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Short Guide

Scottish Traditional Brickwork

HISTORIC SCOTLAND
ALBA AOSMHOR

National Conservation Centre
Ionad Glèidhteachais Nàiseanta

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1. Introduction

Fired clay brick is a building material which, although not as common a masonry type as stone, is a significant part of Scotland's built heritage. This is commonly underappreciated, and the material is generally not valued as much as other traditional building materials. As a result, structures or elements of buildings built of brick are frequently not maintained or repaired in an appropriate manner. This short guide aims to provide building professionals and practitioners, who have cause to work on brick structures, with guidance on a range of problems and issues that might need attention. Whilst the guide is primarily aimed at building professionals, it is likely to be of interest to others, such as contractors, those owning or managing traditionally constructed buildings, and students in relevant fields of study.

This guide is intended to provide a sound base of knowledge in the repair of a masonry type which is likely to be less familiar to building professionals in Scotland than are rubble or ashlar stonework. It covers the broad principles and techniques for the correct repair of traditional brickwork in Scotland. The historic development of brick is discussed and common brick types are described. Basic repair techniques are outlined and the types of replacement bricks and appropriate mortars are considered. Pointing styles are reviewed and considerations when planning cleaning of brick elevations are discussed.

This short guide does not aim to give prescriptive guidance or detailed specifications. Rather, indicative details of repair techniques that may be used in certain situations are outlined and it is the place of the building professional or owner to gauge the appropriateness of the solutions discussed in this document and their suitability to a specific case. If used in conjunction with the suggested further reading and skilled craftspeople it will aid in conserving Scotland's rich heritage of brick built structures long into the future.

The document is published jointly with the Brick Development Association who represent the United Kingdom and Ireland's clay brick and paver manufacturers. The role of the Brick Development Association is to ensure clay bricks are recognised as the materials of choice by architects, regulators, developers, builders, engineers and property owners, and to promote the contribution that brick makes to the places and spaces that people live and work in today. As such they have an important role to play in the repair and maintenance of traditional brick structures.

2. Historical development

Fig. 1 An 18th-century farm house near Dundee built of hand moulded brick.

Brick was introduced to Scotland during the Roman occupation in the first century AD. Following this the use of brick largely died out until the 17th century when isolated examples of brick making emerged and the use of the material began to increase. It was the 18th century which saw the use of brick expand on a considerable scale. This was initially driven by large estates which established small brickworks to supply bricks for the building of garden walls, ice houses and later the construction of domestic housing for estate workers. The 18th century also saw the establishment of a number of commercial brickworks such as that owned by the architect Robert Adam in Kirkcaldy which was operational in 1714. Many early brickworks were located close to or adjacent to harbours and the products transported by sea. In some cases temporary "brick fields" were established to satisfy the demand for bricks for a particular large project such as the building of Fort George or Inveraray Castle.

The number of brickworks and the uses to which brick was put expanded as the 18th century progressed. Many brickworks were situated in areas which had a tradition of building with clay or earth, the raw materials being the same or similar. This gave rise to a number of hybrid construction types; for example brick was used as a permanent shuttering for clay or used to over-clad clay walled buildings. Some early brick buildings were built on a footing of stone rubble and with walls of a thickness which matched those previously used for clay buildings (Fig. 1).

Fig. 2 An early example of a brick built industrial building, The Bell Mill at Stanley Mills, 1785.

Fig. 3 Hand moulding of bricks in Scotland changed little from the 17th to the 20th century (copyright SCRAN).

With the onset of the industrial revolution in the later 18th century and the expansion of urbanisation in the early 19th century brick became an increasingly important building material in Scotland. Urban areas such as Calton in Glasgow and Granton in Edinburgh saw the extensive use of brick to construct housing for the rapidly growing urban population. Industrial buildings were also commonly built of brick, some of the earliest examples being Stanley Mills, Perthshire, built in 1785 (Fig. 2), and a number of large cotton mills in Glasgow built in the first two decades of the 19th century. This demand resulted in a significant expansion of brick making in Scotland. In 1802 an estimated 15 ¼ million bricks were manufactured in Scotland; by 1840 this had risen to 47 ¾ million.

Until the mid-19th century all bricks produced in Scotland would have been moulded by hand and fired in small, intermittent kilns which could hold around 30,000 bricks (Fig. 3). Traditional brick making by hand was a seasonal occupation: autumn was for excavating the clay; the winter frost was utilised to help break up the raw material; spring through to summer saw brick moulding, drying and firing. The clay for manufacturing these bricks came from fairly shallow surface deposits. Such small scale production allowed regular firings of special batches, giving the capacity to produce tiles as well as bricks, something which was economically beneficial to rural brickworks in particular. Temperatures in these kilns could also be controlled with great accuracy. For this reason these small intermittent kilns continued to be used up until the end of the 20th century.

Manufacturing of bricks improved considerably throughout the 19th century, with a greater range of clays, improved moulding techniques, drying methods and firing leading to a considerable rise in the number of bricks produced. The brick making process became increasingly mechanised at this time. The earliest example of this was the adoption of steam rather than horse power to drive pug mills to process clay prior to moulding. This allowed denser clays excavated from deeper pits to be used for brick making. In the 1840s the first mechanised methods of moulding bricks were developed. These operated on the principle of extrusion whereby a column of clay is forced through a brick-shaped die and then cut to shape using wires. One of the earliest commercially successful brick making machines was developed in Scotland, the “Tweeddale Brick and Tile Machine” patented in 1836.

Improvements in manufacturing allowed greater consistency in form and an expansion in the range of shapes and colours of brick available. This gave rise in the period 1850–90 to a much greater level of architectural expression in Scottish brickwork, especially in the construction of industrial buildings. Considerable craft was often devoted to the use of bricks of varying colours to create a polychromatic decorative effect. Other features such as dogtooth courses and new forms of arches also came to be used at this time. Buildings such as Hayford Mills, Stirling (Fig. 4) and Templeton's Carpet Factory in Glasgow, utilised polychromatic brickwork and decorative features to considerable effect.

Glazed brick also began to be produced from the mid-19th century, with Ayrshire becoming a centre of the production of such bricks. Companies such as J and M Craig of Kilmarnock often also produced heavy ceramics such as glazed pipes and sanitary ware. Glazed bricks were employed in Scottish buildings for both decorative and functional reasons where cleanliness or increased light levels were required (Fig. 5).

Improvements in transportation following the expansion of the rail network in the second half of the 19th century allowed the use of brick to spread throughout the country to areas where manufacture did not take place. It also allowed specialised producers to send polychromatic, glazed and special shapes of bricks considerable distances. For example, the polychromatic bricks used in the great Cox's Stack chimney, Dundee (1865) were produced by the firm Allan and Mann of Glasgow (Fig. 6).

Some of the most significant advances in brick manufacturing for Scotland came in the latter decades of the 19th century. New techniques for forming bricks such as the stiff plastic process and the semi-dry process allowed a new raw material, colliery shale, to be used for brick making (Fig. 7). The stiff plastic process first ground the clay before adding just enough water to obtain plasticity, while the semi-dry process subjected the ground clay to significant pressure to form bricks. Colliery shale, often referred to as blaes, was a by-product of coal extraction. At this time many coal companies established brickworks to utilise this waste product, with the bricks thus being termed "colliery bricks".


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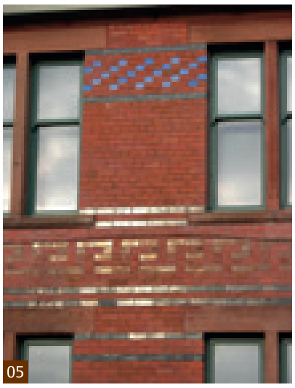
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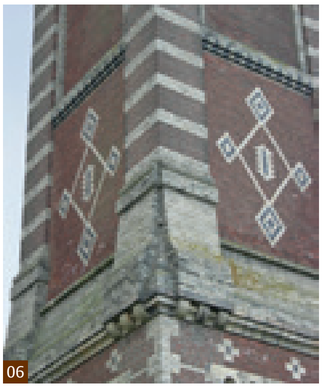
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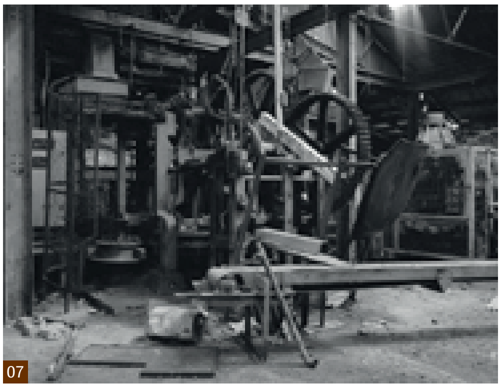
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Fig. 4 Hayford Mills, Stirling, one of many later 19th century industrial structures utilising polychromatic brickwork.

Fig. 5 Glazed bricks were used decoratively and functionally in Scotland as at this late-19th century industrial building, Glasgow.

Fig. 6 Detail of Cox's Stack chimney in Dundee (1865), built using bricks produced by the Glasgow firm Allan and Mann.

Fig. 7 Machines such as this at Drumpark Brickworks allowed methods such as the stiff plastic process to be used with colliery shale as the raw material (copyright RCAHMS).

Fig. 8 Terraced brick housing in Newtongrange, built of colliery shale bricks (1870s). This type of housing was once common throughout much of industrial central Scotland.

Fig. 9 Inchbrayock Viaduct near Montrose, an example of a large engineered structure constructed of brick (1878).

The introduction of continuous kilns which allowed greater numbers of bricks to be fired at a lower cost also took place in the mid to late 19th century. The ability to use blaes as a raw material, to form the bricks mechanically and to fire them in a continuous kiln led to a massive increase in brick production in Scotland, and a significant fall in the price of bricks. By 1900 over 40 million bricks were being produced in the greater Glasgow area alone, in over 30 brickworks.

These developments in manufacturing fundamentally changed brick production and the use of bricks in Scotland. The geographical distribution of brick making shifted from areas where long established clay sources had been exploited along the east coast to the industrialised Central Belt. North Lanarkshire, for example, had just three brickworks in 1850, yet by 1900 it had over 50. Ayrshire, Stirlingshire and Fife also saw rapid expansion in the number of brickworks following the technological advances which allowed colliery shale to be used as a raw material for brick making.

Bricks manufactured from colliery shale were used to construct villages and towns to house the expanding industrial workforce on a scale which is hard to appreciate today. Given the often relatively poor quality of many such buildings the majority have not survived. Isolated examples do still exist, with Newtongrange being the most complete (Fig. 8). Bricks were also commonly used in the mid to late 19th century to form the gable and rear elevations of buildings, particularly tenements, stone being used for the front façade only. Brick replaced stone rubble for this purpose as it became cheaper and more readily available. It also offered the advantages over rubble of being quicker to build and giving a more even structural loading.

