

ENGLISH HERITAGE
PRACTICAL BUILDING CONSERVATION

STONE



ASHGATE

The craft of masonry continued to develop in the medieval period, when ever-more ambitious structures were created from stone. As new sources were identified and more masons trained, the use of stone for large house, public buildings and bridges became more common. This had a ‘trickle down’ effect so, in areas where it was abundant, stone became the material of choice for smaller houses, barns and other domestic buildings. For humbler buildings rubble stone was used, sometimes with only minimal dressing and often rendered or flush-pointed, but often it was roughly squared up and constructed in courses.

The increasing flamboyance of medieval architecture led to the development of more sophisticated construction and fixing methods. Medieval builders had a good understanding of engineering and walls relied to a large extent on thrust and counter thrust for stability. This is well demonstrated by the use of flying buttresses to transmit the outward thrust of a vaulted ceiling to a pier outside the building; the pier was surmounted by a heavy pinnacle that acted as a counterweight transferring the force downwards. Jointing techniques became more sophisticated, with the use of stepped joggles forming interlocking joints, used particularly in arch voussoirs.

Rubble walls

Clockwise from top left:

Some hard, intractable stones broke naturally into random shapes, which were laid closely-jointed to form polygonal or rag walling.

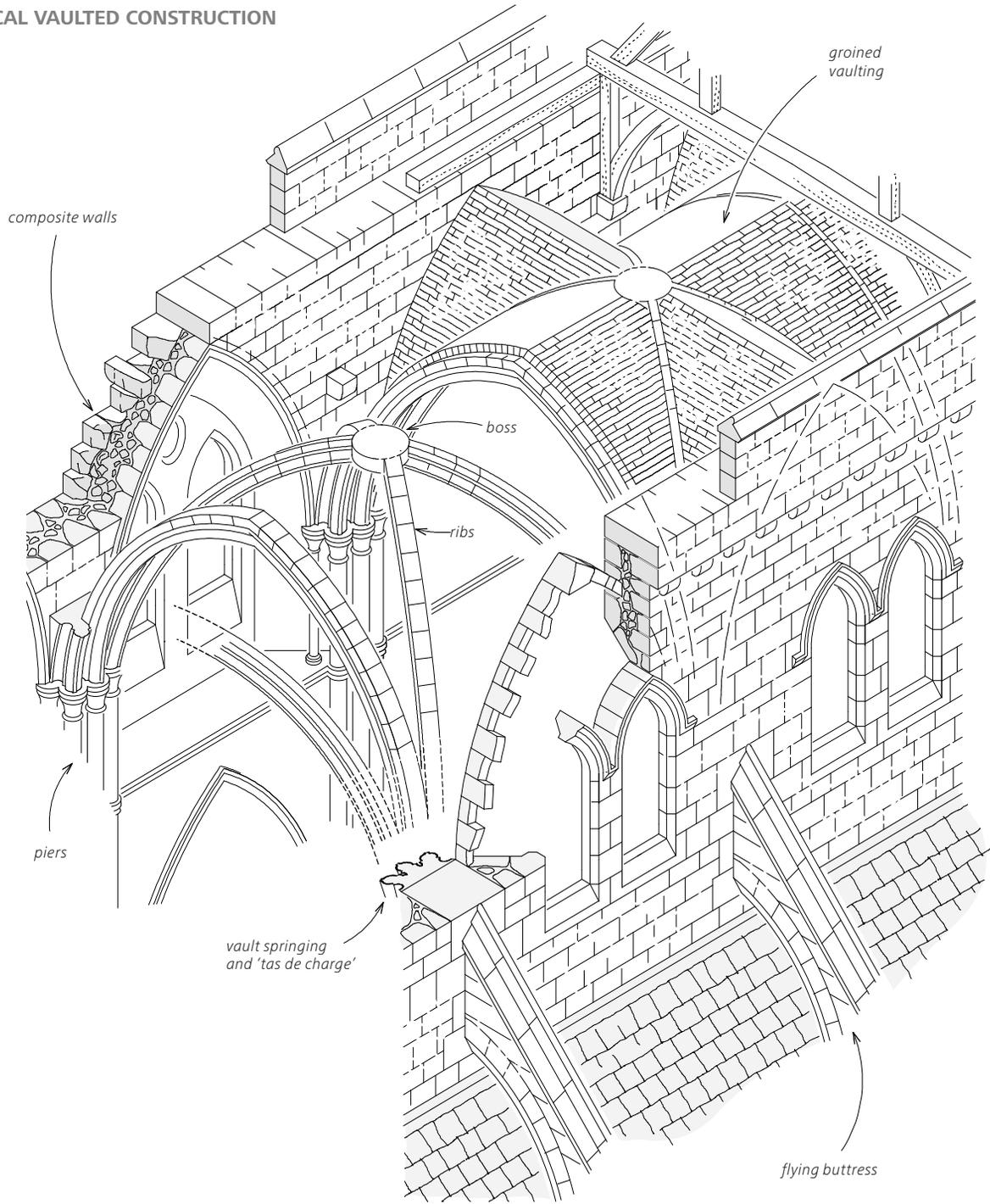
Other stones were of more regular shape and could be roughly coursed.

