TIMBER HAS been used in building structures for centuries, whether for roofs, floor beams and joists, posts and lintels for windows and doors, or for complete timber framed buildings, including load-bearing walls and screen partitions.

The use and form of the timber elements and signs of how they were shaped are useful in dating historic buildings because the type of joints, framework design and tool technology changed over the centuries. Whether or not they are visible, timbers are intrinsic to the historic and archaeological interest of the building.

Structural timbers may deteriorate as a result of decay, over-loading, or as a result of poor design and alterations carried out in the past.

A common problem is decay brought about by moisture, often owing to a leak, poor maintenance or condensation. This allows fungi (dry rot for example) or wood-boring insects (such as woodworm and deathwatch beetle) to colonise the timber and by their action reduce its strength.

Over-loaded structural members fail by cracking, bending or crushing. The over-loading may arise either as a result of weakening following decay, or because they were designed poorly or frugally, or because they were meant to take a different set of loads than they are currently bearing. For example, a roof structure designed for thatch or slate may not be capable of supporting the weight of heavy tiles.

REPAIR OPTIONS

Repairing failed structural timbers is, of course, not a new practice. For centuries repairs have been fashioned using carpentry methods or with blacksmith-made splints, brackets and ties, and these ancient repairs certainly add character and help tell the story of the building.

In more recent times we have also utilised modern materials such as steel, epoxy resins, carbon fibre rods and wire rope to reinforce structures. Building repairs can also be effected by completely replacing timbers with new timber or, where used appropriately and sympathetically, materials such as steel or reinforced concrete. It may also be possible to reduce the loads through the design of secondary structures and in-fills such as brick panels, or packing-up under partly decayed timbers.

The relative merits of each form of repair largely depend on the situation. Although there is no right or wrong method, there is always a solution that is most appropriate to the circumstances presented by the building. The art is to identify it.

When dealing with historic structures, the principles which come into play are:

- **Structural integrity** – ensure the structural members are capable of taking the loads they may have to bear.
- **Minimal intervention** – retain the maximum amount of historic timber and minimise alteration or introduction of new elements. Consider the impact of the repair process on the component and the structure, including access issues, the viability of moving the timbers for repair, and the extent of damage which might be done to other building elements in executing the repair.
- **Reversibility** – try to ensure that alterations and additions can be undone without harm to the fabric.
- **Like for like** – where possible, use the same materials and techniques as previously used.
- **Honesty** – make the solution honest but...
When dealing with historic fabric, it becomes aesthetically and architecturally elegant and either neat or invisible: there is no justifiable reason why modern repairs should not add character and appeal in the same way as the historic ones.

- **Documentation** – record the fabric before intervention and document the intervention itself so that future conservation work is well informed.

In choosing the right approach and repair mechanism you must take all the evidence into account, including the type of failure that has been observed and, by deduction, the reason for it. Things to look for might include the source of extra loading, or the reason why a beam end is getting wet. So, for example, you might look at a cracked upper floor beam in a barn where the crack at the end of the beam is in an area of severe insect attack. In this case you would need to consider the presence of moisture in the wall in which the timber is embedded, and whether there is a leak in the roof, an overflowing gutter or some other source. You will also need to consider whether the upper floor is being asked to take particularly high or increased loads. Perhaps a huge amount of hay or straw is sometimes stored in the barn, or maybe there is a repair post mounted onto the beam which is transferring additional load, perhaps following a change in the roof covering and the subsequent deflection of the roof.

Another factor for consideration is the impact of any particular repair. If the timber were removed, how much damage or loss of fabric would occur around it?

Often these observations, decisions and design solutions are the realm of specific professional consultants, such as structural engineers or building surveyors. Obviously such matters are best left to the expert, but it is important to try to retain as much historic fabric as possible, so the best solution is usually to repair rather than replace components. A common technique is to scarf-in a new piece of timber to the old, like for like. The new section can be connected by a lightning bolt joint (pegged or bolted) or, if in compression, a V-shaped splice. Scarfed joints are particularly useful in cases where one section of the timber has rotted out, such as the foot of a post or jamb, or the ends of a rafter, truss or beam which have been affected by damp. They provide a nice neat repair, in keeping with the character of the original, but require a reasonably high level of carpentry skill if they are to be done well.

**LIKE FOR LIKE REPAIRS**

Sometimes the simplest repair is a straightforward replacement of the whole timber, like for like: for example a completely rotten lintel or exposed verge rafter. At times, replacement provides the opportunity to fit a stronger or more substantial piece of timber or to slightly adjust the design to prevent future failure.

However, as a matter of principle it is important to try to retain as much historic fabric as possible, so the best solution is usually to repair rather than replace components. A common technique is to scarf-in a new piece of timber to the old, like for like. The new section can be connected by a lightning bolt joint (pegged or bolted) or, if in compression, a V-shaped splice. Scarfed joints are particularly useful in cases where one section of the timber has rotted out, such as the foot of a post or jamb, or the ends of a rafter, truss or beam which have been affected by damp. They provide a nice neat repair, in keeping with the character of the original, but require a reasonably high level of carpentry skill if they are to be done well.

**REINFORCEMENT OPTIONS AND SUPPLEMENTARY STRUCTURES**

It’s often possible and preferable to leave historic timber in place and either take or help take the strain with an alternative structural member. For example, the spreading of a roof truss may be restrained by adding a second collar, or a rafter may be doubled up with a new timber either close by or attached to the original. In some cases the right roof repair solution is a new framework built around or over the old. This is sound conservation practice because it saves the original fabric and is generally reversible, although it can look a little clumsy if it is on show.