The increased quality and consistency of brick led to its increasing use for civil engineering structures in the 19th century. From the mid-19th century the ease of transportation and improved durability of brick led to its use in the construction of a number of lighthouses where geology meant that local sources of stone could not be used. It was also employed for the construction of a very large number of railway bridges, either in their entirety as at Inchbrayock near Montrose (Fig. 9), or more commonly to build the arch rings in combination with stone used for the other parts.

3. Assessing the need for repair

Maintenance

It is important to recognise that in most cases the need to perform the repairs discussed in this guide is likely to result from a failure in building maintenance. The inspection of a building for early signs of defects which are then rectified and the carrying out of small tasks in order to prevent future deterioration are crucial for the wellbeing of a building. Good building maintenance is carried out on a planned and regular basis and focuses on factors that can lead to the deterioration of materials or elements forming a building. Proper maintenance does require investment, but by avoiding costly repairs in the future it is cheaper in the longer term. The cost of a yearly inspection and cleaning of a gutter and downpipe, for example, will be much less than the cost of scaffolding a large area of wall to facilitate the replacement of decayed bricks.

Indicators of decay

As with all elements of a traditional building, brickwork will deteriorate and decay if the property is not properly maintained. The main indicators of problems can be summarised as follows:

Algae or green staining: This is caused by water running down the surface or penetrating into brickwork leading to saturation, often from a defective downpipe or gutter (Fig. 10). Normal exposure to moisture will not give rise to algal growth.

Plant growth: Plants such as ferns, ivy or tree saplings indicate a sustained presence of water in the building fabric. A consistently damp wall is readily colonised by woody plants and other growths (Fig. 11). Plant roots progressively loosen and dislodge masonry as they expand and penetrate the mortar seeking moisture, and can cause both significant decay and structural problems if left unattended.

Fig. 10 Surface growth such as algae, moss and lichen is a sign of excess moisture within brickwork.

Fig. 11 Larger biological growth such as ivy can have serious consequences for brickwork if left unchecked and is a symptom of excess moisture within the wall arising from a building defect (image courtesy of City of Edinburgh Council).

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Efflorescence: A white bloom on the surface of brickwork commonly indicates saturation causing salts from the wall core to be drawn to the surface (Fig. 12). Efflorescence generally appears as a white powdery bloom on the surface of bricks or, in more severe cases, a build-up of white crystals over larger areas of brickwork. If salt develops internally (termed subflorescence) the force of crystallisation can be strong enough to fracture the internal structure of the brick, leading to serious damage and deterioration of the face brickwork and spalling of the surface of the brick. Cement re-pointing is the most common source of efflorescence in bricks, though contamination from other sources such as de-icing salts can cause serious damage.

Missing mortar: In all walls the mortar will gradually break down over time. Crumbling or missing mortar is often simply the result of exposure to many decades of rain and frost. Most lime bonded walls will need repairs to the pointing every 50 years or so. Where walls are subject to prolonged exposure or excessive moisture this can rapidly increase the rate of decay of mortar. Where mortar is missing careful assessment should be made of repair needs prior to work commencing, as discussed below.

Spalling: Where bricks are constantly saturated due to poor building maintenance and subjected to the actions of frost, spalling will occur. This shows by the flaking of the brick surface, known as the "fire skin" and eventual complete deterioration of the brick (Fig. 13). Dry masonry will not be damaged by frost and it is therefore vital that bricks are kept free from saturation. Spalling can also be caused by internal formation of salts, as described above.

Cracks: Cracks in brickwork can be a sign of structural problems, particularly if they run through both bricks and mortar and continue to widen over time. Some cracks may have occurred soon after construction and present little or no danger to brickwork. A period of monitoring can determine whether a crack is active or not.


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Fig. 12 Efflorescence on the surface of bricks caused by salt leaching from inappropriate cement re-pointing.

Fig. 13 Spalling of the face of brickwork is caused by the actions of frost on saturated brickwork. Detachment of the hard fire skin will expose the more porous internal part of the brick which can undergo relatively rapid decay.

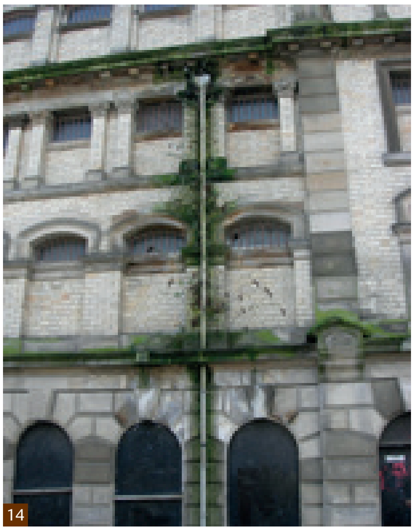
Causes of decay

Blocked or damaged rainwater goods: Blocked gutters and downpipes are a major source of the moisture which leads to decay in brickwork (Fig. 14). Joints between sections of gutters and downpipes can also leak, and although small in volume such leaks can cause saturation of masonry over an extended period. These elements should be kept well maintained and regularly inspected and cleaned to avoid long term damage to brickwork.

Cement re-pointing: The extensive use of cement in re-pointing masonry has unwittingly caused much damage. Cement pointing is hard, brittle and impermeable, and readily cracks on the more flexible substrates of traditional buildings. In some circumstances, especially on exposed areas, such cracks draw water in by capillary action, and due to the impermeable nature of the cement, the water thus admitted is unable to readily escape leading to damage being caused to the brick. Cement pointed walls can become progressively saturated giving rise to decay. This increased water migration can also put pressure on adjacent building elements causing damage. When re-pointing is taking place to traditional brickwork this should be carried out using lime mortar, and where cement has been used in the past and is causing decay its removal should be considered.

Defective surface drainage: At ground level, damage to brick can be caused by inadequate surface water drainage, leading to the adjacent ground becoming saturated and the moisture entering the brickwork. It is not enough to remove water from the roof and into downpipes – the water must also be taken away from the building to prevent dampness entering brickwork at low levels. Sub-surface drainage should be checked to ensure the water from the roof is being taken away from the wall footings.

Copes: Brick walls and chimneys were commonly covered by stone copes (Fig. 15). Where these have become defective water will not be shed effectively, and will instead run down the face of the brickwork. Defects can arise with these copes most commonly where mortar joints require re-pointing or drip details which help the copes shed water are not functioning correctly. The upper part of the wall or chimney then becomes progressively saturated resulting in decay.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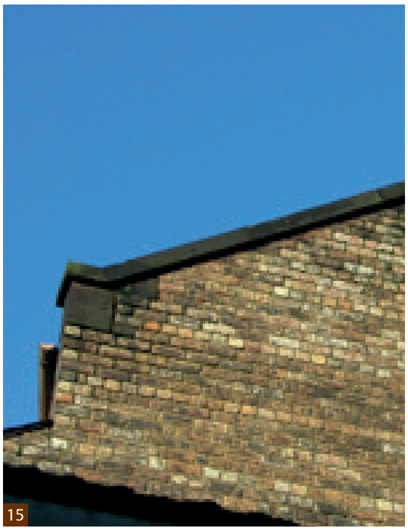
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Fig. 14 Blocked gutters and downpipes are a major source of the moisture which leads to decay in brickwork, in this case causing substantial biological growth.

Fig. 15 Stone skew copes were often used to prevent water entering the joints at the head of brick walls.

Fig. 16 Lead flashing at chimneys and other junctions can be vulnerable to damage.

Fig. 17 The replacement of entire sections of brickwork on an elevation is rarely necessary and can have a detrimental effect on the character and performance of the building.

Roof and other junctions: The junctions between roof and masonry elements are vulnerable to a lack of maintenance and damage. Often protected by lead flashing or mortar fillets, significant damage can result to the masonry if these junctions fail (Fig. 16). Lead parapet gutters, flashings on chimney junctions and mortar fillets on skew copes are particularly vulnerable and ensuring these details function correctly will help protect the brickwork from water penetration.

Condensation: In some internal situations condensation on the inside face of a wall can lead to prolonged saturation and subsequent decay of the brickwork. This is particularly prevalent in basements and areas below ground. The use of modern impermeable paints, applied in an effort to keep damp out, often exacerbate the problem by trapping moisture and preventing evaporation. In addition, the use of modern insulation materials which are impermeable to moisture may also cause problems in the long term. Proper and adequate ventilation is important to avoid decay.

Assessment of repair needs

Where signs of decay are noted during inspection, consideration will need to be given to repair. The decision to repair brickwork should not be made lightly, and repairs only carried out when absolutely necessary. There is always a danger that repairs which are not planned correctly or which are unnecessary could result in more damage in the long term. This can be seen, for example, where small isolated patches of spalling are taken as justification to replace much larger areas of brick. By introducing large areas of denser, less permeable replacement brick, water shed from these areas can increase the risk of decay in the adjacent original bricks. This results in an unnecessary loss of original fabric and often excessive cost (Fig. 17). Likewise where a small area of re-pointing is required, there is no need to re-point an entire elevation. It is important to consider carefully the extent of repair work which is required before it takes place.

Assessing the cause of damage

It is crucial to the success of any repair that the defects considered above which caused the original failure are first assessed and rectified. For example, there is little point in carrying out costly repairs if a source of water remains to cause damage in the future. Likewise, following repairs to brickwork a system of planned maintenance should be put in place to ensure similar problems do not recur in the future. Only through these two actions are repairs going to be truly worth the time and expense. There is a clear link between failures in building maintenance and the need for repair and this should be fully appreciated before any work is embarked upon.

Assessing the need to replace bricks

It is generally the case that when a brick has lost its fire skin through spalling it will need to be cut out and replaced. There is rarely, if ever, a requirement to remove adjacent bricks which have not suffered spalling, and repair should be restricted to only those bricks which have failed (Fig. 18). Where only a small amount of spalling (less than 20% of the brick's surface) has taken place and it is considered that the problem which has led to decay has been rectified, it may be possible to leave such a brick in place (depending on the quality of the original brick). A principle of minimal intervention should generally be adopted. If bricks which have not suffered decay are removed in the process of wider repairs these should be set aside for re-use later. This ensures that original fabric is not lost unnecessarily and also reduces the number of new bricks which have to be supplied.

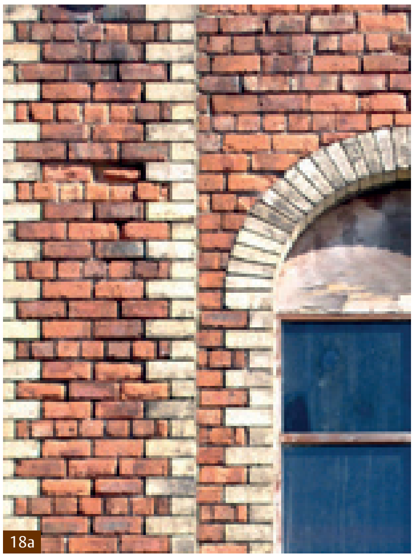
Where bricks exhibit small signs of defects such as cracks or imperfections in the surface their replacement will require a more careful judgement than that where spalling has occurred. These defects may have been present from the time of manufacture. As a general rule if no signs of continuing and worsening decay are present such as cracks widening or the surface of the brick spalling then these should be left *in situ*.