Some rubble stones were dressed to form rectangular blocks that could be laid in even courses.

Many rubble walls were originally lime-rendered for essential protection. Fragments of such renders sometimes survive in sheltered areas.



TYPICAL VAULTED CONSTRUCTION



EXAMPLES TO LOOK FOR WHEN SURVEYING STONE

SYMPTOM	DESCRIPTION	POSSIBLE CAUSES
DETACHMENT		
	<p>Delamination Detachment along the bedding planes of the stone, which can occur whether or not the stone is subject to compressive load</p>	<p>Weathering of weaknesses related to the bedding, such as layers of clay or mica, resulting in water ingress and increased weathering due to wetting/drying stress, salt crystallisation or frost action</p>
	<p>Exfoliation A form of delamination in which the stone breaks down into one or more very fine layers, often curling and twisting</p>	<p>Failure of surface crust in some sandstones and limestones; usually due to hardening of surface resulting in restriction of moisture movement Thermal stresses between the surface and underlying stone</p>
	<p>Contour scaling Separation of outer layer of stone parallel to surface contours of stone (independent of the bedding), occurring almost exclusively in sandstones The detached layer can be from about 2 mm up to 20 mm thick</p>	<p>Differential thermal movements in denser surface layers of sandstone Salt crystallisation behind surface</p>

EXAMPLES TO LOOK FOR WHEN SURVEYING STONE

SYMPTOM	DESCRIPTION	POSSIBLE CAUSES
DETACHMENT		
	<p>Blistering</p> <p>Raised, rounded, hollow swellings on the stone surface, varying in size from <1 mm to several millimetres in diameter, often accompanied by hairline cracks and sometimes broken (burst) in the centre</p>	<p>Thermal stress in surface layer, such as a sulphate crust on limestone</p> <p>In sandstones, more likely to reflect a concentration of salts rather than even distribution of salts (as in contour scaling)</p> <p>Crystallisation of salts behind a water repellent coating or paint layer (usually forms small blisters but can sometimes result in larger areas of detachment)</p>
	<p>Crumbling and flaking</p> <p>Breakdown of stone into friable small fragments or slivers</p>	<p>Expansion of clay in argillaceous sandstones and limestones</p> <p>Dissolution of binder in calcareous and argillaceous sandstones</p> <p>Salt crystallisation in surface pores of stone</p>
	<p>Granular disintegration</p> <ul style="list-style-type: none"> • Powdering (fine grained stone) • Sanding (sandstone and granite) • Sugaring (marble) <p>Breakdown of stone into individual grains of stone or minute fragments, forming a friable surface</p>	<p>Dissolution of binder in calcareous and argillaceous sandstones</p> <p>Salt crystallisation in surface pores of limestones and sandstones</p> <p>Breakdown of kaolinite in some granites</p> <p>Dissolution of calcite along grain boundaries due to action of acidic rain on marble</p>

