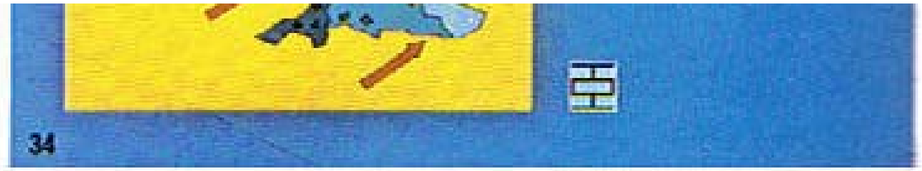
Outer leaves of open-pored bricks having a high rate of absorption will absorb water washing over the surface. In conditions of severe exposure and continuous driving rain, water will eventually reach the inner face through the pore structure, first as dampness and eventually as free water.

Dense bricks with low absorption transfer little water through the body of the brick, but large quantities of water running down the glass-like face may be drawn through capillary paths formed where fine cracks occur when dense cement-rich mortars are used with dense bricks (32). See the section on mortar.



33

Whichever type of brick is used in an outer leaf, it should be


34

The amount of rain penetrating a building depends partly on the quantity of rain which falls, and partly on the force and duration of the wind blowing the rain on to the building. The quantity of rain is measured in mm/annum and the force and duration of the wind as average windspeed in m/s. The product of these two factors m/s × mm is called the Driving Rain Index (34).

The diagram represents a map showing contours joining points having equal driving rain indices.

35

A simplified map based on the driving rain index divides the country into areas of severe, moderate and sheltered exposure.

All areas within 8 km of the coast or major estuaries must be considered as being one degree of exposure higher than that shown on the map (35).

Also published are Driving Rain Roses which indicate the proportion of total time during which the wind blows from a given direction (36). A full explanation of the Driving Rain Index can be found in BRS Digest No. 127 'An Index of exposure to driving rain'.

References quoted in this section and further reading:

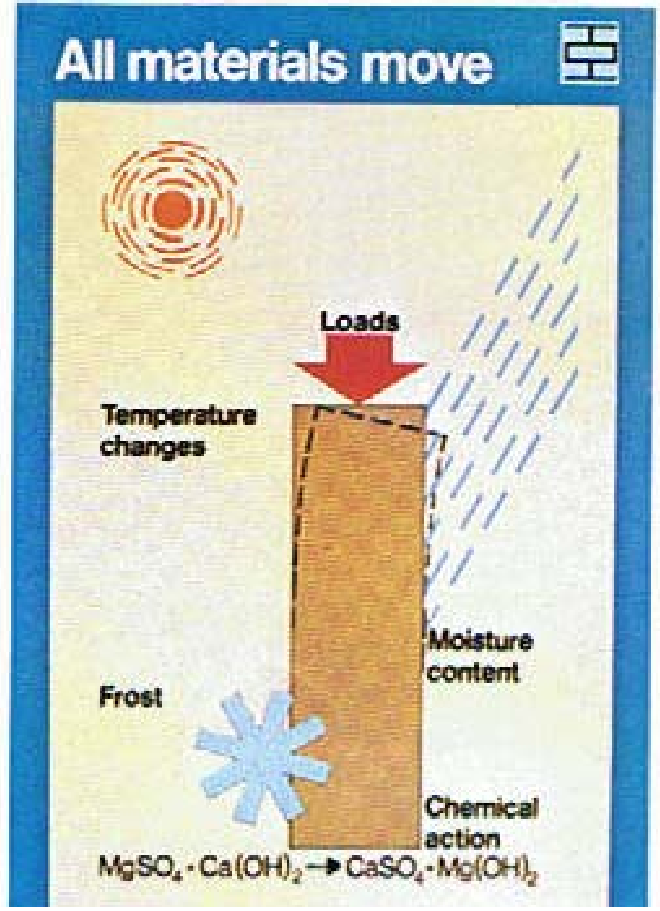
Building Research Station, Digest 127 March 1971. 'An Index of Exposure to Driving Rain'.

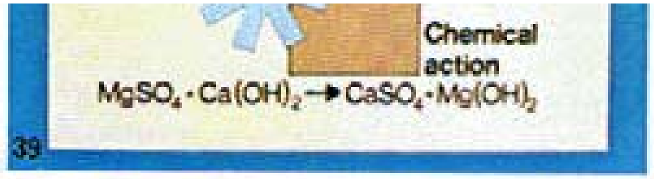
CP 121: Pt 1: 1973 'Walling – Brick & Block Masonry' Section 3.5.1. and figures 8 & 9.

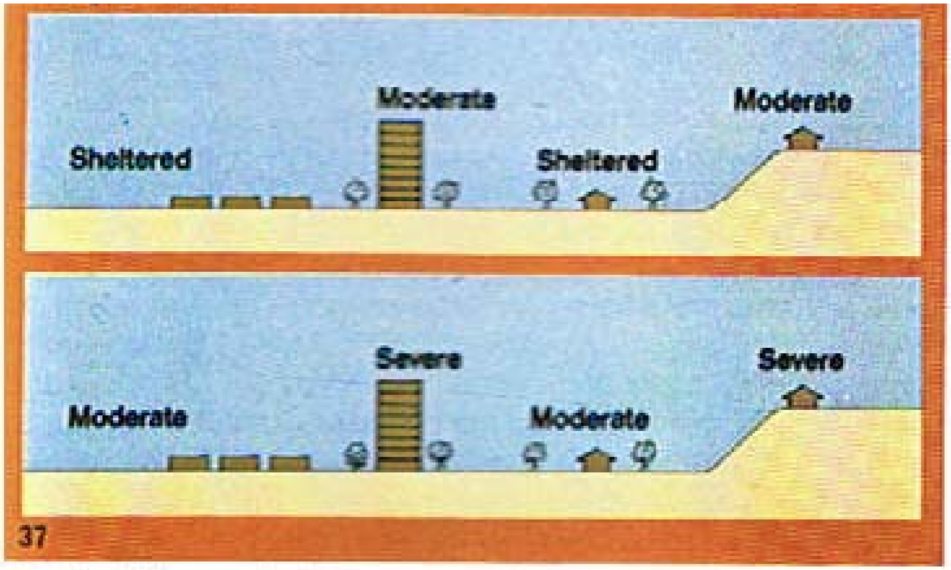
SCP tn5. 'Brickwork: Resistance to Rain'. Structural Clay Products Ltd., 230 Hight St, Potters Bar, Herts. July 1973, 50 p.

DIMENSIONAL STABILITY

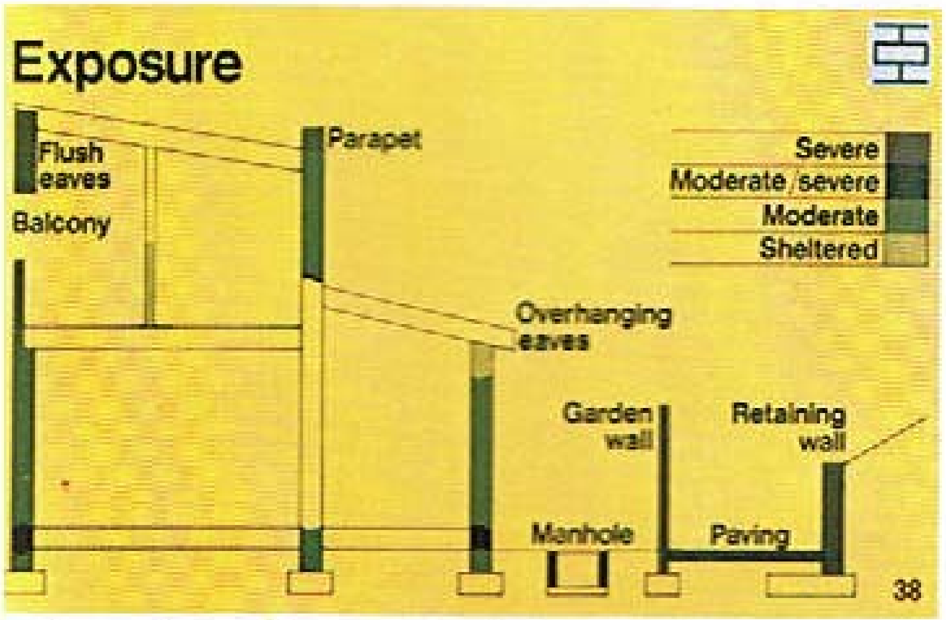
Bricks and brickwork, like all other materials, move. The amount depends on varying circumstances. The consequences of movement must be anticipated and when necessary allowances made in the design (39).







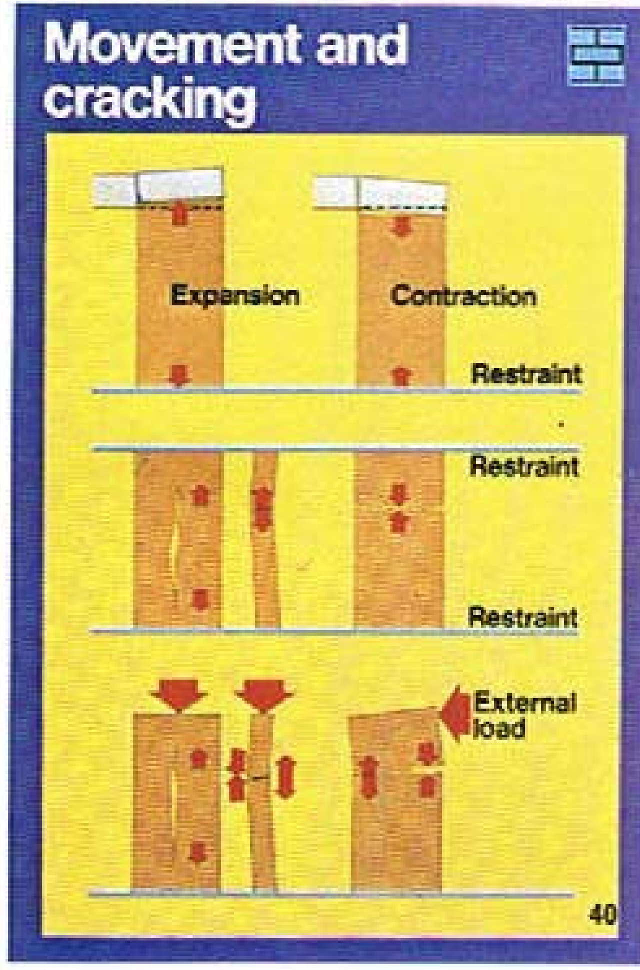
High buildings or buildings on high ground should also be considered as being in an area one grade higher than that shown on the Driving Rain Index map (37).