Where beams or joists are not deep enough for their loading, the result is excessive bending, bouncing floors, and possibly even cracks. One option is to increase the effective depth by fixing additional timber to the top of the component to increase its stiffness. If the depth of a beam only needs to be increased marginally, one very neat solution is to firmly attach the floorboard material to the top of the beam. However, fixing the rest of the floorboards around it can be a head-scratcher. When the ends of beams or joists are decayed, or in cases where either the beam or its support has moved, leaving too little...
bearing, it is essential to increase the junction between the two. Extending the end of the timber can be done with side-planting or splicing-in but the alternatives are many and varied. The bearing can be extended by introducing steel or timber bolted under the beam; by forming a whole box section steel shoe attached into the beam; by adding a timber, steel or masonry post under the end of the beam, down to the ground; or by creating a timber or steel corbel on the wall beneath the end of the timber. Similarly, a beam pulling out of an adjacent beam can be picked up with a fabricated strap like a joist hanger.

Another place for simple splints like these is where overloaded purlins have split. Side-planting steel sections or timbers bolted across the failure and attached to sound timber often work well.

**STEEL AND RESIN OPTIONS**
Where beams are in need of a little more assistance, flitch plates can be inserted along part or the whole length of the beam. This method involves cutting a slot into the timber and making the beam a composite of steel and timber. The plate may also take a T-shape either the right way up (top of the beam) or upside down (underside of the beam). From an engineering viewpoint, the steel section is best let into the underside of the beam and fixed upside down, so the wide part of the T is positioned to carry the greatest tensile forces. From a practical viewpoint, these are difficult repairs to carry out in situ, requiring overhead cutting of the slot by multiple drillings or chain-morticer or chain-saw cutting. The risk assessment alone takes some serious thought.

Despite its higher cost, stainless steel is highly suitable for this kind of repair: it offers higher strength for its size than plain steel, and it withstands corrosion in oak beams. (Even in ancient timbers, the tannic acid present will corrode many metals.) The downside to using any steel is that the parts which show may not be as aesthetically pleasing as with other solutions. However, with a bit of forethought elegant solutions are possible (albeit at a slight extra cost), such as recessing nuts and bolt heads and plugging the holes with timber, or just rounding the ends of brackets. Adding a simple blacksmith-style decoration can make the repair much more elegant, while keeping the repair ‘honest’ and its history clear. Where the ends of fastenings are on show, square plates can be neatly welded to the ends of threaded bar or bolt-heads and rebated into the surface of the timber.

Another method of strengthening timbers in a similar way is to let in steel bars or carbon fibre rods. These are usually fixed with an epoxy resin. The letting-in can involve cutting slots or drilling holes lengthwise from the end of the timber or diagonally across cracks.

When the timber to be repaired is historically significant, a partial replacement is vital. To preserve the character of the original timber, one option is to remove the face as a veneer for later reapplication over a newly inserted piece. Where there is limited access or risk of damage to the surrounding plaster, it is possible to treat a beam which has been eaten away to within an inch of its life by building up a laminated resin and timber beam in situ. The face can then be consolidated with resin poured into the beetle flight holes before being reattached to the beam. Such solutions tend to be very satisfying, but obviously complex, expensive and unnecessary for most repairs.

A combination of replacing rotten or failed timber with new timber and strengthening with resin bonded steel or carbon fibre rods can be adopted to good effect in many situations. Some companies will even supply pre-shaped repair pieces with the rods already bonded in place, ready to fix to the prepared end of a failed timber.

Resins offer a variety of advantages: minimal loss of fabric, versatility, gap-filling and the opportunity to carry out certain repairs which are impossible by other methods. However, they are not particularly reversible and can be prone to failure in humid environments.

**SPREADING ROOF STRUCTURES**
Turning our attention to roof structures, spreading out of the A-frame is often indicative of inadequate ties or decay at eaves level. Inserting additional, often lower collars (tie beams) between the trusses or rafters, assists greatly in reducing roof-spread, and this consequently restrains the outward thrust on walls. Timber is commonly used but an alternative is steel wires bolted in a substantial, but sensible way to the timber and tensioned. Improved rigidity can also be achieved by securely bolting a gusset made of ply to a nearby truss or rafter and to a ceiling joist below. This strengthens the joint and triangulates the roof. The technique is especially useful in roof spaces where the collars are necessarily high for headroom. It is an effective solution but shouldn’t really be on show.

Where the junction of trusses and collars have weakened or slipped, a simple steel Y-shaped plate bolted in place can stabilise the structure.
Stainless or other wire ropes can also be employed to withstand lateral movement such as where all the rafters are ‘racking’ – that is to say the apex of the roof has shifted sideways at right angles to the line of the trusses. In that case tensioned wires fixed diagonally across the rafters can add some triangulation, which will prevent further movement. Timber or solid steel straps can be used in a similar way, but it is frequently a neater and more easily installed solution to use wires. However, the strength of the wire in tension must be able to withstand the loads involved in service or they will simply stretch and become ineffective.

Clearly, there are many possibilities for repair. The right solution is the one which works for the building (and ideally for the client as well). Probably the conservation principle to which you should give most emphasis is minimising the extent of intervention. Each technique and each material has pros and cons, but we generally find that the minimal intervention approach will lead to a cost-effective solution which saves surrounding historic fabric. If this means the repair is visible, well at least it’s honest and with a spark of creativity can be made tidy and aesthetically pleasing.

Acknowledgement
Working on timber repair solutions with Patrick Stow & Associates over the years has inspired me greatly, for which I’d like to thank him.

ROBIN RUSSELL BEng(Hons) is Director of Corbel Conservation Ltd (www.corbelconservation.co.uk). He has over 25 years of management experience and believes that his firm of contractors can provide the best historic building repairs by ensuring that his managers fully understand the engineering options and the conservation approach.