EXAMPLES TO LOOK FOR WHEN SURVEYING STONE

SYMPTOM	DESCRIPTION	POSSIBLE CAUSES
DISCOLOURATION, STAINING & ACCRETION		
	<p>Discolouration: orange/brown</p> <p>General deepening of the colour of stone over time</p>	<p>Weathering and oxidation of iron minerals in the stone</p>
	<p>Discolouration: moist area</p> <p>Wetting and darkening of the stone surface in discrete areas</p>	<p>Dampness concentrated in a particular area, emanating from sources such as groundwater, leaking rainwater goods, seepage of rainwater via core voids or blocked drains</p>
	<p>Discolouration: reddening</p> <p>Reddening of block of stone</p> <p>May affect isolated blocks of stone, or all the blocks in an area</p>	<p>Oxidation of iron minerals to ferric oxide caused by exposure to fire.</p> <p>Discolouration of isolated blocks suggests re-use of stone from an earlier structure. Discolouration of an area of blocks indicates alteration <i>in situ</i></p>

EXAMPLES TO LOOK FOR WHEN SURVEYING STONE

SYMPTOM	DESCRIPTION	POSSIBLE CAUSES
DISCOLOURATION, STAINING & ACCRETION		
	<p>Staining: orange/brown</p> <p>Streaks or patches of orange/brown discolouration, usually close to a joint or adjacent to an iron component such as window frame or railings</p>	<p>Iron oxide from rusting of iron fixings</p>
	<p>Staining: blue/green</p> <p>Blue/green streaks, often immediately below copper, bronze or brass elements</p>	<p>Run-off (usually copper carbonate or copper sulphate) from corroding copper, bronze or brass elements</p>
	<p>Staining: bright to very dark green</p> <p>Areas of green staining, varying from bright green to very dark green (almost black)</p>	<p>Algal growth usually indicative of high levels of dampness, nutrients or both. Usually associated with rising damp or with concentration of run-off caused, for example, by defective rainwater goods or poor detailing of masonry. May also indicate run-off from accumulations of bird guano</p>

Although this method can be very effective, it is irreversible. As with all interventions, this will need to be weighed against the advantages of improving the structural stability of the building.

Pinning with dowels can be used to give structural support and cohesion to individual stone elements, either on its own or in conjunction with grouting. It should be noted, however, that if movement continues, pinning may just cause cracking elsewhere within the same stone, or in adjacent stones.

A firmer bond between dowel and stone is achieved if the surface of the dowel is roughened: for metal this means using a threaded rod, and for materials such as fibreglass, the surface can be hatched. Grade 316 austenitic stainless steel is the standard for historic building repair. It is especially resistant to corrosion, since it contains molybdenum as well as the nickel and chromium used in other austenitic steels.



Decayed or missing jambs, lintels or mullions may require temporary support, either to allow further investigation or as part of the repair process. This is best done with timber struts or pins supported on either side of the opening.

Helical ties or twisted wires can be inserted into a horizontal joint to tie across vertical cracks and act as a restraint for further movement.



The diameter of the dowels will depend on the particular application, but can often be minimised by careful choice of location and direction. Helical ties, as their name suggests, are engineered uniform spiral dowels (usually galvanised steel or stainless steel) that, when fixed with grout or resin into a pre-drilled aperture, provide a strong, even anchorage into the masonry. They are available in various lengths and diameters.

Holes for pinning should be drilled with a non-percussive variable-speed drill, using tungsten-carbide or diamond-tipped bits. The diameter of the bits, and the length, location and number of holes and fixings must be chosen to suit the size, scale and type of stone. Pilot holes should be drilled to make it easier to control direction and orientation, and these can then be widened with ever thicker bits, until both the dowel and the fixing grout can be accommodated. The pins should be recessed behind the surface to a minimum depth of 10 mm where possible. The hole is then filled with mortar or a stone plug.

POINTING

Existing pointing can provide evidence about the materials and techniques used in the construction and later interventions, but even the best mortar will tend to erode and may need to be replaced. It is not surprising, therefore, that repointing is the most common intervention on masonry. However, although many historic mortars may be quite soft and crumbly, they may still be functioning perfectly well in keeping moisture from penetrating the wall. Replacement, even of cementitious mortars, is only necessary where the pointing is clearly failing, is loose or missing to a depth equal to or more than the width of the joint, or is damaging the surrounding masonry (for example, a hard impermeable mortar causing deterioration of the arrises).