...ally the degree of exposure to which brickwork is subjected will depend on its position in a building and upon the detailed design

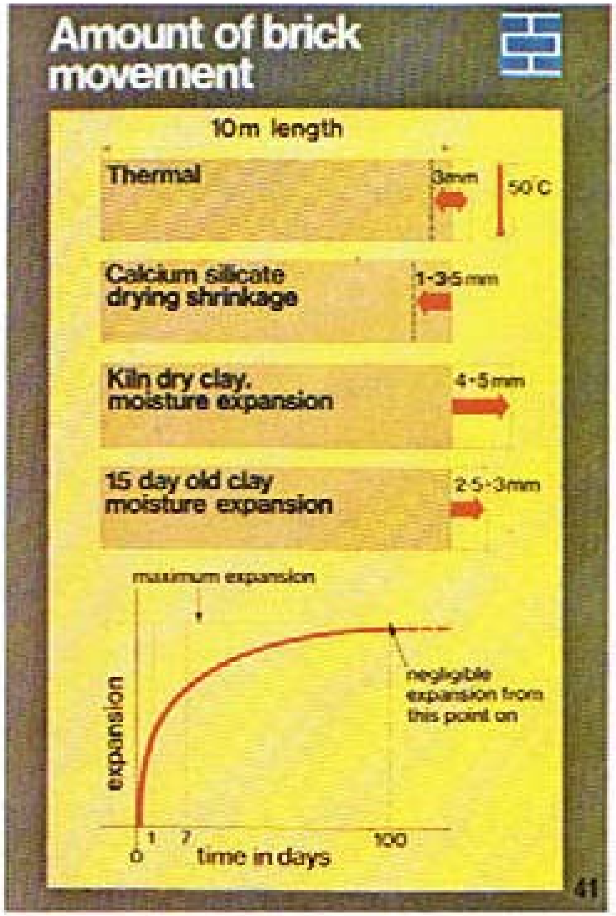
If the effects of movement are ignored:

1. damage may be caused to adjacent materials
2. the material which is attempting to move, if restrained and unable to contain the forces set up, may crack or deform (40).



In order to make provisions for movement it is necessary to know the nature and extent of movements in brickwork.

The diagram (41) indicates the movement which might occur in a



ten metre length of unrestrained wall. The amounts are derived from the coefficients of movement quoted in CP 121: Appendix C. Students should refer to this for more detailed information.

All bricks are subject to reversible thermal movements which persist for the life of a building. The amount of movement is greater for dark-coloured materials and for those exposed to the sun for long periods *(CP 121: App. C. Table 10)*.

Calcium Silicate (sandlime, flintlime) bricks are subject to some initial and mostly irreversible shrinkage soon after the completion of building. The amounts in the diagram are a direct interpolation of the movement of individual bricks *(CP 121: App. C: Table 12)*. In practice, movement may well be less than this as the units seldom become as completely saturated or so completely dry as in the conditions of test given in BS 187: Part 2.

From the moment clay bricks leave the kiln they begin to take up moisture and expand. In most cases 50 % of the total expansion

If a long wall of clay bricks is restrained at one end only, the unrestrained top may expand horizontally more than the restrained bottom causing diagonal tension cracks in the weakest parts between windows. Flexible dpcs offer less restraint and may result in the wall sliding over the dpc.

A wall of calcium silicate bricks, subject to initial shrinkage, may develop random vertical cracking usually at points of weakness through windows and door openings (42).

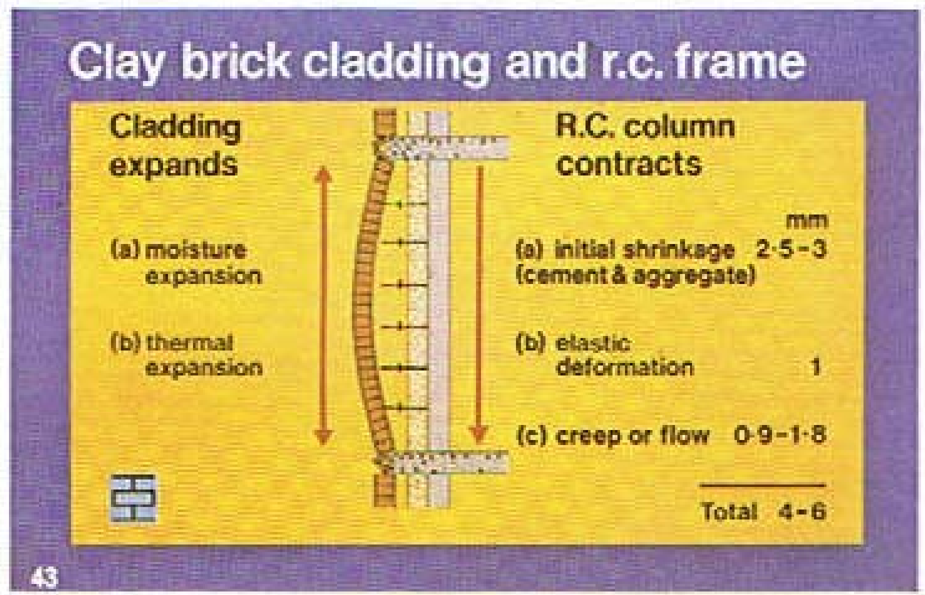
Cracking can be avoided in all such instances by the provision of movement joints at positions chosen by the designer and in the case of calcium silicate bricks by using the correct strength of mortar. Many solutions are possible but they are best considered at the earliest stages of the design, rather than put in as an afterthought.

The frequency of movement joints is recommended in CP 121 section 3.3.6.2. ie *a 10 mm wide joint every 12 m for clay bricks and between 7.5 m and 9 m for calcium silicate bricks.*

Horizontal reinforcement in the bed joints has been used in a wall with movement joints at 24 m intervals. No distress has occurred over a period of seven years.

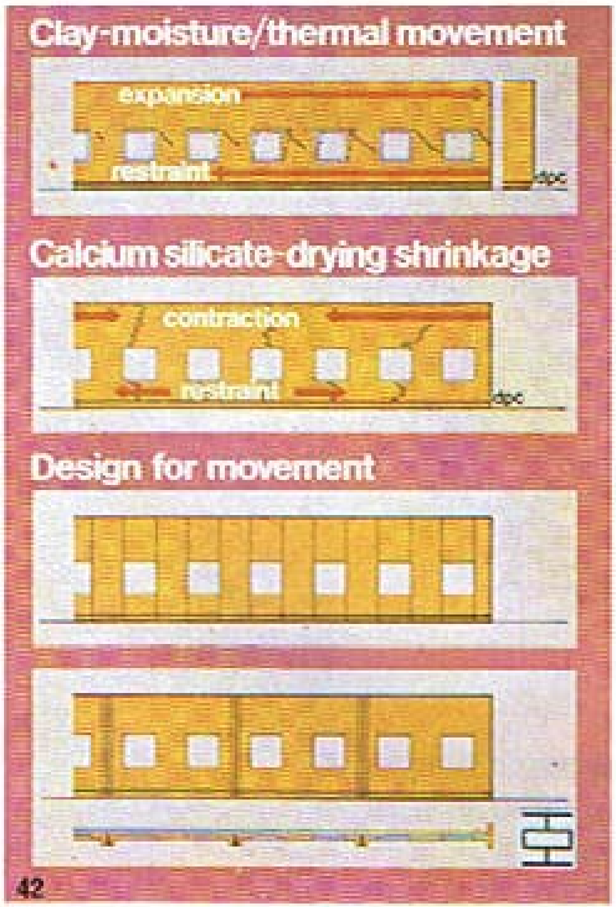
The positioning of movement joints in a building requires the special attention of architects and engineers for each new project. Guidance is given in 'Movement Joints in Brickwork' by K. Thomas.

For calcium silicate bricks see 'Movement in Brickwork' by the Calcium Silicate Brick Association.



of building. The amounts in the diagram are a direct interpolation of the movement of individual bricks *(CP 121: App. C: Table 12)*. In practice, movement may well be less than this as the units seldom become as completely saturated or so completely dry as in the conditions of test given in BS 187: Part 2.

From the moment clay bricks leave the kiln they begin to take up moisture and expand. In most cases 50 % of the total expansion takes place in the first 2 days. Often the degree of compression caused in a restrained wall can be contained. In situations where buckling may result or where short returns in half brick walls may lead to cracking, movement joints should be incorporated and it may be advisable to avoid the use of bricks fresh from the kiln *(CP 121: Appendix C: Table 11 for coefficients of movement and clause 3.3.3.1.)*.