Assessing the need to re-point

Mortar will fail at different rates over a building depending on exposure, and it is unlikely that an entire building will require re-pointing at one time. As a rough guide unless water is penetrating through a joint it will not require re-pointing until it has eroded back to a greater depth than its height i.e. if the joint is 10mm in height but has only eroded 5mm re-pointing will not be required. An exception to this rule would be if inappropriate cement re-pointing was leading to excessive decay in adjacent bricks. In this case it may be felt that the removal of this and re-pointing in lime was required.

Listed Building Consent and planning

Where a building is listed or in a conservation area there may be restrictions on work which can be undertaken and additional consent processes which apply. In all cases it is advisable to contact the local authority planning department prior to any work taking place to establish what consents are required.



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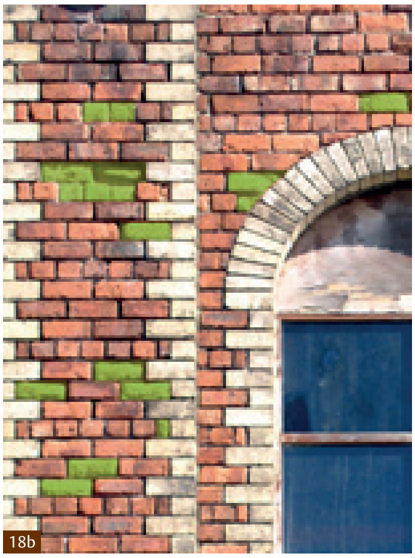

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Fig. 18 Although the wall shown in image (a) needs fairly extensive re-pointing, the number of bricks which need to be replaced is small as highlighted in green in image (b).

4. Traditional and replacement bricks

When replacing bricks during repair work these should match the originals as closely as possible in terms of type, colour, surface texture and finish, durability and size. This section will describe each of these aspects in turn as well as considering the sourcing of bricks for repair work.

Types of brick

There is often a mistaken belief that a brick is a generic building material and that all bricks are interchangeable. In common with other traditional building materials, this is not the case. Just as different stone types vary in their characteristics, so too there are a number of different types and qualities of brick which can be found in common use in Scotland. Broadly these fall into five main types:

- Common bricks
- Facing bricks
- Glazed bricks
- Special bricks
- Engineering bricks

Common bricks

Common brick is the name given to any brick which does not lay claim to any special properties and is intended to be used where aesthetics are of secondary importance and there are no particular physical requirements. They vary widely in their characteristics. Some can be almost as dense and durable as engineering bricks, whilst others such as those known as “composition” or “colliery” bricks, formed by pressing clay mixed with shale waste from coal mines, can be weaker and more porous. Good quality common bricks, well maintained, are a versatile and strong building material. Those of poorer quality were intended to be harled or for internal use, and where used in exposed locations may be susceptible to deterioration and will therefore require greater care. Some common bricks fired at lower temperatures were specifically manufactured for internal work and are unsuitable for use externally.

Facing bricks

Facing bricks are of a higher quality and are more durable than most types of common bricks. They are also likely to be denser, with a smoother surface and of uniform colour. Where suitable quality clay was available, along with appropriate moulding techniques and kiln technology, a brickworks could manufacture facing bricks for use on principal or exposed elevations (Fig. 19).

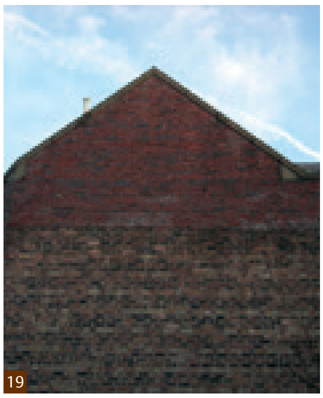


Fig. 19 An example of facing bricks on an exposed elevation with common brick on the lower parts which would have originally been protected by a now demolished adjoining building, Stirling.

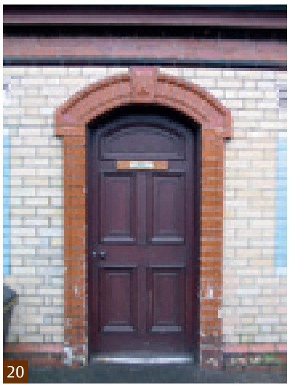


Fig. 20 Polychromatic glazed brickwork used at a public toilet in Rothesay, circa 1900 showing a range of colours, sizes and shapes available.

Fig. 21 Detail from Fig. 20 showing trademark of glazed brick makers J & M Craig of Kilmarnock. A concentration of companies manufacturing glazed brick and sanitary ware existed in Ayrshire into the 20th century.

Glazed bricks

Glazed bricks are typically used where a higher level of hygiene or light was required, or sometimes as a decorative element. Glazed bricks were produced in a wide variety of colours and shapes (Fig. 20). The makers of such bricks also often manufactured sanitary ware (Fig. 21). Machine made and precise in shape, enabling setting with very fine mortar joints, glazed bricks could be employed to striking visual effect. In repair work these are frequently mistaken for tiles and damaged as a result.

Special bricks

A wide range of non-standard shapes and sizes of bricks were utilised alongside the standard rectangular shape in brick construction. Raw clay can be moulded into almost any shape to suit a particular purpose and traditionally a wide range of bricks of different shapes was manufactured in order to fulfil standard architectural features, or bespoke-made for specific functional and/or aesthetic purposes (Fig. 22). Such special bricks were often manufactured from white or yellow clay to allow

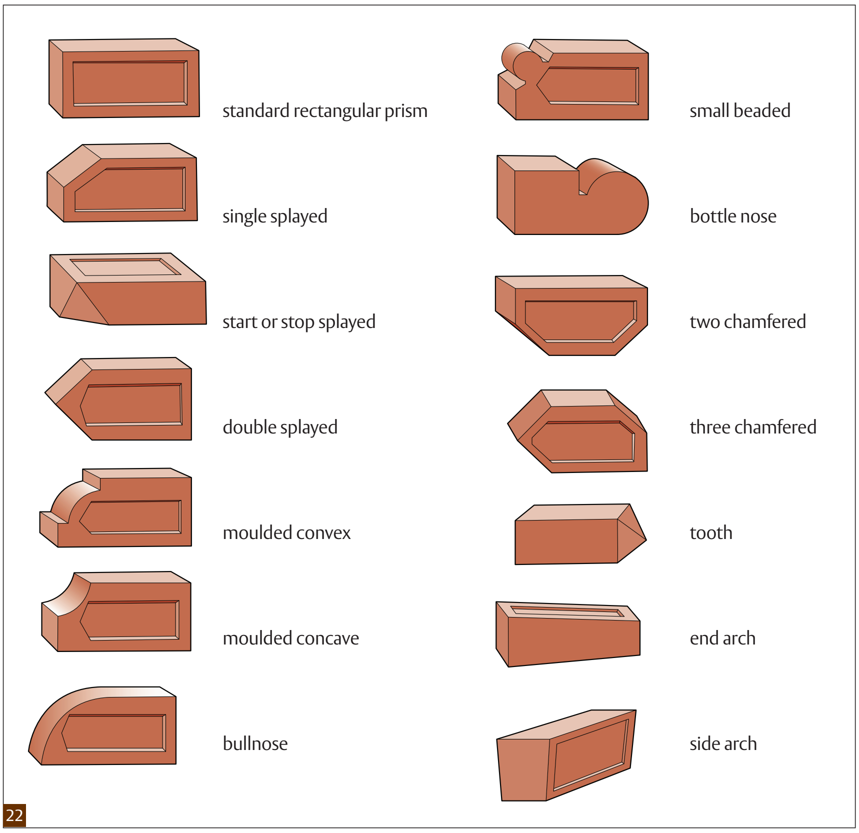


Fig. 22 Some indicative examples of special brick shapes found used in Scottish brickwork, based on those supplied by Allan and Mann of Glasgow in the late 19th century.

their use in polychromatic decoration. Some of the most common special bricks are as follows:

Bullnose bricks: These have one corner rounded-off and are most commonly found on the corners, or "quoins", of buildings where a sharp edge is not desired (Fig. 23a).

Coping bricks: These were manufactured in a wide range of sizes and shapes with a sloped or pitched top to form protective copes on walls.

Arch bricks: These were manufactured to be used to form arches. Termed voussoirs, they were made in the shape of a truncated wedge with the sharp end cut off (Fig. 23b).

Circle or compass bricks: Used to build elements within a building which had a tight radius and other curved structures such as industrial chimneys.

Splayed or cant bricks: Bricks with one or two corners cut diagonally, these bricks were generally used at corners where a sharp edge was undesirable (Fig. 23c).

Air bricks: Manufactured with perforations to allow the passage of air, these bricks were incorporated where ventilation through the wall was required.

Fig. 23 Special shaped bricks in use for a variety of applications:
a. Bullnose bricks used for window cill;
b. Arch voussoirs bricks;
c. Splayed bricks for corner details.

Engineering bricks

Engineering bricks are formed from high-quality clay and manufactured in such a way as to make them very dense, impermeable and able to withstand greater compressive pressures than other forms of brick can. Available as best quality, Class A blue engineering bricks or red coloured Class B engineering bricks, they are highly durable and can be found on civil engineered structures or sometimes on the lower levels of brick buildings where the brickwork is more vulnerable to damage and decay. Where engineering bricks are found it is vital that bricks of similar compressive strength and porosity are used in any repair work. These should also be of an F2 durability rating, meaning they can withstand the highest degree of frost damage.

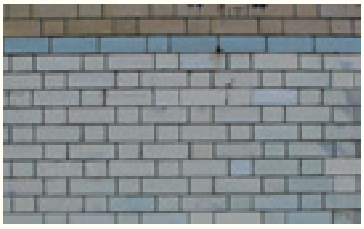
Type of brick	Identifiable features	Illustration
Common (also referred to as colliery or composition brick)	These bricks vary significantly in both texture and colour, generally being rough to the touch and with variegated colour.	
Facing	Specially made or selected to give an attractive appearance.	
Glazed	Uniform, glossy appearance, manufactured in a wide range of colours.	
Engineering	Often of a darker colour and dense appearance.	
Special shaped brick	Moulded in a non standard shape to form a specific purpose (this example is of moulded convex bricks used for a decorative architectural bracket detail).	

Table 1 The main types of brick used in Scotland.