The repointing of stonework can have a significant effect on the appearance of the stone as well as its long-term survival. To be effective and visually appropriate, repointing requires attention to detail and must be executed to the highest standards. Sometimes earlier repointing in inappropriate materials is so superficial that it can be removed easily, to reveal a perfectly serviceable original mortar beneath. **◀ MORTARS**

Pointing is often replaced unnecessarily when the original mortar is still sound

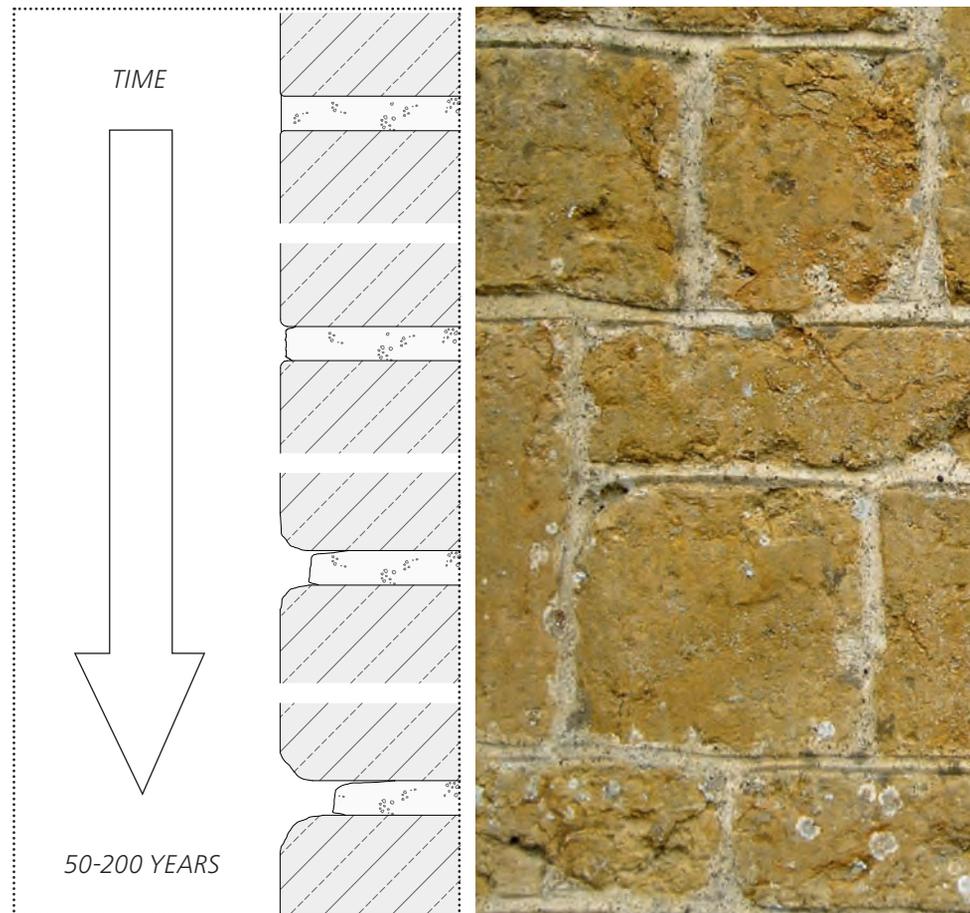
Here the thin joint between the stones visible in the centre of the picture appears sound, but it has been repointed in a cement mortar that has itself been overlaid with a paler mortar. The result is that the pointing no longer acts as a path for water evaporation. The appearance of the wall is now dominated by pointing, rather than by the close-fitting stone blocks.



Typical weathering of a lime- mortar joint

Left: Most joints in squared rubble or ashlar were finished flush with the face of the stone. Over time, frost action and cycles of wetting and drying will have caused the mortar and surfaces of stonework to decay. The exposed arrises are particularly vulnerable, and will have tended to become rounded.