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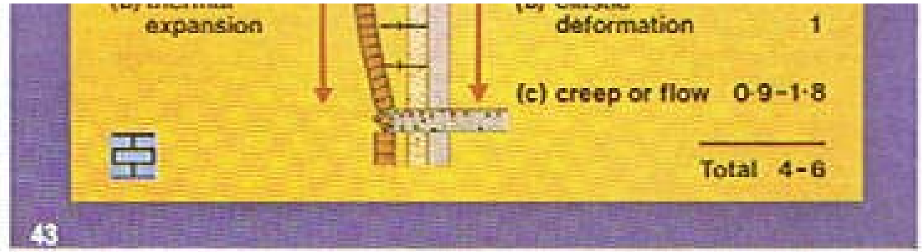
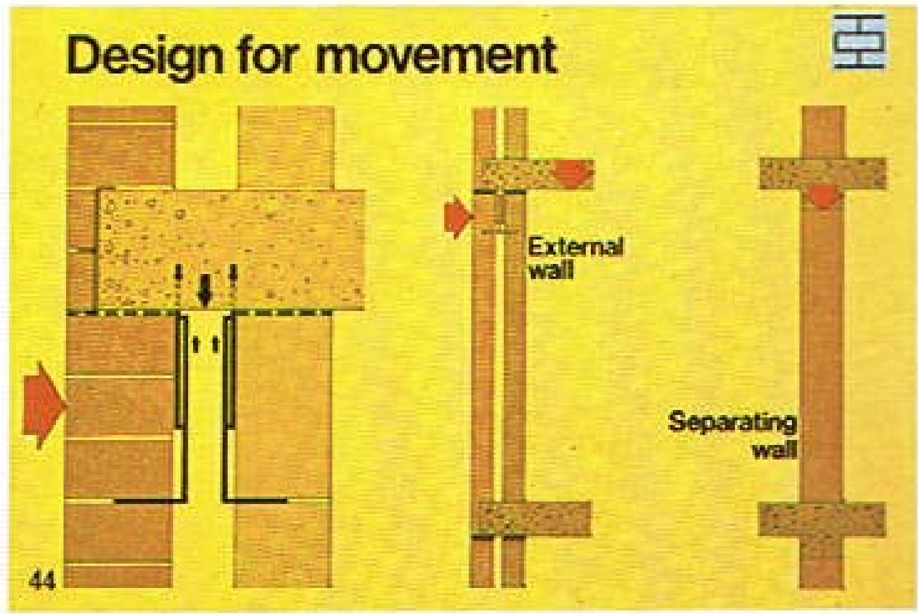


43

Brickwork cladding should not be built tightly into a reinforced concrete framed building. The considerable shrinkage in each storey of the concrete frame, for the reasons shown, and the slight moisture and thermal expansion of the bricks may cause bowing of the cladding particularly when brick slips are used and the half-brick outer leaf overhangs the concrete structure (43).

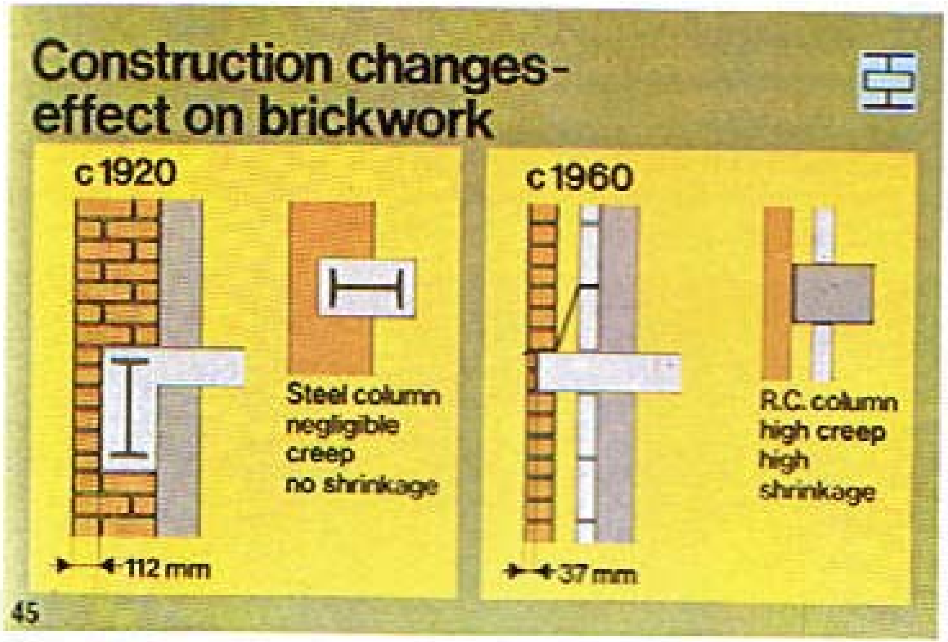


44

This problem can be avoided by providing a movement joint between the top of the brickwork and the concrete. An anchorage must then be provided in order to restrain the top of the brickwork horizontally while allowing differential vertical movement (44).

This problem does not occur with internal walls such as separating walls as these readily absorb the compressive forces without deforming.

This subject is dealt with fully in BDA Technical Note No. 9.

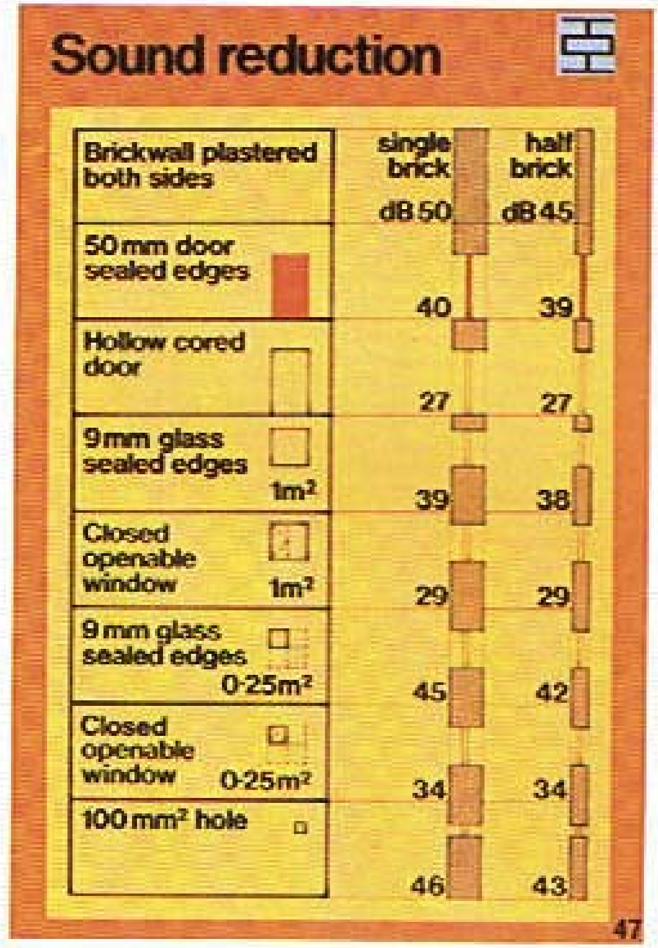


This recent problem has arisen from insufficiently considered design changes. Structural steel has been replaced by reinforced concrete, and solid one and half brick cladding has been replaced by cavity walls with a half-brick outer leaf having only 68 mm of support (45).

This example emphasises the need for an understanding of the physical properties of materials, a constant reference to basic design principles and an up-to-date knowledge of technical reports compiled from experience.

References quoted in this section and further reading:
CP 121: Part 1: 1973 'Walling – Brick and Block Masonry'.
*BDA Technical Note No. 9, 'Further observations on the design of brickwork cladding to multi-storey rc frame structures' by Donald Foster RIBA. April 1975.
'Brickwork: Dimensional Stability' SCP tn4 Structural Clay Products Ltd, 230 High St., Potters Bar, Herts. December 1971, 50 p.
'Movement in Brickwork—recommendations for the construction of movement joints'. Publicity Committee Paper No. 1 by the Calcium Silicate Brick Association Ltd, Lloyds Bank Chambers, 3 Town Square, Stevenage, Hertfordshire. SG1 1BP.
*Obtainable from The Brick Development Association.

Regulation G(1) and (2) concern the requirements for sound reduction in walls between dwellings. The requirements are deemed to be satisfied if the wall is built of brick plastered both sides with a minimum of 12.5 mm of plaster and the whole weighs on average not less than 415 kg/m². This requirement can be met with most types of bricks and, in fact, the difference in sound reduction between walls using the heaviest and lightest bricks is scarcely discernable. The requirement in Scotland is for a wall to be not less than 490 kg/m². *(See Schedule 10 H2(1) The Building Standards (Scotland) (Consolidation) Regulations 1971).*

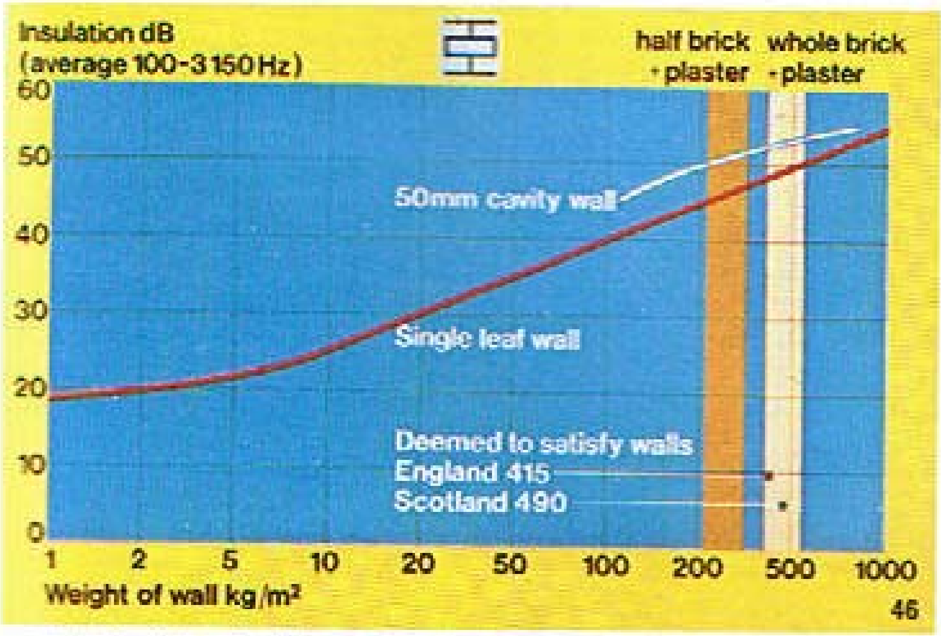


The excellent sound reduction qualities of brick walls can be negated by the introduction of designed or accidental openings which greatly reduce the effectiveness of a wall, making the difference between a wall one-brick thick and a half-brick wall negligible

of movement joints'. Publicity Committee Paper No. 1 by the Calcium Silicate Brick Association Ltd, Lloyds Bank Chambers, 3 Town Square, Stevenage, Hertfordshire. SG1 1BP.
*Obtainable from The Brick Development Association.

SOUND INSULATION

Walls which are heavy but not too rigid are, in general, still the most economical and practicable way of reducing sound transmission between rooms or buildings to an acceptable level, despite recent developments in the use of lightweight walls for this purpose. A wall one brick thick will give 5 or 6dB reduction more than a half-brick wall (46).