Size of bricks

The size of bricks can vary considerably depending on type and date of manufacture. Generally, brick sizes, which until relatively recently were given in imperial measurements, have developed as follows:

Time period	Typical sizes	Notes
18th – early-19th century	8–9 x 3 x 2½ (inches)	These bricks were handmade and can vary in size but are generally thinner than later bricks.
Mid-19th – mid-20th century	9 x 4½ x 3¾ (inches)	As the brick making process became mechanised, larger bricks were produced.
20th century Imperial	8⅝ x 4⅛ x 2⅝ (inches)	The British Standard for imperial sized bricks.
Modern Metric Sizing (1965 onwards)	215 x 102.5 x 65 (mm)	The new modern brick size is inappropriate for use in repair of traditional brickwork.

Table 2 Sizes of brick in Scotland over time.

There are always exceptions to the figures given in Table 2. For example, facing bricks were commonly made thinner than common bricks (Fig. 24), whilst engineering and glazed bricks were typically produced larger and set with finer joints. Additionally, a particular brickworks, especially if producing dense bricks of low absorbency, may have simply produced larger sized bricks.

Where replacement bricks are being sought for work on traditional brickwork it is important to establish the average size of the bricks used and to source replacements of matching size. Generally the average size of 12 bricks over several courses is taken to give an accurate indication of the size of the bricks throughout.

Fig. 24 Example of block bonding on an area where facing bricks meet common bricks.

Fig. 25 Where new bricks are being manufactured for a repairs project these should be carefully assessed to ensure they match the characteristics of the originals.

Colour and texture

The colour of bricks comes from a combination of the mineralogical nature of the raw materials employed in their manufacture, the temperature reached during firing and the level of oxygen within the kiln. Colour typically ranges from dark reds to oranges, with white, cream or yellow bricks also produced in Scotland, the latter often employed as decorative dressings to quoins and window openings. It is important that when brickwork is being repaired replacement bricks should match the colour of those used originally as far as possible to minimise visual impact. Many brick manufacturers will offer a colour matching service (Fig. 25). The surface finish and texture of replacement bricks should also match that of the original, this being dependent largely on the method of manufacture and the raw materials used.

When working on a conservation project where replacement bricks are to be inserted it may be appropriate to distinguish the repair works by dating one of the replacement bricks. This can be done by pressing the date into the brick before firing.

Sources of replacement bricks

The best source of replacement bricks suitable for repairing large areas of traditional brickwork is often newly manufactured bricks which match the originals as described above. There are various companies who can still manufacture such bricks to the Harmonised European Standard EN 771-1, many of whom will provide a brick matching service. Trials should be undertaken before an order is placed to allow matching and estimation of production times. The Brick Development Association can provide information regarding suppliers of bricks for repairs to traditional brickwork (see contacts at the end of this guide).

The other source is reclaimed or second-hand bricks. Careful inspection of second-hand bricks is necessary before using them for repair work and their provenance must be declared. If they do not have an external weathered surface then they should not be considered; neither should bricks which have been damaged during demolition or through careless handling. As all historic bricks were graded for suitability of use, a reclaimed brick that was used for internal walling is likely to fail if placed in an external wall. Adequate time should be allowed to source a good match before a project commences.

5. Mortar types for Scottish brickwork

To form a wall bricks are laid in mortar. Given the high percentage of mortar in a brick wall (typically 15–20%) it has a significant impact on the appearance and character of a wall and, crucially, its strength. Traditionally constructed brickwork of the 18th and 19th centuries was built using a lime-based mortar, which would have been significantly weaker, more porous and flexible than a wall built today using modern bricks and Ordinary Portland Cement (OPC). All repairs to traditional brickwork should be made with a lime mortar that seeks to replicate the performance, composition and appearance of the original (Fig. 26). Modern cement should not, therefore, be used in a repair mortar as this removes the ability of the wall to "breathe" and allow water which may penetrate the brickwork to escape safely.

Mortars could be pigmented using earth or vegetable-based materials to produce a specific colour and there are documented examples of this occurring in Scotland. Mortar joints could also be finished in a variety of profiles (Fig. 27). Whilst there is less evidence for this in Scotland than elsewhere (joints usually being finished flush), where such jointing profiles do exist it is important to replicate these in any repair work and not to substitute a profile which is modern on a historic façade.

Fig. 26 Lime mortar with the consistency of modelling clay, with hawk and trowel ready to begin re-pointing work. If this mortar was being used for bedding bricks slightly more water would be used to give a less stiff mix.

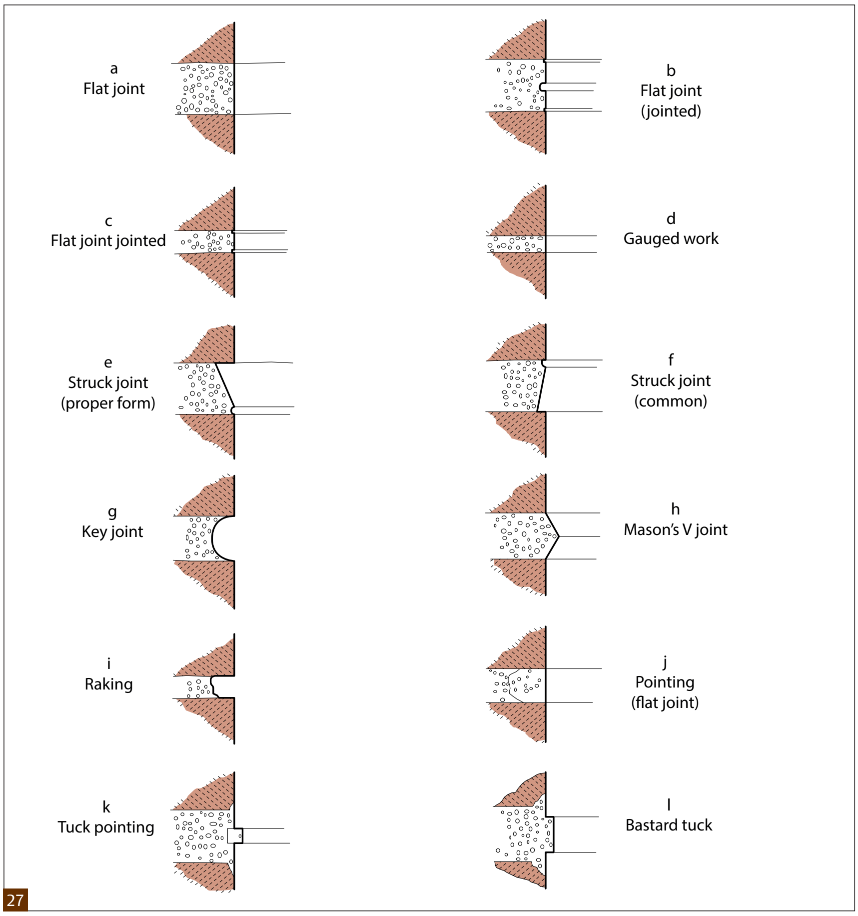


Fig. 27 Common joint profiles used in brickwork. With the exceptions of d, k and l examples of all of these are known in Scottish brickwork. Where evidence of joint profiles survive these should be replicated in re-pointing work.

The composition and site practice of using lime mortars is not considered in detail in this guide. For more information on this see Historic Scotland's Short Guide 6: *Lime mortars in traditional buildings.* It is important when considering mortars for the repair of brickwork that the following points are noted:

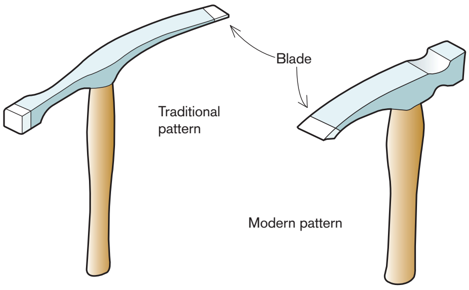
- Use clean water which is potable i.e. fit for drinking.
- A minimum amount of water should be used to make the mortar workable for its intended use, either re-pointing or bricklaying, but sufficient to allow for the full set to occur.
- Use lime of an appropriate strength category: mortar should always be weaker than the bricks which it surrounds.
- Use sand which is suitably graded and well-washed, free from earth and other materials which may adversely affect the performance of the mortar.
- Joints should be properly cleared out, back to sound mortar, leaving the back of the joint square, solid and clear of dust and debris.
- Beds and joints should be dampened (not saturated) prior to new mortar being placed in a wall.
- New pointing mortar should be adequately protected from rain, wind and direct sun, always working in temperatures above 5°C and rising.
- Hydraulic lime mortars must be kept damp for the first 72 hours to ensure the hydraulic set is initiated.
- New pointing mortars should be "cured" by intermittent, fine-mist spraying with potable water for several days.

6. Tools for the correct repair of brickwork

This section presents a brief description of some appropriate tools for carrying out common repairs to brickwork. For fuller descriptions and consideration of a wider range of tools see Lynch (1994), Vol. 1, Chapter 6 on which the drawings below are based.

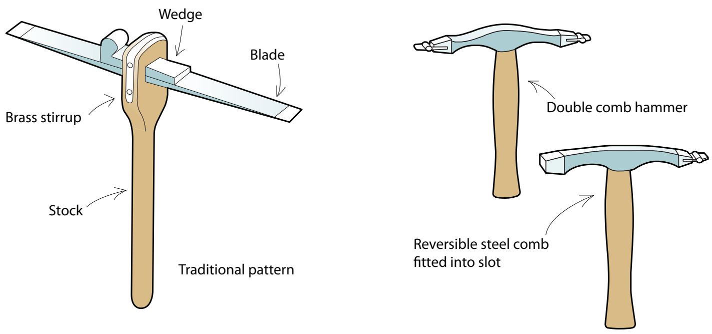
Brick hammer

This type of hammer is square at one end and flat bladed at the other, used for rough cutting of bricks to shape where required.



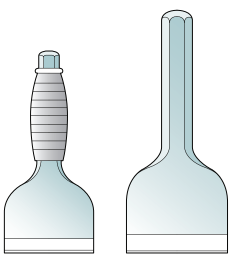
Scutch or comb hammer

A single scutch hammer is similar to a brick hammer but instead of the flat bladed end there is a slot into which a comb or scutch blade is inserted which can be removed and replaced when blunt. A double scutch hammer simply has the slot at both ends. Used for more accurate dressing of rough cut bricks.



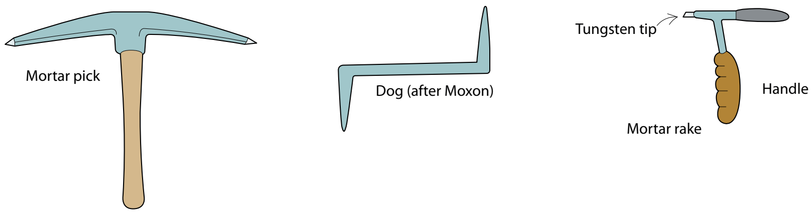
Bolster

Used with a heavy lump or club hammer to quickly cut bricks to shape or size.