Right: Historic 'bird's beak' pointing on 17th century stonework: this has a distinctive projecting V-shaped profile.



POINTING DESIGN

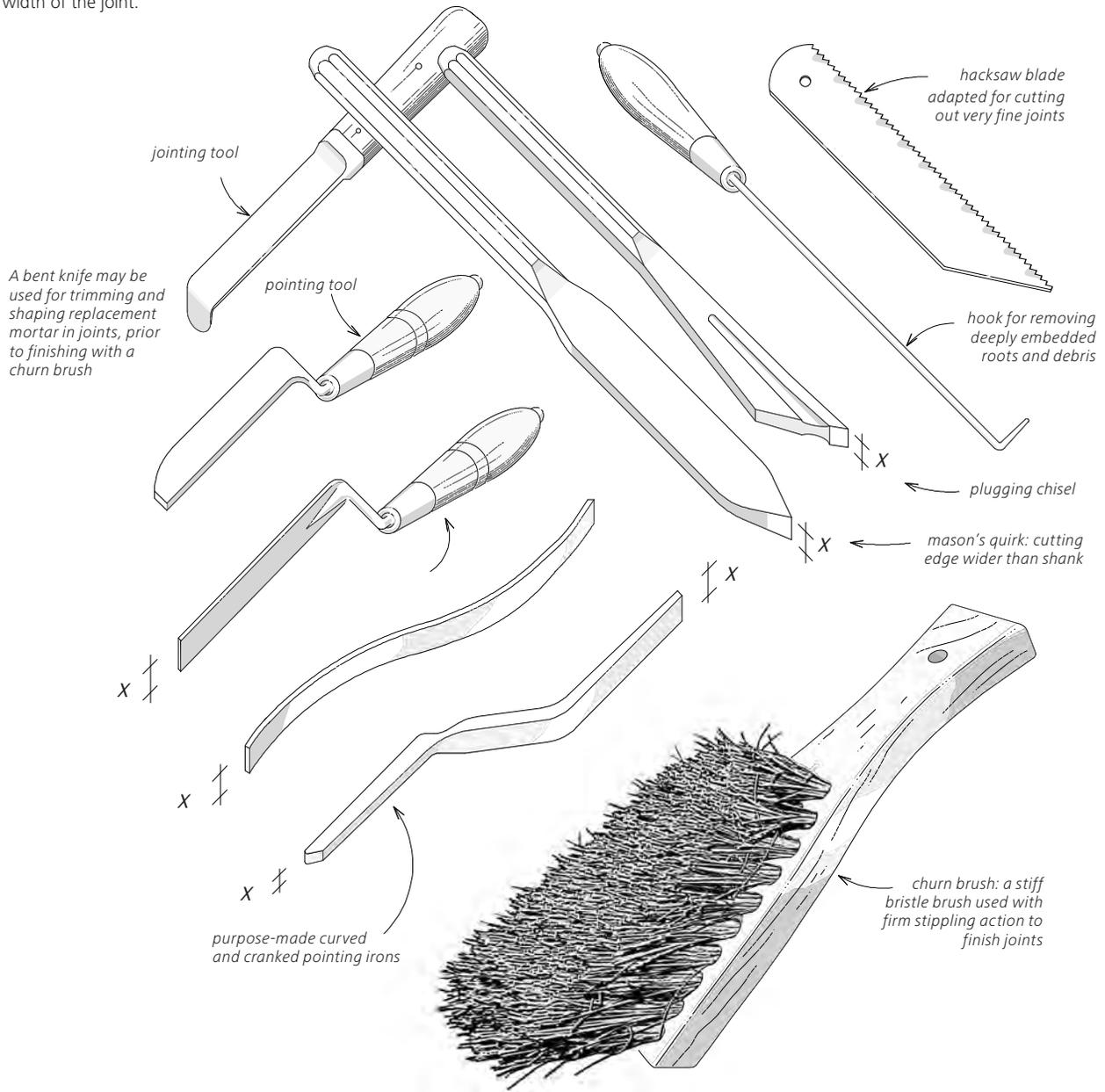
Although pointing may amount to as little as 5 % of the surface area, its colour, texture, thickness and finish will affect the overall appearance and behaviour of the masonry. Repointing should match the original not just in colour and texture, but also in design and application.