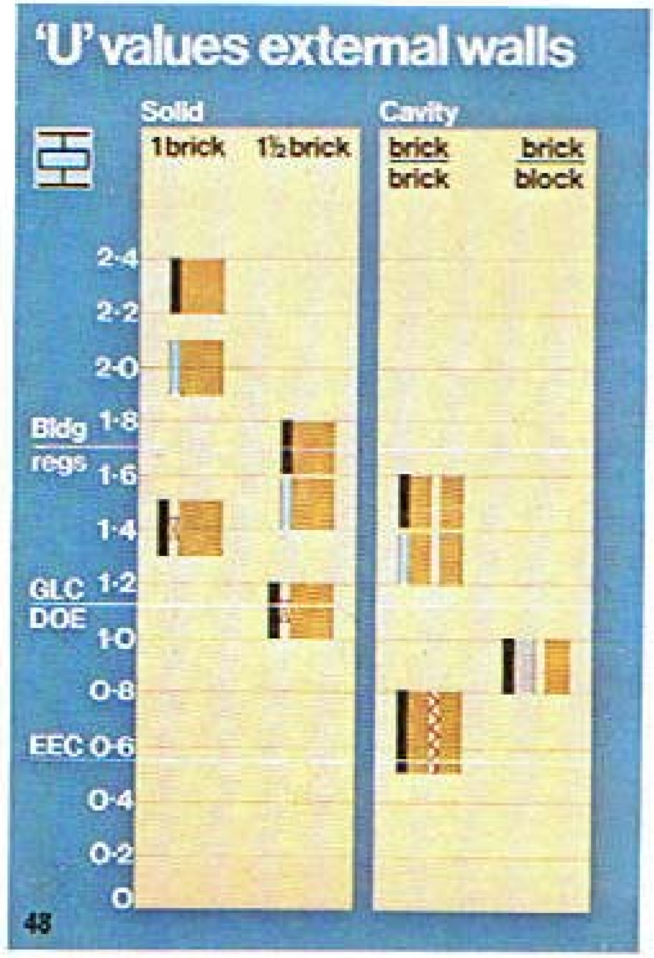


Part G of the Building Regulations concerns sound insulation.

The excellent sound reduction qualities of brick walls can be negated by the introduction of designed or accidental openings which greatly reduce the effectiveness of a wall, making the difference between a wall one-brick thick and a half-brick wall negligible (47).

THERMAL INSULATION

Events have now overtaken the production of this diagram (48) and regulation F3(1) of the Second Amendment to the Building Regulations requires the 'U' value of any part of an external wall to be not more than 1.0 W/m² °C. Forms of construction deemed to satisfy this regulation are set out in Schedule 11 of the Second Amend-

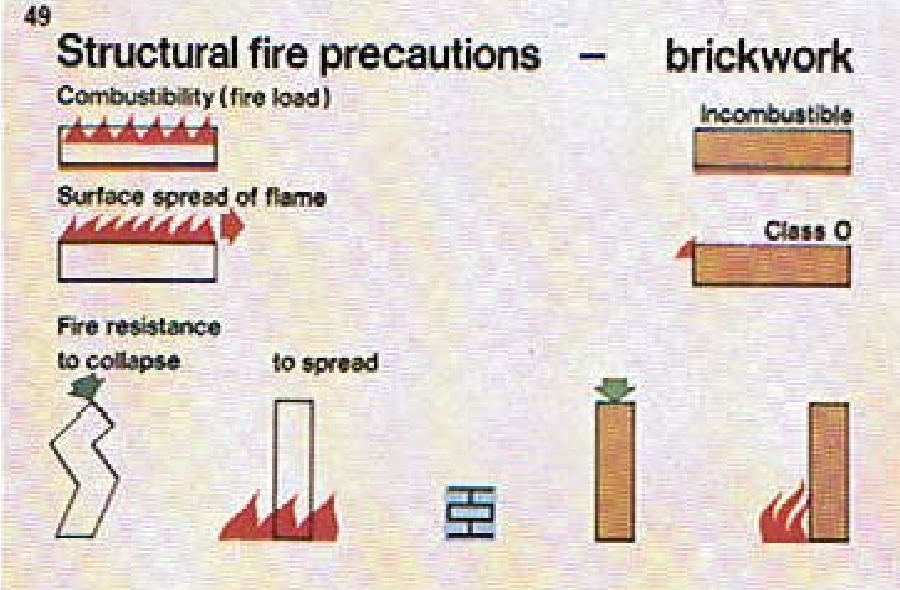


ment. However, the new regulations are complex and the requirement of F3(2) for an average 'U' value of perimeter walling, including openings, of not more than 1.8 W/m² °C means that, depending on the proportions of the external wall and the amount of opening, the 'U' value of the external wall may have to be better than 1.0 W/m² °C to satisfy the Building Regulations. Methods of attaining improved standards of thermal insulation in external brick walls are described in BDA Technical Note No 10 'Thermal insulation and sound insulation of walls to dwellings'.

FIRE PROTECTION

Brickwork is incombustible and does not contribute to the fire load of a building (49).

49



Brickwork does not facilitate the spread of flame and is Class 0, the highest class, when tested in accordance with BS 476. Some surfaces, notably those to circulation areas in buildings other than 2 storey houses, are required to have a class 0 surface *(see the Table to Building Regulation E15).*

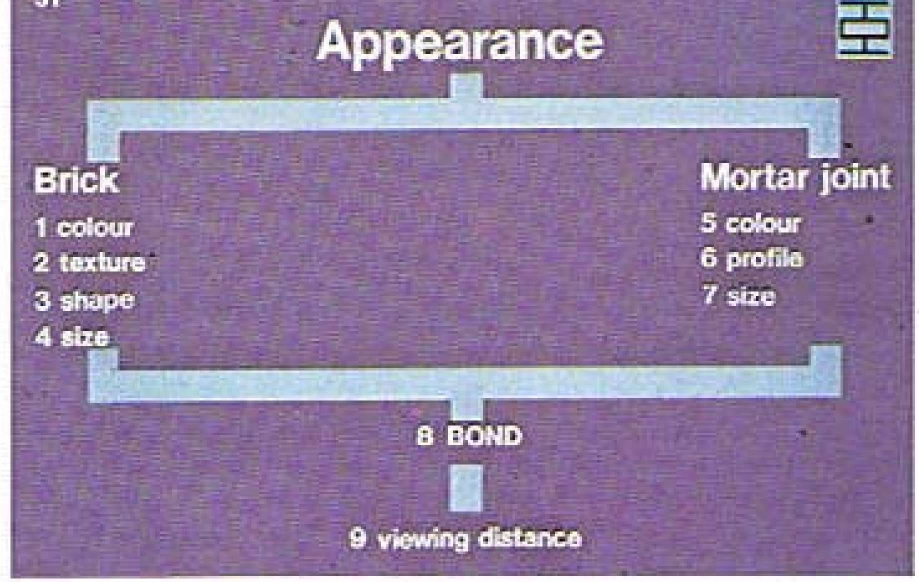
Brickwork is highly resistant to collapse in fire and to the transmission of fire from one side of a wall to the other. The term 'fire resistance' in the Building Regulations concerns both these properties.

50

APPEARANCE

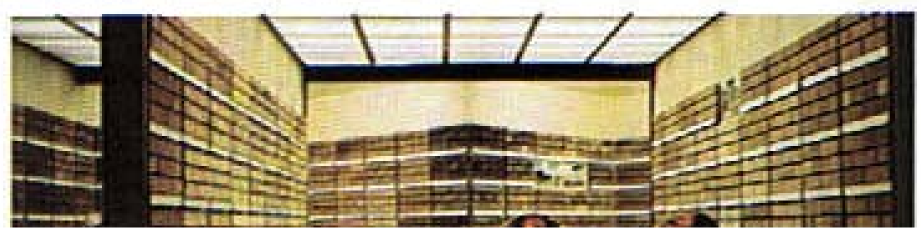
The appearance of brickwork depends not only on the aesthetic judgement of the designer but also on his knowledge and experience. It is useful, therefore, to analyse the factors which affect the appearance if only to form a basis for evaluating the buildings around us (51).

51



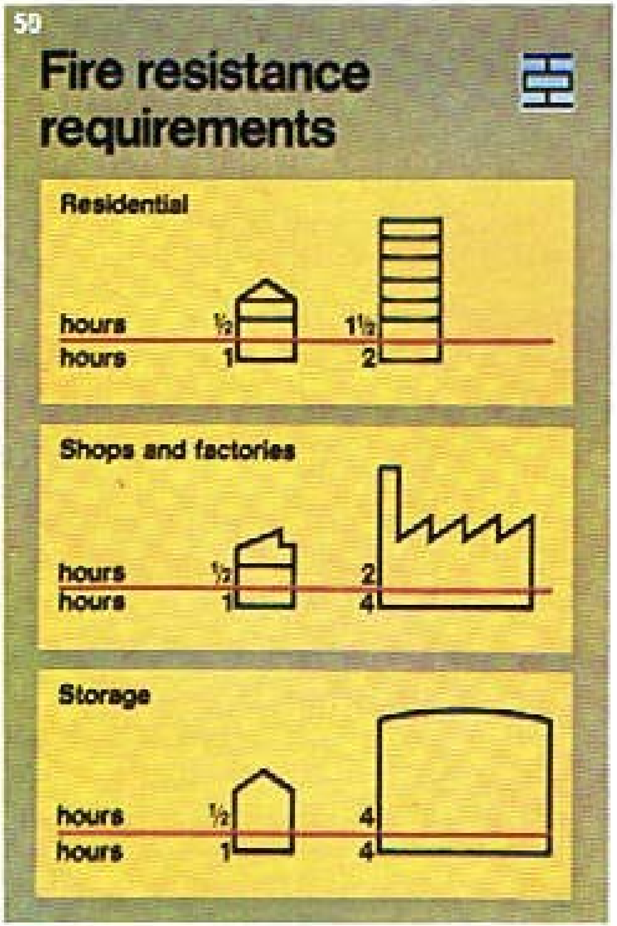
Brick colour and texture

The variety of raw materials, methods of firing, the use of additives and surface treatment by sanding or texturing produce nearly two thousand different bricks. An indication of the wide range available is given in the BDA publication 'Brick is Colourful'. Many manufacturers produce catalogues of their full brick range in colour and, in 1975, the Brick Advisory Centre was opened on the ground floor of the Building Centre in Store Street, London (52). Bricks are displayed in panels classified by colour. Staff from the Brick Development Association are on hand to give further information on the properties of the bricks.