Mortar pick or rake

These tools are sometimes used to rake out old mortar ahead of re-pointing. The traditional tool for this was known as a dog but these are little used today. Whatever tool is being used to rake out old mortar care should be taken not to damage the arris (edge) of the brick.



Spray bottle

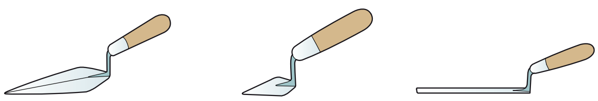
This is used to wet down brickwork prior to re-pointing and can either be of a small hand held type for wetting down small areas ahead of re-pointing or for larger areas a pump action type.

Pointing trowels

Resembling normal laying trowels but much smaller, these come in a range of sizes for different applications. It is easier to employ a smaller trowel, called a "dotter", for the vertical joints (known as perpends or cross joints) than for horizontal bed joints.

Finger or window trowel

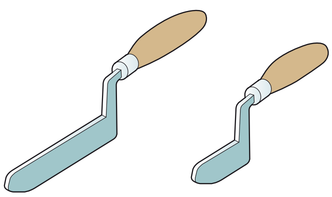
A narrow parallel bladed trowel, often the most appropriate tool for inserting mortar into a joint during re-pointing work.



Pointing trowel   Dotter   Finger or window trowel

Jointers

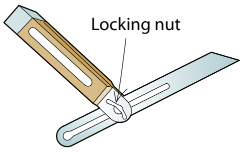
These are used to apply a finish to joints after inserting the re-pointing mortar and come in a variety of sizes and profiles. It is important to ensure that the right size, width and length of jointer is used for the bed and perpend joints.



Bed jointer   Cross jointer

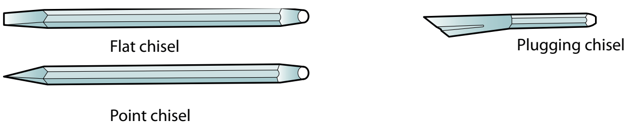
Sliding bevel

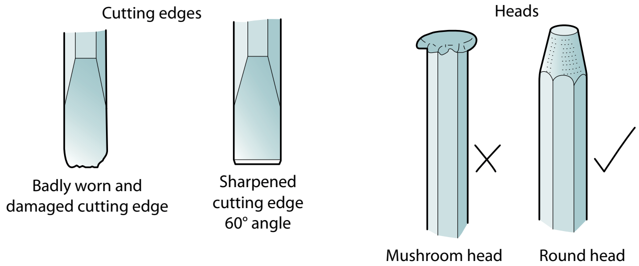
The sliding bevel is used to establish precise angles where bricks require to be cut, for example in repairing arches or forming skewbacks.



Tungsten-tipped chisels

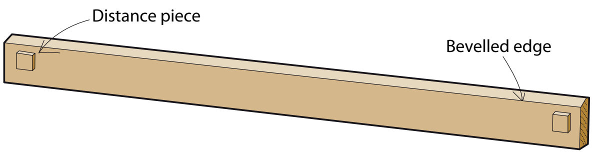
Masons' "quirks", lettering or carving chisels come in a wide variety of sizes and are the best tool for removing old mortar from joints. Always select a size small enough for the joint being worked on. A standard plugging chisel is unsuitable for this type of work.





Pointing rule

Used in the forming of ruled joints, this tool is made of wood, typically around 1.2m in length. The top is level to guide the jointing rule and knife for trimming any surplus mortar. It is bevelled on one side and wood, cork or rubber "distance pieces" fixed about 75mm in from either end. This keeps the pointing rule clear of the wall by about 5mm, allowing trimmed mortar to fall clear between the wall and the rule.



7. Replacement of decayed bricks

Fig. 28 Inappropriate patching-in of bricks of the wrong colour set in hard cementitous mortar giving a poor quality repair.

Fig. 29 The use of a modern replacement brick bedded in a cement mortar is inappropriate to this traditionally constructed building.

Where a brick has been judged to have deteriorated or been damaged to such an extent that it is no longer performing its function in a wall it will be necessary to cut out and replace it. Replacement bricks should match those which they are replacing as described in section 4 of this guide (Figs 28 and 29).

The steps which may be taken when cutting out and replacing an area of brickwork or a single brick, can be summarised as follows:

Assessment: Survey the brickwork to decide which bricks need to be replaced. Adopt a minimum of intervention approach and never replace more of the existing work than is necessary. It is always desirable to retain original fabric and avoid unnecessary work and expense.

Cutting out: Carefully chisel out the mortar around the decayed brickwork. This will be best achieved by hand using appropriately sized tungsten tipped chisels. The use of mechanical methods of cutting out bricks may be appropriate in certain situations where inappropriate cementitous mortar has been used over a large section of brickwork and has to be removed. Where this is being contemplated it should only be undertaken by a skilled operative. A tool with a suitably sized and tungsten tipped oscillating blade, smaller than the width of the mortar joint, should be used. Disc cutters should never be used, and care must be taken not to damage the adjacent sound brickwork. There are also health and safety issues regarding excessive and fine dust with this type of work.

Fig. 30 Three bricks which had suffered severe decay have been removed, and the pocket which is left has been cleaned free of dust and debris. The brick which can be seen in the lower of the three courses is one of the three replacement bricks which will be inserted.

Cleaning and dampening: When the bricks to be replaced have been removed (Fig. 30) all dust and debris should be cleaned away and the surrounding brickwork dampened prior to the replacement bricks being inserted. It is important that this cleaning and dampening goes right to the back of the void to receive the replacement bricks. Wetting the area prevents the moisture in the mortar being absorbed too quickly by the surrounding area, causing shrinkage and cracks on the mortar. Due to the porous nature of some brickwork, more dampening may be required than would be for stone masonry.

Bedding new bricks: Having appropriately dampened the area and ensured it is free from dust and debris, mortar should be pushed to the back of the void into which the bricks are being inserted. This should evenly coat the brick which the replacement will abut. A layer of mortar should also be applied to the upper side of the existing underlying bricks to form a bed joint for the replacement brick. Mortar should then be applied to the top and side of the replacement brick and it should be carefully inserted into the void without staining the adjacent brickwork.

Finishing joints: The mortar should be pushed back firmly into the joint using a narrow bladed pointing trowel or key as in re-pointing work. This action should continue until the joint is packed full of mortar and it is flush with the surrounding brickwork. If necessary the joint can then be finished with a joint profile to match the surrounding brickwork.

Maintain bond: The term bond refers to the way in which bricks are laid and interlocked in relation to each other within a wall. When replacing bricks or sections of brickwork it is important to both the structural integrity of the building and its appearance to maintain bond. The original purpose of a bond was to provide strength, appearance and economy. There is a wide range of bonds which may be found in Scotland although the most common are Flemish, English and Scottish bond (also known as English garden wall bond). When discussing bonds the terms header (a brick with its head or narrow end to the front) and stretcher (a brick with its longer face to the front) are used. Some bonds commonly found in Scotland are described and illustrated in Table 3.

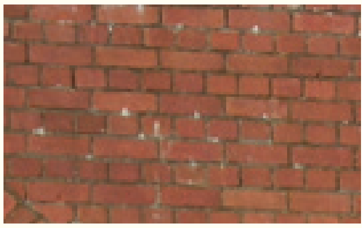
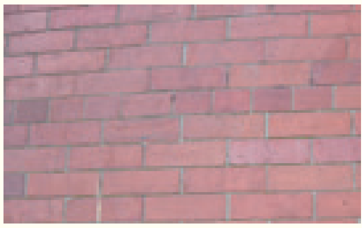
Bond type	Description	Photograph
English bond	Alternate courses of headers and stretchers. The strongest bond hence its prolific use in civil engineering structures.	
Scottish bond (English garden wall)	One course of headers to every three, four or five of stretchers, this was a quick and economic bond to use.	
Flemish bond	Alternate headers and stretchers in each course, this was considered the best bond for appearance but lacking in strength.	
Stretcher bond	This consists of stretchers for the whole of each course apart from at every other course at the quoin where a header is inserted so half bond is maintained.	
Header bond	In this bond all the bricks are laid as headers, commonly used for curved walls but also seen on some façade walls.	
Herringbone bond	This is one of a number of decorative bonds occasionally found in Scotland. Bricks are laid at an angle of 45° in opposite directions, forming a strong interlocking effect creating a distinct visual appearance.	

Table 3 The main bonds used in traditional brickwork in Scotland.

8. Re-pointing brickwork

Throughout the life of a building there will always be some loss of mortar leading to a need to re-point areas of brickwork. If unaddressed this can result in water penetration, leading to internal dampness, decay and structural instability. The process involved in re-pointing traditional brickwork can be summarised as follows:

Assessment: The first stage is to assess exactly what parts of the building need re-pointed. In many cases it will not be necessary to re-point an entire building or even an entire elevation. As some parts are more exposed than others, pointing will fail at different rates. Before any work is carried out it is important to establish which parts of a wall are to be re-pointed and which are sound. As a general guide, providing the joints are not allowing moisture to penetrate, they do not need to be re-pointed until they have eroded as deep as they are wide. The negative effects of re-pointing unnecessarily using an inappropriate material can be seen in Fig. 31.

Raking out: Where re-pointing is necessary, the old mortar should be carefully raked out prior to the work taking place. In most cases this will often be best achieved using hand tools (Fig. 32), although a mechanical aid fitted with tungsten tipped oscillating blades may be used if carefully employed by a skilled and experienced operative, particularly where hard, cement-based mortar is being removed. In general a joint should be raked out to a depth of at least 2½ times its width (i.e. a 10mm thick bed joint requires 25mm rake out), but if this is not sufficient to get back to sound mortar it may be necessary to rake out to a greater depth. After the joint has been fully raked out, all dust and debris should be brushed out or, preferably, vacuumed clean in preparation for dampening (Fig. 33).

Dampening down: Before re-pointing work takes place the joints and porous bricks should be well dampened but not saturated. It is important when doing this to ensure that the interior of the joint is damp and not just the surface of the bricks. This is particularly important where dense bricks have been used that will shed the water being sprayed down the face, away from the joint. Wetting prevents moisture in the mortar being sucked out too quickly by the dry existing brickwork as well as by the actions of wind and/or sun, all of which can cause too rapid drying resulting in shrinkage cracks in the mortar. In addition, lime-based mortars must cure and harden in the presence of moisture.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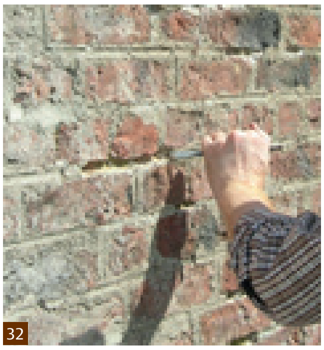
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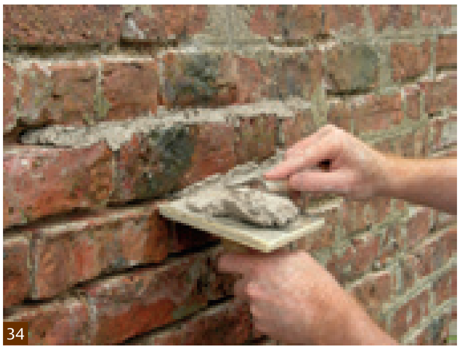
Fig. 31 The negative visual effects of poor re-pointing using an inappropriate material can be seen in this building, where the character of the brickwork has been changed to such an extent as to give the appearance of a newly-constructed extension.