There are few examples of early 'pointing', as common practice was simply to strike off the bedding mortar at the face.

More consideration began to be given to the appearance of the joints from the 16th century onwards, when pointing sometimes became part of the design of the masonry (for example, tuck pointing). Modern joint finishes commonly include weather-struck (finished with a pointing trowel) and bucket-handle (a concave finish formed with a brick jointer), but these are quite unlike any historic profiles. As well as being visually overbearing, they are less effective in protecting the masonry.

POINTING TOOLS

The correct tools are essential for good pointing. This diagram shows a range that would be suitable for most situations; the 'X' dimensions need to be just less than the width of the joint.



APPLYING THE POINTING

The wall should be rinsed down well in advance of pointing, so that by the time of mortar application, it is damp rather than wet. This encourages good bonding between the new mortar and the substrate. The weather must be suitable; high temperatures or high winds will cause the mortar to dry too quickly, inhibiting carbonation. If necessary, the fresh pointing can be covered with damp hessian and plastic sheeting to slow drying. Repointing should be avoided entirely if the temperature is expected to drop below 5°C during the application or curing period.

It is best to start repointing at the top of the wall, so that any dripping water rinses the stonework rather than washing out the new mortar. It is worth taking the time to select and obtain a pointing key of the correct size, as this makes for the swiftest and most accurate application.

The main stages in successful repointing

1. Removal of old pointing using a quirk.
2. Cleaning out the joint using a hand-held blower (this helps prevent debris being washed down the wall).
3. Thorough wetting of the joint.
4. Applying the pointing.
5. Compressing the pointing with a pointing key of suitable width.
6. Allowing the mortar to take an additional set.
7. Cutting back mortar to slight recess.
8. Stippling the surface with a churn brush.
9. The finished joint.

The joint must be kept damp both during the process, and for some time afterwards.





INTRODUCTION

Historic ruins differ from intact historic buildings in ways that can make them challenging even to experienced historic building surveyors. Deprived or partly deprived of roofs and floors and with damaged walls whose cores are exposed to the weather, they behave differently to complete buildings and have different needs. Not everything is as it seems. Earlier interventions may have kept some of the building standing so that fractured, leaning, bulging and overhanging masonry may have been consolidated. Conversely some bulging and cracking or water movement in walls may indicate recent problems that require new intervention. It is usually the case that replacement of fabric will have been absolutely minimal and consolidation work will have been contrived to be visually unobtrusive and may therefore be difficult to identify. In many cases, the whole of a 'ruin' site is of extreme archaeological sensitivity and may be of considerable ecological importance: these factors increasingly dictate what is possible and permissible and the manner in which any proposed work is carried out.

A preliminary understanding of the character and identity of the site and its ruination is essential for any accurate assessment. Modern technology (such as rectified photography, ground penetrating radar, pulse radar, resistivity measurements and thermographic surveys) can be used to provide information but should only be used as supplementary tools for the other responsibilities of observation and the recognition and identification of problems.

COMPOSITE WALLS & ASSOCIATED FEATURES

Composite walls typically consist of two skins of masonry, with a central core of mortared rubble. Their stability will depend on the surviving height, the original width, the quality of the mortar and their method of assembly. The main destructive agents of the broken composite wall can be summarised as:

- water penetration of the wall head
- water degradation of the core
- substantial root growth in the core
- detachment between core and facing
- stone robbing at the wall base
- washing out of joints
- salt crystallisation coupled with frequent wetting/drying and freeze/thaw cycles
- distortion and cracking of unsupported/unbraced wall sections
- inappropriate remedial treatments.

Facing page: The ruins of Goodrich Castle, in Herefordshire

If you require an alternative accessible version of this document (for instance in audio, Braille or large print) please contact our Customer

Services Department:

Telephone: 0870 333 1181

Fax: 01793 414926

Textphone: 0800 015 0516

E-mail: customers@english-heritage.org.uk