2 storey houses, are required to have a class 0 surface (*see the Table to Building Regulation E15*).

Brickwork is highly resistant to collapse in fire and to the transmission of fire from one side of a wall to the other. The term 'fire resistance' in the Building Regulations concerns both these properties.



The degrees of fire resistance required, measured in hours, for various walls in different types of buildings are set out in Table A to Building Regulation E5 and vary from a half-hour to four hours. Note that the highest standard can be met by unplastered brickwork 200 mm thick (50).

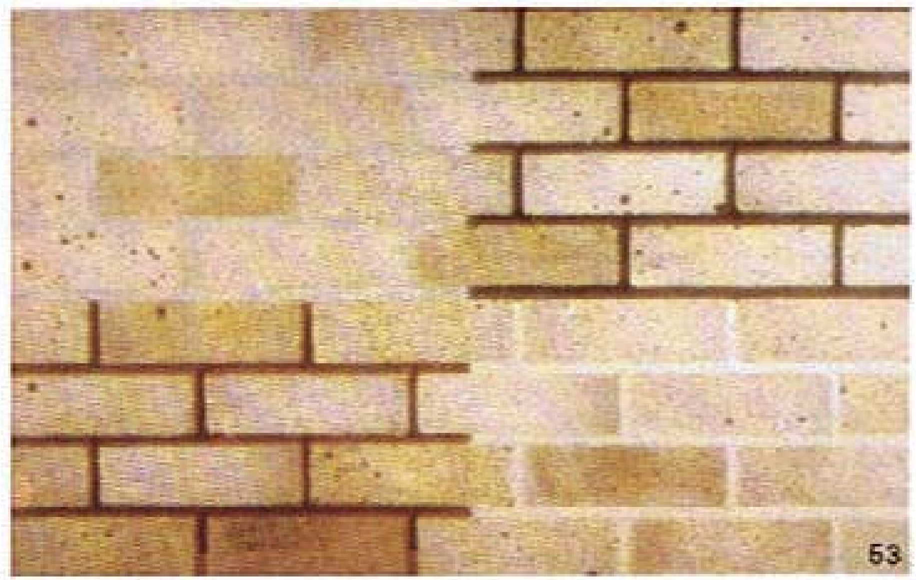
The forms of construction which will meet these standards are described in Schedule 8 of the Building Regulations and brick is dealt with in Part I A3, A10, B3, C3, Part V A(A) 2 & A(B) 1.

mation on the properties of the bricks.


52

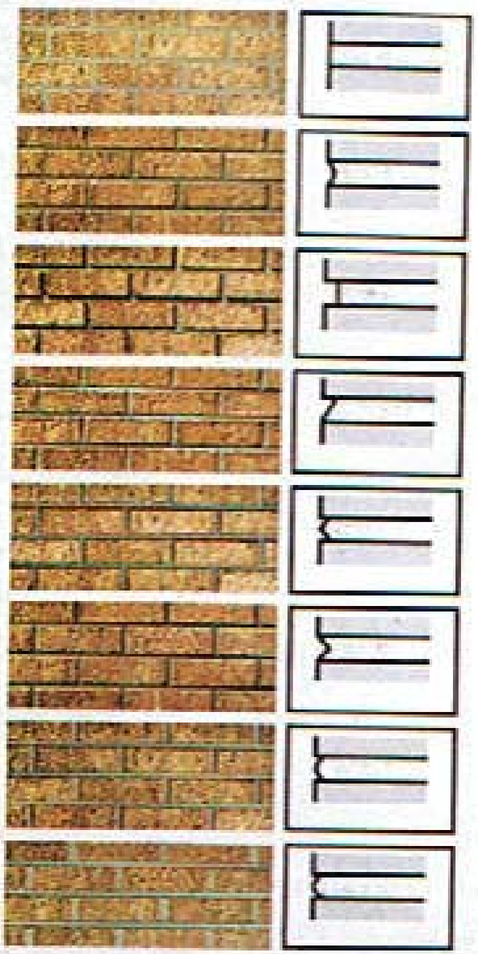
Joint colour

With each brick type, different mortar colours can be used to extend still further the variety of brickwork. The colour of mortar depends to some degree on the sand and the mix. Coloured pigments can be added to the mortar but should conform to BS 1014: 1961 and should not exceed 10 % by weight of the cement. If carbon black is used it should not exceed 3 % by weight (53).


53

Joint profile

The profile of bed joints and perpends considerably modifies the appearance of finished brickwork especially when viewed at close quarters or in the middle distance (54 & 55). Generally, brickwork is jointed by striking, raking or rubbing the mortar while it is still 'green''. Pointing on the other hand consists of raking out the 'green' mortar in the joint to a depth of 13–20 mm and then refilling the joint with fresh mortar. Pointing should be specified only when it is impracticable to gain a desired visual effect by jointing which is not only cheaper than pointing but disturbs the mortar bed far less. Recommendations concerning jointing and pointing are made in CP 121: clause 3.12.3. It is often convenient to specify ready-mixed mortars where a consistent colour is important.



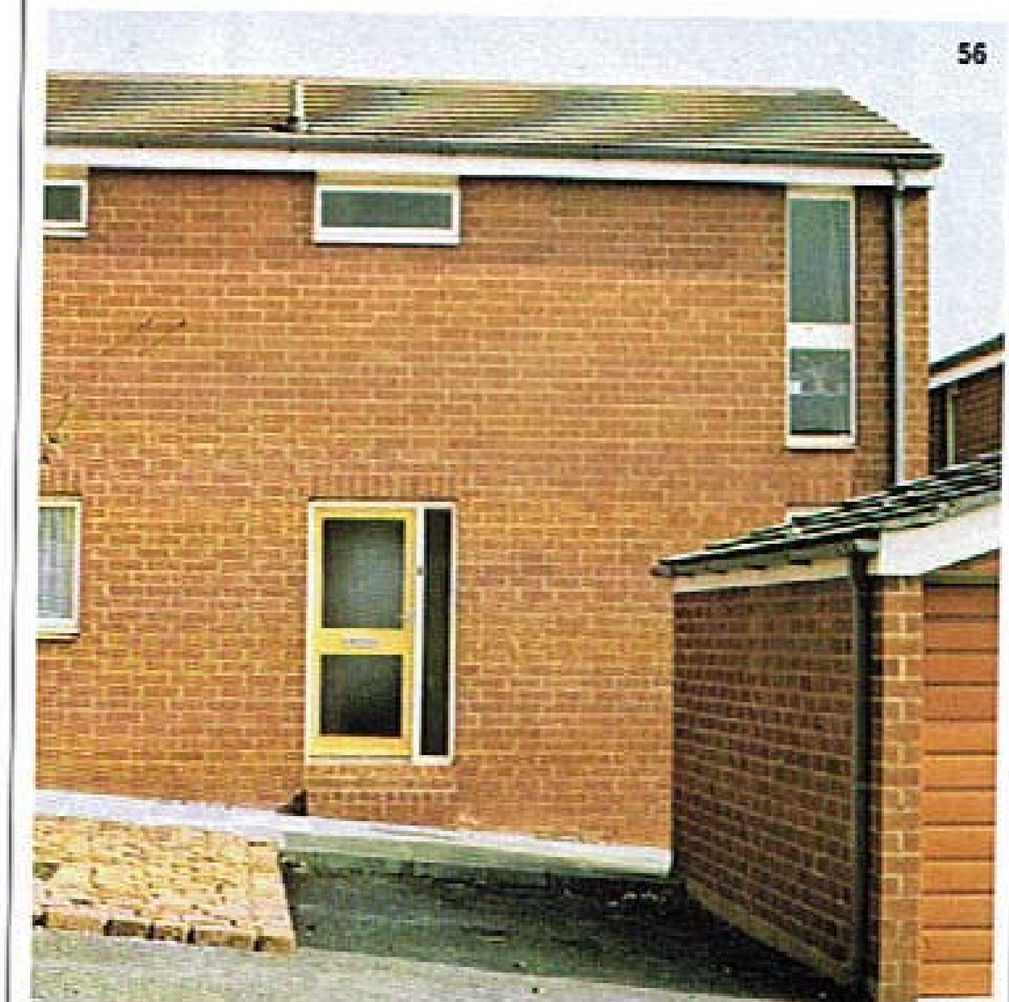
54

Brick size and shape

The British standard brick has a format size, which includes an allowance for jointing, of 225 mm × 112.5 mm × 75 mm high. Other sizes are quoted in a British Standards Draft for Development DD34: 1971 'Clay bricks with modular dimensions'. These format sizes are:

300 mm × 100 mm × 100 mm
200 mm × 100 mm × 100 mm
300 mm × 100 mm × 75 mm
200 mm × 100 mm × 75 mm

Use of these bricks which have an unfamiliar size and proportion will affect the scale of the building (56).