Fig. 32 Cementitious mortar being cut out using an appropriately sized tungsten tipped chisel. Note it is easier to work into the open joint.

Fig. 33 Dust and debris should be brushed or vacuumed from the raked out joint prior to dampening down.

Re-pointing: An appropriate mortar should be used for all re-pointing work to brickwork. This should be lime based and match the original as far as possible, with mortar analysis being employed where appropriate to ensure this is the case. A sufficient quantity of stiff mortar (the consistency of modelling clay) is then placed on the hawk and a small quantity the width of the mortar joint prepared by tapering it down to a thin edge. This is then lifted off with the trowel or jointer and pushed firmly into the prepared joint, ensuring it is fully compacted into the back of the joint (Figs 34 and 35). It is generally advisable to work away from the original sound mortar or from the previous day's re-pointing as the work progresses. As far as possible avoid applying the mortar so it smears the face of the brickwork, and where this accidentally occurs it can be removed when the mortar has firmed up a little. The finger trowel, brick jointer or pointing key used should exactly fit the width of the joint. A joint surface finish can then be applied if appropriate after the initial set (Fig. 36).

Aftercare of new pointing: In dry weather, particularly in conditions of wind and/or warm sun, it may be necessary to cover the re-pointed brickwork with dampened hessian to prevent the work drying out too quickly. Likewise the new work should be protected from the destructive effects of adverse weather conditions such as frost or rain. Work with lime mortar should not take place unless there is a minimum temperature of 5^{O}C and rising, or an enclosed and warmed scaffold is provided to create a 'micro climate' during periods of work below that temperature. Further guidance on this can be found in several publications referenced at the end of this guide.



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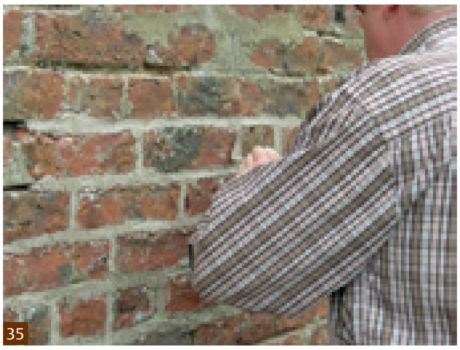

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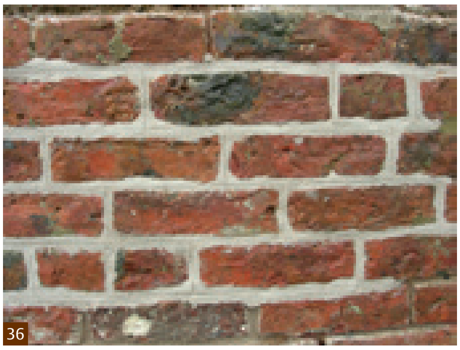

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Fig. 34 New mortar is pushed back firmly into the pre-dampened joint using an appropriately sized tool.

Fig. 35 Excess mortar is then trimmed from the arris of the brick.

Fig. 36 Having trimmed the mortar back this joint has been given a "ruled" joint finish to match that which was originally present.

9. Structural defects and repair

The most common and noticeable sign of a structural fault in brickwork is cracking (Fig. 37). Cracks in brickwork can be caused by structural movement due to unstable ground or foundations, physical damage, tree roots or defects in the original construction. Cracks can be an indication of a serious structural problem and where they appear suddenly advice should be sought from a suitably qualified and experienced professional. A period of monitoring may be required to establish if the crack is stable or "live" (meaning it is still expanding) and a decision made as to an appropriate solution. It is worth bearing in mind, however, that some cracks may have happened during natural settlement soon after building and are stable.

In some cases where cracking has occurred it may be necessary to not only cut out and re-point the joints but also to replace fractured bricks. This approach is appropriate where the original cause of the crack has been rectified or where movement has ceased. It may be necessary to introduce some form of reinforcement into an area of brickwork which has suffered from cracking (see Fig. 38). This most commonly takes the form of appropriately coded stainless steel lattice work, thin rods or helical reinforcement placed to the manufacturer's instructions, typically every three or four courses. If a particularly strong repair is desired it can be placed in every course. Where a crack has occurred to a corner, or "quoin", reinforcement can be inserted so as to go around it to strengthen the bond. This is particularly useful where two walls were not bonded properly in the original construction. In all cases it is important to identify the cause of the movement and put remedial measures in place to resolve the problem.

With certain serious problems such as bulging or delaminated face brickwork, proprietary helical fixings can be used to re-bond the outer and inner wall elements which are separating. Where severe problems have been identified and determined by a structural engineer, tie rods and patress plates can be specified (Fig. 39). It is now possible to fix these after removing a section of brickwork which can then be replaced so they are not as visually intrusive as previous solutions using this method. Alternatively, the area of brickwork can be taken down and re-built incorporating re-enforcement.

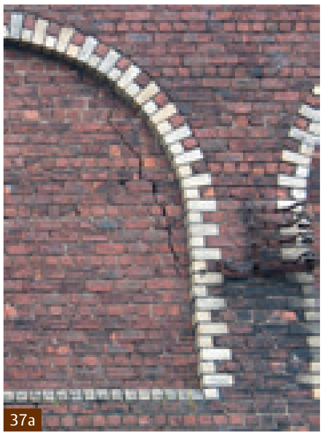

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Fig. 37 With severe cracks such as this it will be necessary to cut out the fractured bricks and replace them. The addition of stainless steel reinforcement will almost certainly be advisable.

38

Fig. 38 Helical, mesh and ladder type reinforcement can be inserted into the joints of brickwork suffering from cracks or other structural problems. In this example a helical rod is being inserted into a joint to strengthen the brickwork.

39

Fig. 39 Wall ties and patress plates have traditionally been used to strengthen brick structures such as this bridge in Montrose; there are now proprietary systems available which allow such re-enforcement to be hidden.

Fig. 40 Structural movement leading to distortion of walling, Glasgow. In situations such as this a structural engineer with experience in traditional masonry should be consulted.

Distortion or sagging of brickwork as seen in Fig. 40 can result in a need to underpin a building, but this is an expensive operation and should not be contemplated without consulting a structural engineer with proven experience of traditionally constructed masonry.

Repairing brick arches

Arches are a means to span an opening using small masonry units and are integral to almost all brick buildings in Scotland. They come in a variety of types and shapes, though the three main shapes of arch found in Scottish brickwork are shown in Table 4.

Arch type	Description	Photograph
Flat/camber	Flat on the extrados with a very slight curve or "camber" on the intrados/soffit.	
Segmental	Formed of a curve less than a semi-circle.	
Semi-circular	Formed in a semi-circular shape.	

Table 4 The main shapes of arch found in Scottish brickwork.

Arches are also categorised by the way in which the bricks are shaped, as follows:

- *Rough arches:* In this type of arch the bricks are not cut to shape but simply used as they were manufactured. In small arches building like this would lead to very wide joints at the outer edge of the arch (known as the extrados) and therefore tend to be built with bricks laid as headers in a series of concentric rings, or used on wide-span arches (Fig. 41).
- *Axed arches:* Built with bricks which are cut on either side to radial shape to fit the arch but left with the extrados and intrados uncut and therefore straight, or tangential, to the curve. This can be done to varying degrees of accuracy depending on the quality of the brick and the build. Most arches in Scotland are of this type (Fig. 42).
- *Gauged work:* This type of brickwork is the highest expression of the bricklayer's craft. Specially produced softer rubbing bricks forming the arch voussoirs are exactly cut and gauged to precise size and shape to form the arch enabling the bricks to be laid with joints of just 1mm. Such work is rare in Scotland and where it is encountered specialist advice should be sought before embarking on its repair.
- *Purpose-made arches:* As methods of production became increasingly mechanised during the 19th century and bricks of special shape became more common, arch sets could be manufactured to a specific size and shape by the brickworks for on-site assembly (Fig. 43).

There are other geometric shapes and types of arches which may be encountered when repairing Scottish brickwork, such as three or four centred arches, Venetian, ogee and so forth, particularly in industrial buildings (Fig. 44). As the considerations for the repair of such arches are broadly similar to those for the three basic arch types listed above, these variants will not be considered in detail. For information regarding these arch types reference can be made to the technical works in the further reading section of this guide, such as Allen (1893) and Hammond (1875).

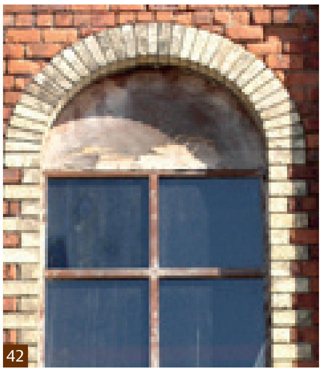

Fig. 41 By re-building this segmental arch using uncut bricks, the joints are noticeably "v-shaped" and wider on the extrados than the intrados. The angle of the skewback has been maintained, however, and the surrounding face bricks, which meet the extrados and form the skewback, have been accurately cut.

Fig. 42 The bricks forming the voussoirs in this arch have been roughly cut to shape forming an "axed" arch.

Fig. 43 An arch constructed of purpose-made voussoirs and bedded in coloured mortar. Note the acute angle of the skewback, 40° in this case.

Fig. 44 This unusual style of arch is one of many variations out with the most common which can be found in Scottish brick buildings.

Repairing a brick arch can be a complex task requiring a high level of skill, although there are some basic steps which can be taken to help ensure a successful outcome. When repairing brick arches it is important, both aesthetically and structurally, that the original profile, accuracy, bonding and quality of finish is followed. If the arch has individual slipped voussoirs (the individual bricks which form the arch), the structure must be supported as the joints either side are carefully cut out to allow bricks to be re-positioned or fully removed and re-bedded. Where voussoirs have decayed to such an extent as to require replacement it may be that the arch requires to be taken down and rebuilt. Where this is necessary the position of the bricks forming the arch should be carefully marked on the centering (the timber frame used to support the arch during construction) and numbered before taking down to allow accurate rebuilding and/or cutting of replacement bricks that should match in all respects. Replacement voussoirs can then be built into the arch where appropriate. It will be necessary when carefully taking apart and rebuilding the arch to provide a timber centering of sufficient robustness to support the work as it is re-built. Information on setting out and constructing arch centering can be found in the technical reference works at the end of this guide. The centering should be left in place for sufficient time after the arch has been re-erected, in order to allow the mortar to set and the masonry to settle into place.