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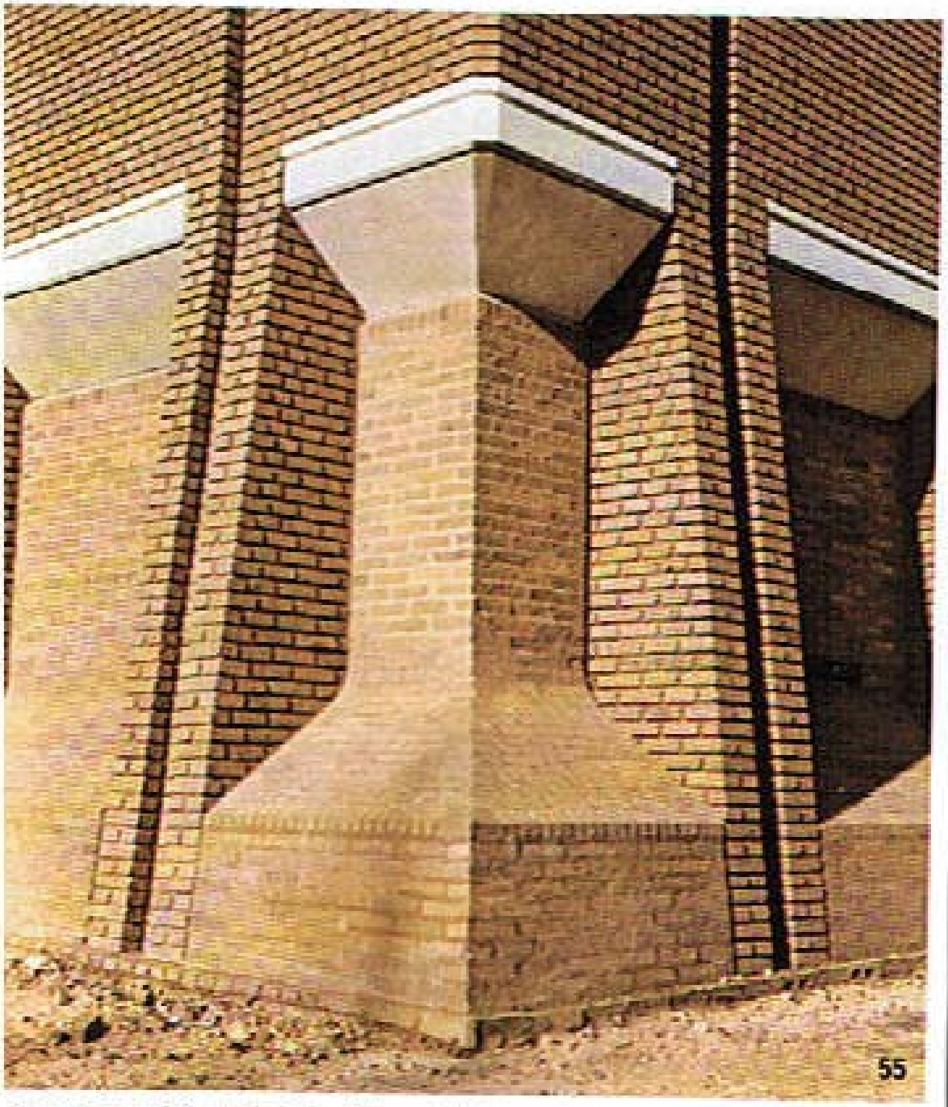


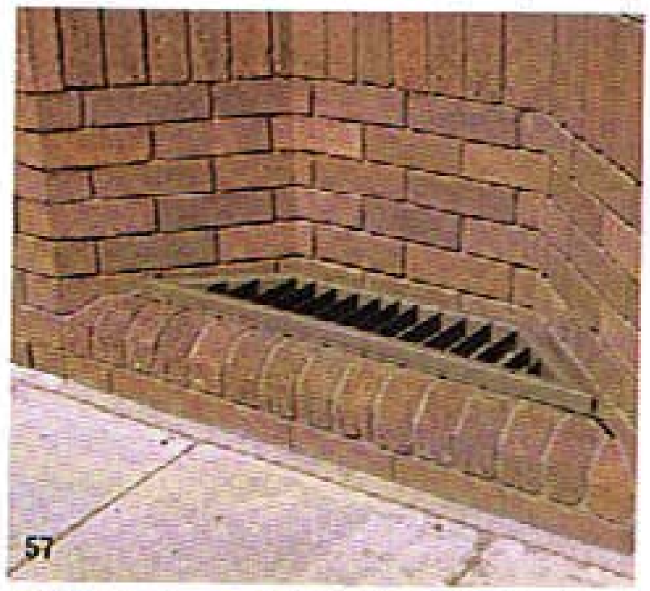
55

aked and flush joints. Warwickshire Masonic Temple, Birming-m. Architects: John Madin Design Group.

56 300 × 100 × 100 *brickwork. Ashworth Street housing development, Blackburn. Architects: Borough Architects' Department.*

Bricks of different shapes from the normal standard brick are made by many manufacturers and are being increasingly and effectively used by architects to produce a variety of modelling in brickwork. The more common of these special shaped bricks are included in BS 4729: 1971: Shapes and Dimensions of Special Bricks and in a BDA Brick Information Sheet: 'Standard special bricks'. But designers should not assume that all manufacturers make all the special bricks described in this Standard and should make early enquiries of particular manufacturers concerning availability, delivery times, and costs.

It is possible to effectively model a building with only a few carefully selected special bricks. The use of too many different specials in one building can unduly increase the cost and delay the delivery of bricks. All manufacturers will be pleased to advise on this aspect and welcome early enquiries (57).



57

57 *Standard special bricks. Grattan House, Dublin. Architects: Stephenson, Gibney & Associates.*

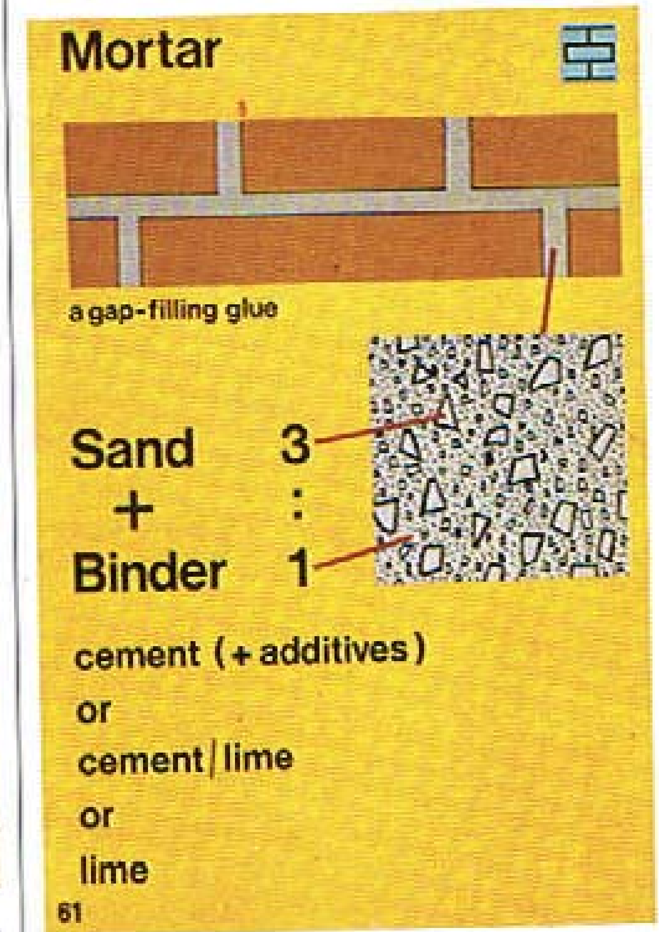
Viewing distance

Brickwork presents a variety of attractive colours, textures and patterns depending on the viewing distance. Detail with a human scale is readily achieved at close quarters where it is of importance in the urban landscape in creating an interesting texture which attracts rather than alienates passers-by (58, 59 & 60).

58

59

MORTAR



61

Mortar can be thought of as a 'gap-filling glue' which evens out slight irregularities in size and shape between bricks, provides a uniform bed and enables loads to be distributed uniformly (61).

Mortar also helps to prevent the penetration of air and water through brickwork.

Mortar consists of an aggregate and binder. The aggregate is a sand having a suitable mixture of grain sizes. The binder was

58, 59, 60 *Three views of Clair Hall, Haywards Heath. Architects: Architects Partnership Aylesbury.*

Mortar can be thought of as a 'gap-filling glue' which evens out slight irregularities in size and shape between bricks, provides a uniform bed and enables loads to be distributed uniformly (61).

Mortar also helps to prevent the penetration of air and water through brickwork.

Mortar consists of an aggregate and binder. The aggregate is a sand having a suitable mixture of grain sizes. The binder was formally lime but today is more often a mixture of lime and cement or cement with the addition of a plasticiser to assist workability.

Mortars made wholly with lime are seldom used today as, apart from having a low ultimate strength, the slowness with which they develop initial strength and stiffness make them impracticable for building slender walls required for reasons of economy.

Lime is used in modern cement mortars mainly in order to improve workability. A good mortar should cling to the trowel and spread smoothly. A cement mortar is harsh to spread and difficult to hold on the trowel.

Today, additives are often used instead of lime to give improved workability more conveniently. Most additives work by entraining small air bubbles which act as a lubricant.

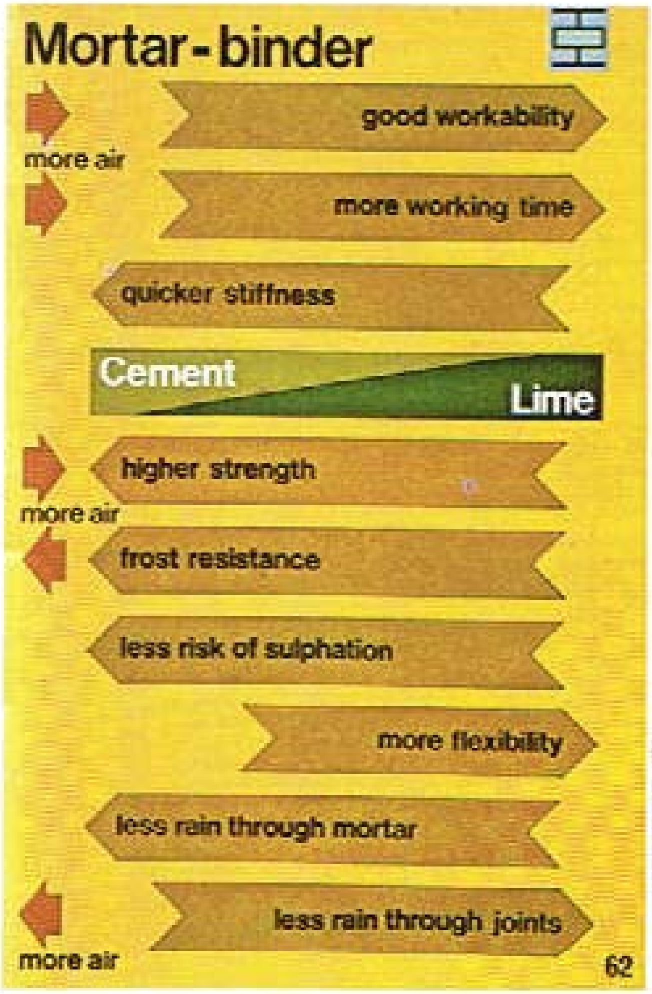
The air spaces between particles of sand account for about one quarter of the total volume. This explains why most mortar mixes are based on a ratio of 1 binder : 3 aggregate.

The proportion of cement and lime in the binder affects the properties of the mortar. Those properties which concern the bricklayer are shown at the top of the diagram and those which affect the finished building are below (62).

Lime improves workability and prolongs the working time. Air-entraining additives produce similar characteristics.

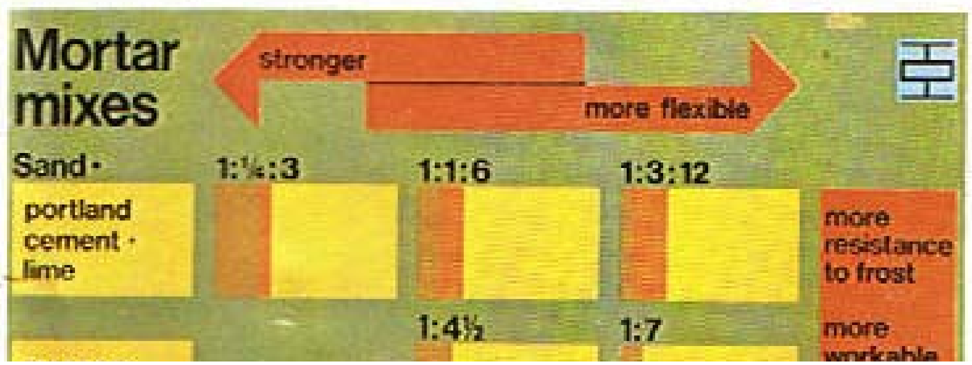
Too much lime delays the setting of the mortar and walls may be unstable and liable to wind or other damage. Bricklayers generally prefer additives to lime as they are more convenient to use.

More cement produces stronger mortar, improves frost resistance, and reduces the risk of sulphation because cement-rich mortar joints in the finished wall absorb less water. A dense mortar, although water resistant within itself, bonds less well with the bricks and small hair cracks may develop and form capillary paths. Strong mortars, that is those rich in cement, tend to produce rigid walls less able to adapt to settlement and other movements than



weaker, more flexible, mortars.

Too much additive or prolonged mixing reduces the mortar strength. With calculated loadbearing brickwork, additives may be permitted only with the permission of the design engineer.



requirements, the type of brick, the degree of exposure and the time of year. Guidance on mortar specification is given in BDA Practical Note No 2 (64).

Publications for further reading and reference:
*BDA Practical Note No 2 'Mortars for Brickwork'
BS 1200: 1955 'Sands for Mortar for Plain and Reinforced Brickwork, Blockwalling and Masonry'.
BS 4887: 1973 Mortar plasticizers.
CP 121: Pt. 1: 1973 'Walling – Brick & Block Masonry' Section 2.5 Materials-Mortar. Table 4.1 Minimum quality of fired-clay units and mortars for durability. Table 4.2 Minimum quality of calcium silicate and concrete units and mortars for durability. Table 3.11 Design-Mortars. Table 4.4 Workmanship-Mortars.
*Obtainable from The Brick Development Association.

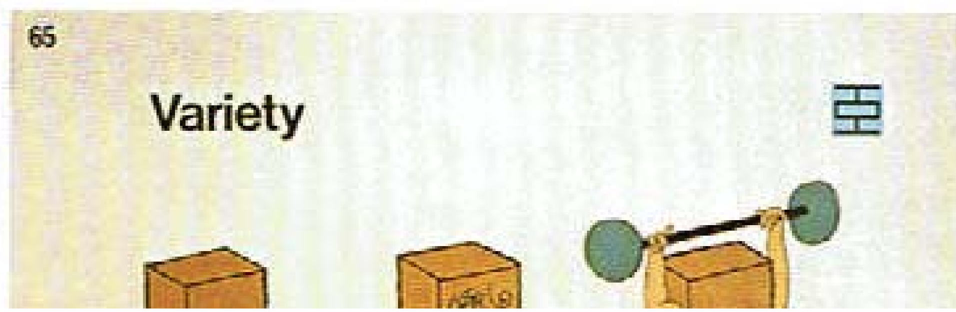
CLASSIFICATION

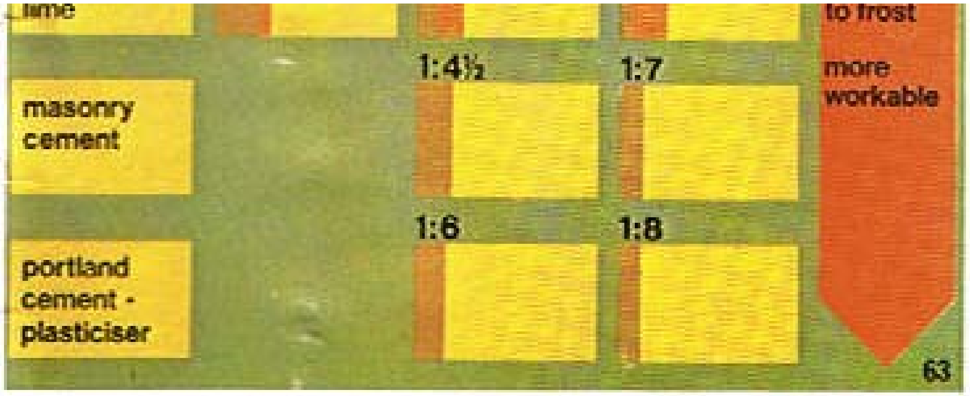
Bricks are classified under three varieties in BS 3921 section 3.2 (65):

1. Common bricks make no special claim to give an attractive appearance but the term does not imply any particular lack of quality in performance.

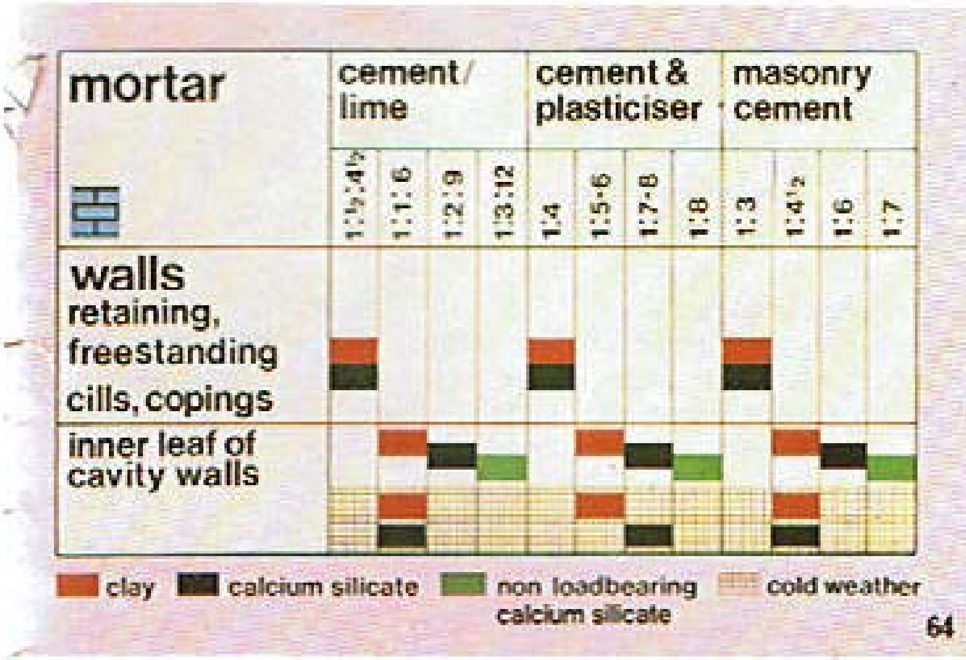
2. A facing brick is specially made or selected to give an attractive appearance but, again, the term implies nothing concerning the physical qualities of the brick. The attractive appearance may result from the natural colour of the material or a texture applied before the brick is fired.