Where an arch is axed the replacement voussoirs should be cut to meet the profile of the original bricks which have been removed. This can be done using a scutch hammer to trim after cutting with a lump hammer and sharp bolster. In instances where the original bricks were purpose-made “specials” produced for the job, replacements that match the originals in colour, texture, porosity and method of manufacture can be sourced if the dimensions and characteristics are carefully recorded.

Another position at which bricks may need to be cut during the repair of brick arches is at the springing point where the arch meets the brick wall (Fig. 42). It is important to ensure that the angle of skew is maintained. This angle can vary considerably from as shallow as 40^{o} up to 80^{o}; with 60^{o} or 70^{o} being most common in Scotland. The replacement bricks which form the skewback should be marked with the sliding bevel and cut to shape accordingly. The mortar joint here should be no thicker than in other parts of the arch face and should never be used to “smooth out” irregularities in the bricks at the springing point.

In a segmental or semi-circular arch the bricks laid directly above and which meet the curve or extrados of the arch will also need to be accurately cut to shape to aesthetically compliment the overall arch construction.

Brickwork and other building materials

As well as bricks and mortar there are a number of other materials which might be encountered when repairing traditional brickwork. These can present various challenges, particularly when structural repairs are being undertaken.

Timber may be found in a number of structural applications. In brickwork up to the mid-19th century, bond timbers were sometimes built into an internal wall to provide longitudinal strength (Fig. 45). Another common application was wooden bricks, sometimes referred to as “dooks” built into brickwork to allow fixings for nails and screws where an element such as a door or window was to be inserted. An alternative to this was the use of narrow wood slips placed in joints. Where timber elements are present in brickwork it is important to ensure that these are kept free from dampness to avoid them rotting and deteriorating and potentially destabilising the masonry. Where decay is present it may be necessary to either replace redundant timber elements using brickwork or other modern alternatives. With decayed bond timbers, these should only be cut out and replaced in small sections to prevent collapse.

Metal, most commonly iron, may also be encountered in conjunction with brickwork, particularly in structures dating from the second quarter of the 19th century onwards. Where iron structural elements are incorporated these can corrode causing oxide or rust-jacking and cracking of the masonry. Lengths of hoop iron were sometimes built into brick walls to fulfil the same purposes as bond timbers. Wrought iron was employed to tie elements of brickwork together, such as in arched flooring. If corroded metal reinforcement is found during repair it may be necessary to replace this with appropriately specified stainless steel reinforcement. Where it is felt the original material is performing well however, on the advice of a structural engineer, it may be carefully exposed to clean off all corrosion, treated with a rust inhibitor, then re-built with fully-filled joints and left *in situ*.

Fig. 45 Timber built into brickwork and showing advanced decay.


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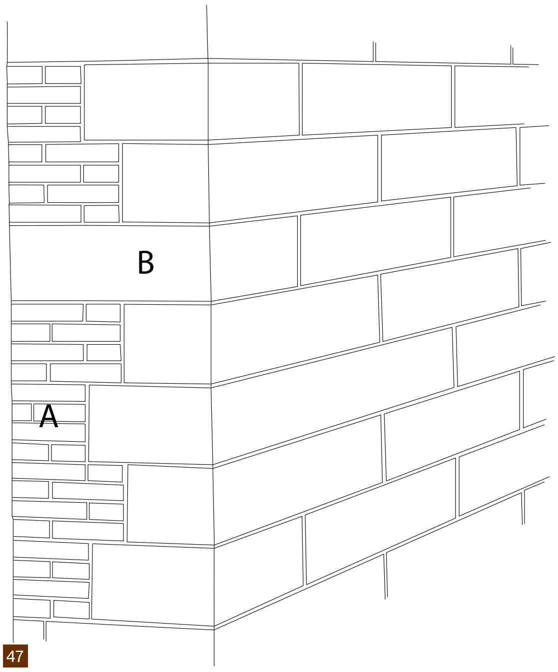

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Brickwork is also often employed with stone in a wide variety of applications. Where a stone elevation links to one of brick it is important to ensure that the two are fully bonded together. This can be an area where original construction has become defective and additional reinforcement measures may be required (Fig. 46). Stone can also be present as dressings, for example at quoins, lintels and window cills in a brick-built building. Brick was often employed as a backing to fine ashlar stone work and where this is found to be the case the original bond method should be maintained if it is still functional (Fig. 47). Bed joint reinforcement is often specified where dissimilar materials are being repaired to reduce the likelihood of mortar cracking.

Fig. 46 Stone elements becoming de-bonded from brickwork, by years of downward water movement flushing out the mortar joints. Such action can affect the structural stability of a building and should be correctly and carefully repaired.

Fig. 47 Brick was used in both the 18th and 19th century as a lining for ashlar walls. Here the ashlar is shown 'block-bonding' with the brickwork (A), with through-stones used to strengthen the bond as at (B).

10. Efflorescence and sulphate attack

Salts can be a significant cause of deterioration in brickwork. Salts can enter bricks from an external source due to water ingress, or commonly water ingress simply brings salt already present in bricks or mortar to the surface. Salt damage is particularly common in brick-lined chimney flues where sulphates from smoke and flue gases have penetrated the brickwork over a number of years. When these mix with moisture either from condensation within the flue or from rainwater penetration they become soluble and can enter the brick resulting in deterioration. Such a process is common where a redundant chimney has been sealed without providing adequate ventilation. Salts can also be introduced into brickwork from seawater or sea spray, and contamination from winter de-icing salt is a further threat. The most common source of movement of soluble salts in brickwork, however, results from the use of cement-based mortar for repairs.

The most obvious sign of the presence of soluble salts is efflorescence. This generally appears as a white streaking on the surface of bricks or in more severe cases a build up of white crystals or a powdery deposit over areas of brickwork. This indicates that salts present within the brickwork are migrating in solution to the surface and crystallising. If salt crystallisation occurs within the brickwork (known as subflorescence) the force of crystallisation can be strong enough to lever the internal structure of the brick apart leading to significant damage and deterioration (Fig. 48).

Fig. 48 Subflorescence showing as a white build up on the surface of brickwork. On this occasion it is likely to have been caused by the inappropriate use of cement re-pointing.

Fig. 49 Formation of salts on brick masonry due to migration of contaminated groundwater through a retaining wall.

Lime mortar joints can aid in the protection of bricks by allowing salts to migrate to the surface through the mortar rather than the brick, thus ensuring that the bricks themselves are undamaged (Fig. 49).

The first step in addressing efflorescence is to stop the water ingress which is causing the problem and remove the source of salts if this is possible. When this has been resolved any build-up of salts on the surface of the brickwork should be cleaned off using a stiff, non-ferrous bristle brush, but must be collected on a plastic sheet and responsibly disposed of to prevent the salts going into the ground and migrating back into the brickwork. It may be that when efflorescence has been removed spalling or other damage is revealed which will require replacement of bricks. There are poultice and wicking treatments which can be applied to remove salts from brickwork should this be necessary, although such treatments are designed for specialist situations and are unlikely to be used in most cases. Where such treatments are being considered it is vital to get expert, impartial advice, proper product information, and to carry out trials on several test panels to assess both their effectiveness and determine any possible harm that might occur to the brickwork.

11. Biological growth

Biological growth on brickwork falls into two main categories: small, surface growths such as moss and lichens, and larger plants such as creepers, ivy or small trees. Both types of growth, if unattended, can cause deterioration of brickwork. Biological growth is an indicator of the presence of excess moisture in brickwork, the source of which should be identified and stopped prior to repair work taking place. Mosses and lichens can hold moisture against the surface of bricks and mortar and increase the level of moisture ingress leading to saturation. The vines of creepers, left uncontrolled, can grow through and wrap around elements of brickwork causing serious structural instability or failure. Similarly the roots of larger plants can dislodge bricks and pointing which, if unchecked, can lead to cracking and structural damage (Fig. 50).

Surface growth can be removed using a stiff, non-ferrous bristle brush. Larger growth will need to be cut away from brickwork. Where creepers are to be removed, the first step is to cut through the stem of the climbing plant at a convenient height above ground level, to allow it to die of its own accord. Once it has withered careful removal of the dead plant can proceed, in small sections. In all cases of larger biological growth the temptation to pull it clear of the wall using a rope should be avoided as this can pose a serious health and safety risk and could result in extensive damage to the wall. Where roots have penetrated into a wall it will be necessary to fully remove these using appropriate cutting out tools. All defective joints will have to be re-pointed and any damaged bricks cut out and replaced as appropriate (Fig. 51).

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Fig. 50 Larger growth can cause more extensive damage than can smaller plants and can require more extensive intervention and repair following its removal.

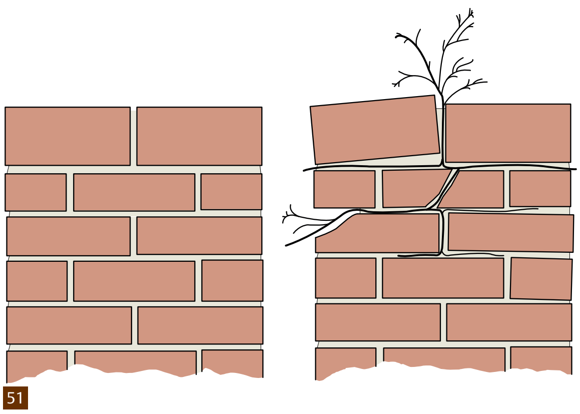

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Fig. 51 The roots of plants can cause severe damage to brickwork as seen here lifting bricks out of place, creating a route for water ingress and fracturing the brickwork. Any plant growth should be removed as early as possible to avoid such problems developing.

12. Cleaning brickwork

The cleaning of traditional brickwork should be approached with caution as inappropriate cleaning can result in considerable damage to bricks (Fig. 52).

In general the following principles should apply when the cleaning of traditional brickwork is being contemplated:

- Seek expert advice.
- Only clean if absolutely necessary. There should be a general presumption against cleaning in most cases.
- Try cleaning with water first as this will avoid unnecessary use of chemicals and other harsher methods.
- Always undertake test panels and monitor the cleaning method proposed.
- Use an experienced contractor with proven credentials and fully trained in the system to be employed.
- Always check that the contractor is actually using the correct equipment and materials and in the specified way.

There are a wide range of methods employed in cleaning brickwork, but these can broadly be split into three categories: water, chemical and abrasive cleaning.