3. An engineering brick has defined limits of compressive strength and absorption.

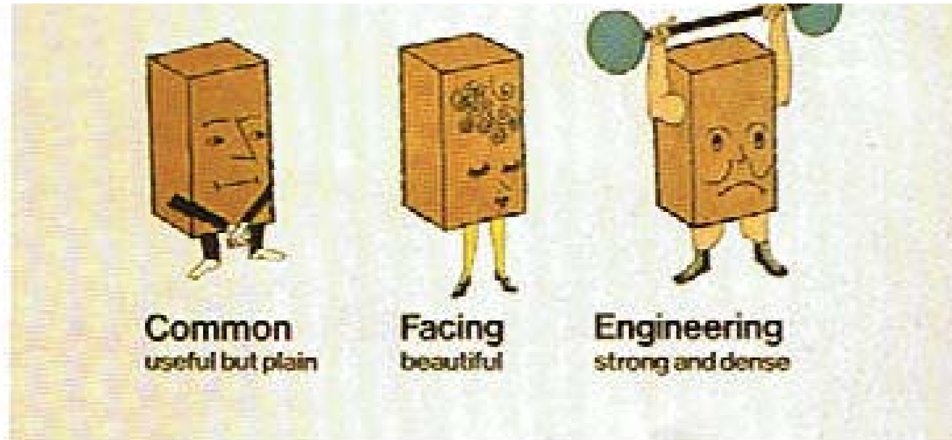


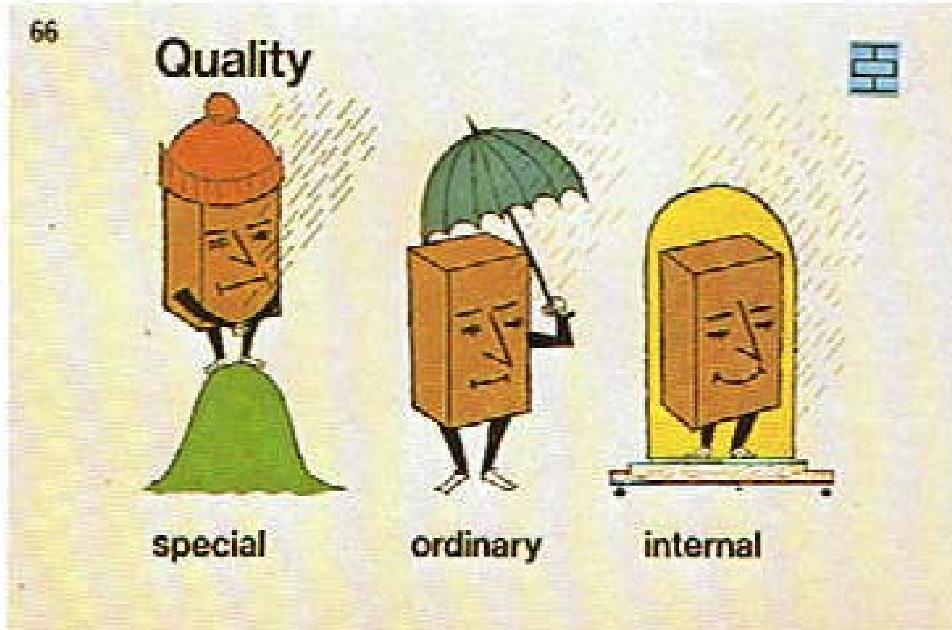


Many factors will affect the choice of mortar. For any given situation a designer may specify a cement/lime mortar, a cement mortar with a plasticiser or a masonry cement. The latter contains an inert filler, such as chalk, to improve workability and a greater proportion of masonry cement is used than Portland cement. Thus 1 part of portland cement to 4 parts of sand plus a plasticizer is the equivalent of 1 part of masonry cement to 3 parts of sand (63).



The specification of mortar mix is vitally important in producing successful brickwork and the choice will depend on strength





Section 3.3 classifies bricks under three qualities (66):

1. Special quality bricks are durable even when used in the most exposed conditions where the structure may become saturated and frozen.

2. Ordinary quality bricks are normally durable in the external face of a building but should be protected from exposed conditions by protective detailing at vulnerable positions such as the tops of walls and window cills.

3. Interior quality bricks may need protection on site during the winter.

Variety	Quality: Special	Ordinary	Internal
Common	✓	✓	✓
Facing	✓	✓	✓
Common engineering	✓	✓	✗
Facing engineering	✓	✓	✗

67

Common and facing bricks may be offered in all three qualities but, in practice, all engineering bricks are special quality (67).

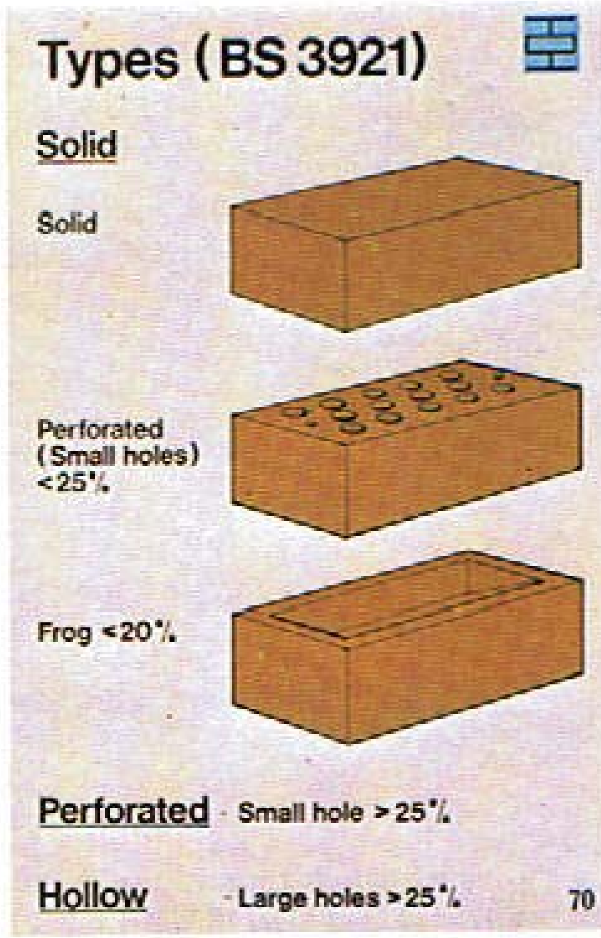
Property — Quality-BS3921

Property	Special	Ordinary	Internal
Strength	≮ 5·2 MN/m^2	≮ 5·2 MN/m^2	≮ 5·2 MN/m^2
Frost resistance	Durable in extreme exposure (a) evidence (b) strong or dense as engineering bricks	Durable in external walls of buildings	Protect construction during cold weather
Soluble salt content	Maximum % by weight	No requirements	No requirements
Efflorescence	Not worse than moderate	Not worse than moderate	Not worse than moderate

68

The physical characteristics of the three qualities of bricks are described in greater detail in BS 3921 sections 11, 12 and 13 (68).

The term engineering brick does not apply to calcium silicate bricks although some reach 48.5 MN/m^2 and more, the strength of a class B engineering brick.



70

BS 3921: section 3.4 defines three types of brick, Solid, Perforated and Hollow.

The bricks with which most of us are familiar come under the category of 'Solid' bricks even though they may in fact be perforated or contain frogs. Perforated bricks are classified as 'Solid' provided the perforations do not exceed 25 % of the total volume. Frogged bricks are classified as 'Solid' provided the frog does not exceed 20 % of the total volume (70).

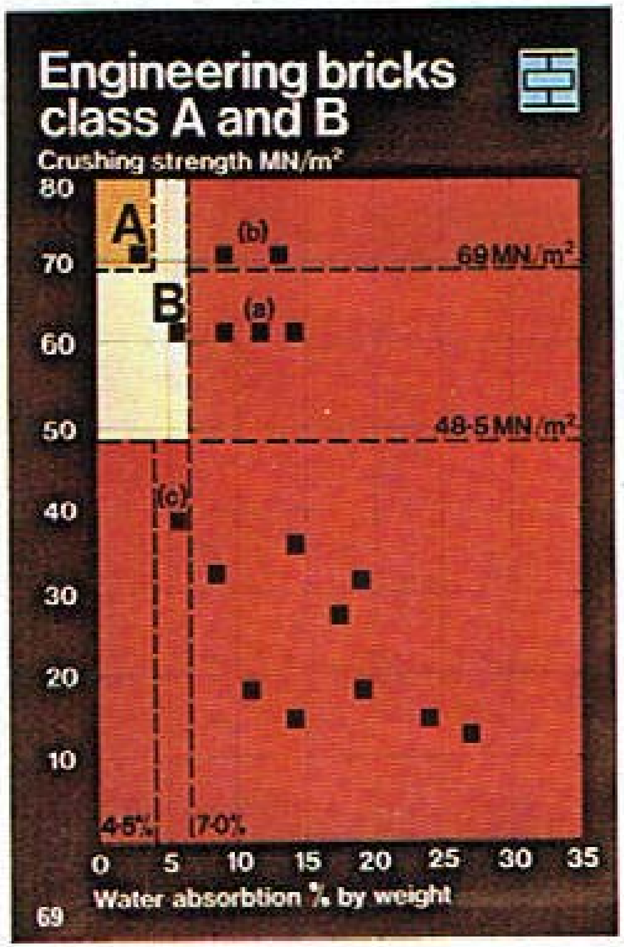
Technical services

The Technical Department of the Brick Development Association

salt content	by weight		
Efflorescence	Not worse than moderate	Not worse than moderate	Not worse than moderate

68

The physical characteristics of the three qualities of bricks are described in greater detail in BS 3921 sections 11, 12 and 13 (68).



69

In this diagram, A & B represent class A & B engineering bricks. Bricks (a) and (b) are as strong as class A & B respectively but their absorption rate is too high to be classed as engineering bricks. Brick (c) is as dense as a class B brick but is not strong enough for an engineering brick. Sometimes bricks (a), (b) and (c) are mistakenly called semi-engineering bricks. Engineering bricks are designated in Table 6 of BS 3921 (69).

ated or contain frogs. Perforated bricks are classified as 'Solid' provided the perforations do not exceed 25 % of the total volume. Frogged bricks are classified as 'Solid' provided the frog does not exceed 20 % of the total volume (70).

Technical services

The Technical Department of the Brick Development Association is always ready to assist with problems of brickwork design or construction. It is also prepared to offer independent advice in cases of special difficulty. Most member companies of the Association maintain expert technical advisory services which are freely available to users of their products.

The BDA Publications Mailing List

All members of the professions associated with the construction industry are entitled to be included in the mailing list maintained by the Association. Addressees regularly receive copies of The Brick Bulletin, BDA Technical Notes, Research Notes and Practical Notes. Applications for inclusion in the list should be sent to: Information Department, The Brick Development Association, 19 Grafton Street, London W1X 3LE. Tel: 01-409 1021.

Students are particularly requested to note that bulk supplies of BDA publications are available to colleges throughout the country. Requests for publications should therefore be made through their Heads of Department—not direct to the Association.

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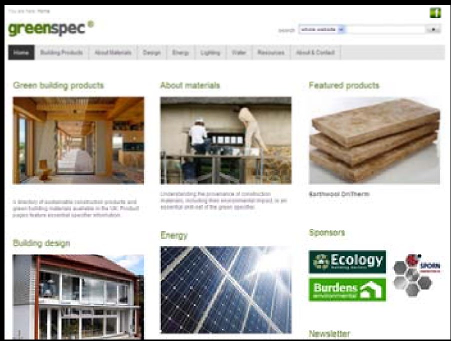

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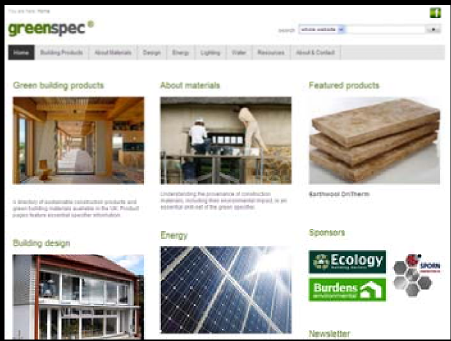

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