Water-based cleaning: Cleaning of elevations with water at low pressure with a hand bristle brush is generally the most appropriate and risk free way to remove modest soiling. A phosphor bronze brush can also be used. Ferrous metal brushes should not be used as this will damage the brickwork and leave a metallic residue which will rust. If a large area is to be cleaned it is important to prevent the lower portions of the masonry becoming saturated as water runs off from above. Systems which make use of super-heated water and steam can be very successful in removing some forms of biological growth and other surface deposits such as paint and bitumen. It is important when using such a system that care is taken not to damage adjacent woodwork, glass or other building elements. Cleaning and applying quantities of water should be avoided during or in anticipation of frosty conditions to avoid potential damage to brickwork and mortar.

Fig. 52 Damage to brickwork from cleaning. The vitrified surface (known as the fire skin) which can be seen on the un-cleaned brick (a) has been removed from the cleaned brickwork (b) leaving the brick more vulnerable to moisture penetration and decay.

Chemical cleaning: Cleaning with chemicals must be considered very carefully before being employed on traditional brickwork. Chemical residues can become trapped within the bricks themselves or the mortar, leading to a discolouration and breakdown of the fireskin of the brick, leaving the softer material beneath vulnerable to further attack (Fig. 52). Chemicals may also be absorbed into the mortar leading to a breakdown of the binder and accelerated decay.

Many chemicals may also introduce salts or cause the mobilisation of inherent soluble salts already present in the brickwork. It is therefore important to be aware of what chemicals are present within the product being used and the likely consequence of their use. It is also vital to undertake cleaning trials and allow these to properly dry out over time before consideration is given to extending the treatment further, thus hopefully avoiding costly damage. Glazed bricks are particularly vulnerable to damage from acid cleaning, and other cleaning options should be considered.

With these considerations in mind where a chemical is to be used for cleaning brickwork it is important that the appropriate type and strength is employed and it is applied in accordance with the recommended instructions. If acidic substances are being used this should be in a diluted form and the substance not left in contact with the brickwork for any length of time. There are proprietary biodegradable acids available which may be more appropriate. The brickwork should be wetted before application and fully washed off afterwards, with care being taken not to force water deep into the brickwork. At all times the manufacturers' advice should be adhered to.

Where specific areas of heavy soiling have occurred it may be acceptable to use an appropriately specified poultice as the cleaning product. The poultice will usually take the form of clay or cellulose mixed with an approved chemical cleaning agent. As previously stated, preliminary trials should be undertaken before a particular technique is applied.

Abrasive cleaning: Mechanical abrasive cleaning should be avoided as it can remove the outer surface from the bricks. This will leave them scarred and pitted producing a roughened, textured surface more prone to decay. The use of sand or grit blasting should never be permitted as it will quickly remove the surface of the brick, and lead to rapid re-soiling leaving it highly vulnerable to subsequent decay and damage.

A variety of soft textured, round shaped abrasives, designed to cause less damage to the brickwork are available as are various systems of application which form a vortex that swirls over and gently abrades surface deposits from the brickwork. In skilled and experienced hands these may be suitable in certain situations to clean traditional brickwork but it is vital that an approved contractor is used, and in general abrasive methods of cleaning should be avoided. Here, again, the vital importance of monitored trials on test panels is stressed.

13. Contacts and further reading

Contacts

Historic Scotland
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EH9 1SH
0131 668 8600
www.historic-scotland.gov.uk

Historic Scotland Technical Research Unit
(Technical enquiries)
0131 668 8668
hs.conservationgroup@scotland.gsi.gov.uk

Historic Scotland Heritage Management Team
(Planning/listed building matters)
0131 668 8600
hs.listingsandconsents@scotland.gsi.gov.uk

Historic Environment Grants Team
(Funding options)
0131 668 8801
hs.grants@scotland.gsi.gov.uk

Brick Development Association
(Brick Manufacturers)
020 7323 7030
www.brick.org.uk

British Brick Society
(Brick History)
www.britishbricksoc.free-online.co.uk

Scottish Lime Centre Trust
(Advice on lime mortars)
01383 872 722
www.scotlime.org

Further reading

Allen J. (1893), *Practical Building Construction*, Crosby: Lockwood

Brick Development Association (2000), *BDA Guide to Successful Brickwork*, Butterworth-Heinemann

English Heritage (2014), P*ractical Building Conservation, Earth, Brick and Terracotta* Ashgate: London

Gibbons P. (2003), *Preparation and Use of Lime Mortars*, Historic Scotland

Hammond A. (1875), T*he Rudiments of Practical Bricklaying*, Crosby: Lockwood

Hasluck P. (1905), *Practical Brickwork,* Cassell

Jenkins M. (2009), *Building Scotland*, John Donald

Lynch G. (1994), *Brickwork: History, Technology and Practice volumes 1 and 2* Donhead

Lynch G. (2007), *History of Gauged Brickwork: Conservation, Repair and Modern Application*, Elsevier

Nicholson P. (1838), *Practical Masonry, Bricklaying and Plastering*, Kelly

Scott Burn R. (1870), *The New Guide to Masonry, Bricklaying and Plastering, Theoretical and Technical*, McCready, Thompson and Niven

Sutcliffe G. (ed.) (1898), *Modern House Construction Vol. 1*, Blackie and Son

Warren J. (1999), *Conservation of Brick*, Butterworth-Heinemann

14. Glossary

Aggregate:	*Any material which, when combined with a binder, forms a mortar.*
Arch bricks:	*Bricks tapered in length or width to serve as voussoirs in arches.*
Arris:	*The sharp edge of a brick.*
Ashlar:	*Masonry constructed of stones with a polished surface, of regular size and tight mortar joints.*
Bat:	*A broken section of brick, larger than a quarter brick, often used in Scottish brickwork as an alternative to a closer.*
Bed joint:	*The horizontal joint between two courses of brickwork.*
Binder:	*A material that binds together the aggregate in a mortar; in traditional brickwork this is usually lime.*
Block bonding:	*The use of several courses of brickwork in joining parts of a wall or building together. This is particularly common where a front wall of stone or facing brick joins to a side wall of common brick.*
Bond:	*The arrangement of bricks in a pattern for strength or occasionally decoration and particularly designed to ensure joint is broken.*
Bond timbers:	*Pieces of timber built into the inner face of a wall to provide horizontal reinforcement.*
Brick ashlar:	*A wall with a facing of ashlar backed by brickwork.*
Bullnose bricks:	*Bricks with one or two arris rounded.*
Camber arch:	*An arch whose upper edge or extrados is horizontal, but whose lower edge or intrados is slightly curved or "cambered".*
Cant bricks:	*Bricks with either one corner (single cant) or two corners (double cant) cut off diagonally.*
Closer:	*A brick cut or specifically moulded to expose a half header on the face of a wall and used to complete bonding patterns.*
Clamp:	*A fairly crude but effective method of firing bricks in large numbers, a clamp is formed by interspersing unfired bricks and fuel.*
Collar joint:	*The joint between the front face of one brick and back of the brick in front in a wall more than half a brick thick.*
Common bricks:	*Bricks used where strength or appearance is not of the utmost importance. Can have a variegated colouring and texture, often used in Scotland for hidden elevations of buildings and referred to as "colliery" or "composition" bricks.*

Compressive strength:	*The ability of a brick or other building element to resist compressive or crushing pressure.*
Course:	*A horizontal layer of bricks.*
Cross joints:	*The vertical joints between two bricks in a course also called perpends or "perps".*
Dog leg bricks:	*Bricks specially made for use where two walls join at an obtuse angle.*
Dooks:	*Wooden blocks or plugs inserted into brickwork to allow fixings.*
Durability:	*The ability of a brick or other building element to resist the effects of weathering and frost action.*
Efflorescence:	*A deposit or build-up of salts on the surface of brickwork.*
Engineering bricks:	*Dense bricks, of a uniform size and often darker colour which have a high crushing strength and low porosity.*
Extrados:	*The upper or exterior curve of an arch.*
Face:	*The exposed side of a brick visible when looking at a wall.*
Facing bricks:	*Bricks selected or manufactured to be used on the exposed surface of a wall because of superior appearance.*
Glazed bricks:	*Bricks which have had a glaze applied to them, often only on one face, and used in situations for cleaning or light reflecting properties.*
Harling:	*A thrown or cast on finish of lime and aggregate.*
Hoop iron:	*A type of re-enforcement in which flat bars of wrought iron, often dipped in tar and sand, are laid at regular intervals in a wall such as every 4th or 6th course.*
Hydrated Lime:	*Commonly used to describe non-hydraulic lime powder which is used in modern cement/lime/sand mortars. It is important to distinguish between this and hydraulic Lime which is the material most commonly used in lime mortar mixes in repair work.*
Hydraulic Limes:	*Limes which give a chemical set that is quicker and harder than the carbonation of pure limes.*
Intrados:	*The inner or lower curve of an arch.*
Jointing:	*The finishing of the mortar between adjacent bricks in a jointing style.*
Knocking up:	*The re-working of a mortar mix to regain plasticity before use.*
Mortar:	*A material which can be worked or placed in a plastic state, becomes hard when in place and which can be used for bedding or pointing bricks in a wall. It is formed of a binder, aggregate and enough water to make it workable.*

Nogging: *Brick used as an infill material to a timber frame.*

Ordinary Portland Cement (OPC): *The most common modern cement, it is often suggested for use as a binder in re-pointing work but is wholly unsuited for use in traditional brickwork.*

Perpend: *The vertical joint between two bricks in a course.*

Plasticity: *A description of the ease of spreading and cohesiveness of mortar.*

Pointing: *The application of a superior mortar to the raked out joints of ordinary mortar commonly carried out to allow for the application of a joint profile.*

Polychromatic brickwork: *The use of different coloured bricks for decorative effect, most commonly in Scotland cream or yellow bricks are used at quoins or window and door openings in contrast to the red brick used for the main body of the work.*

Porosity: *The level at which a brick absorbs water; the higher the porosity of a brick the more water will be absorbed into the brick in a given period of time.*

Quoin: *A corner of a building or section of brickwork.*

Rubble: *Masonry using irregular and variable sized pieces of stone as distinct from ashlar.*

Segmental arch: *An arch whose curve forms part of a circle smaller than a half circle.*

Shale: *Hard laminated rocks which may be crushed and mixed with water to form a plastic material suitable for brick making. A common material in the making of bricks, particularly common bricks in Scotland from the late 19th century.*

Skewback: *The section of brickwork which has an inclined face to provide an abutment for an arch.*

Slaking: *The controlled process of combining quicklime with water to form slaked lime.*

Spalling: *The loss of surface material from a brick due to decay.*

Specials: *Any purpose-made bricks of non-standard shape.*

Springer: *The first brick on each side of an arch.*

Straight joints: *Vertical joints directly above or below other vertical joints in successive courses; the main purpose of bonding is to avoid this as it results in a reduction of strength within a wall.*

Subfloresence: *The formation of salt deposits within the structure of a brick.*

Voussoirs: *A brick shaped to form part of an arch.*

Decorative brickwork,
Templeton's Carpet Factory in Glasgow.

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