Society for the Protection of Ancient Buildings

Technical pamphlet 2

Strengthening timber floors

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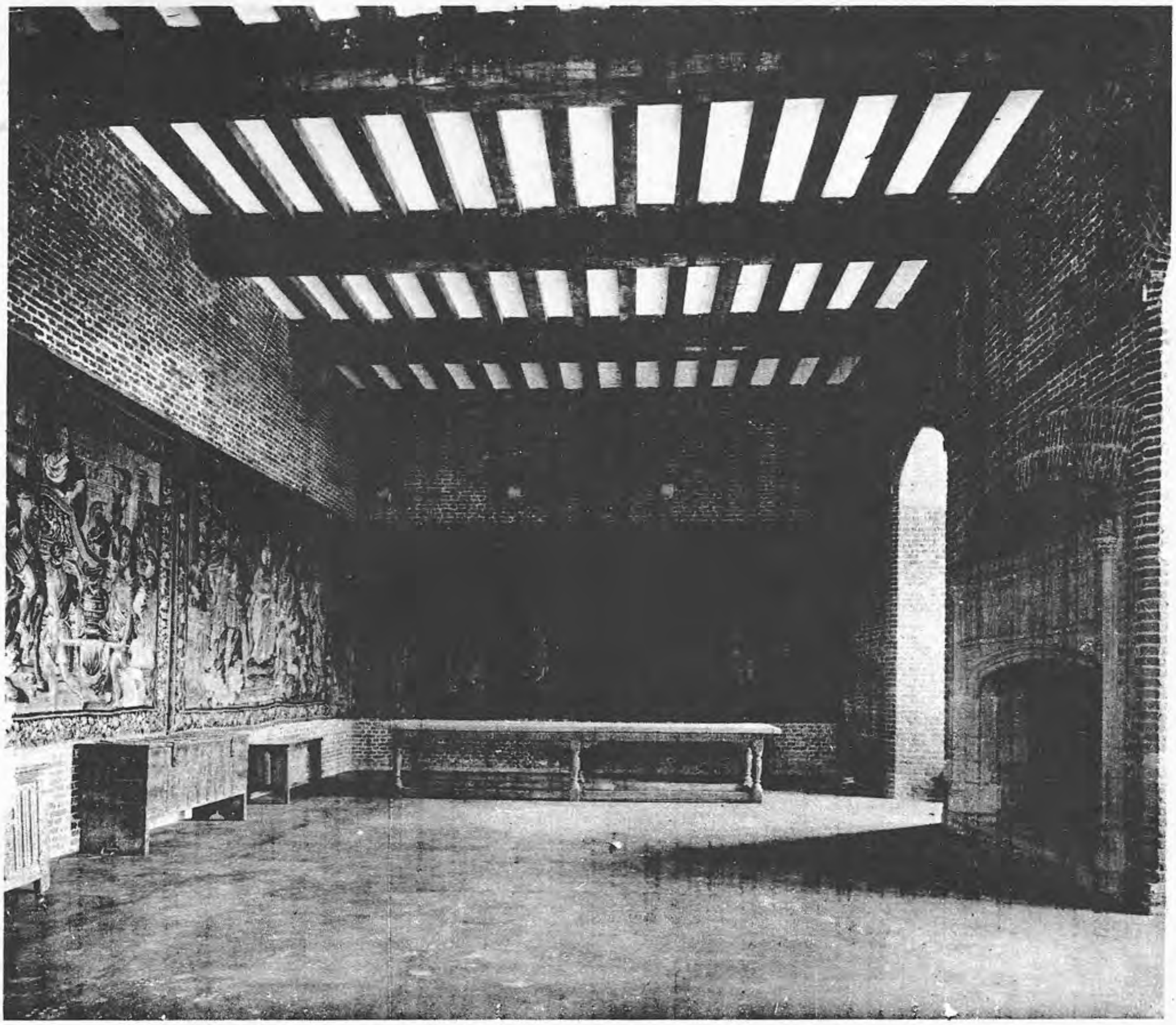
Contents

Sloping or springy floors may be due either to the failure of the supporting structure or to distortion caused by a defective beam or system of beams.

This pamphlet suggests ways in which faulty beams can be made capable of performing their proper function with the minimum of disturbance and leaving practically no trace of the work that has been done.

This pamphlet is a record of John Macgregor's own experience in strengthening timber floors. Every building problem is different and the SPAB would like to stress the importance of consulting an expert before this type of work is contemplated as methods cited here may not be appropriate in any particular instance.



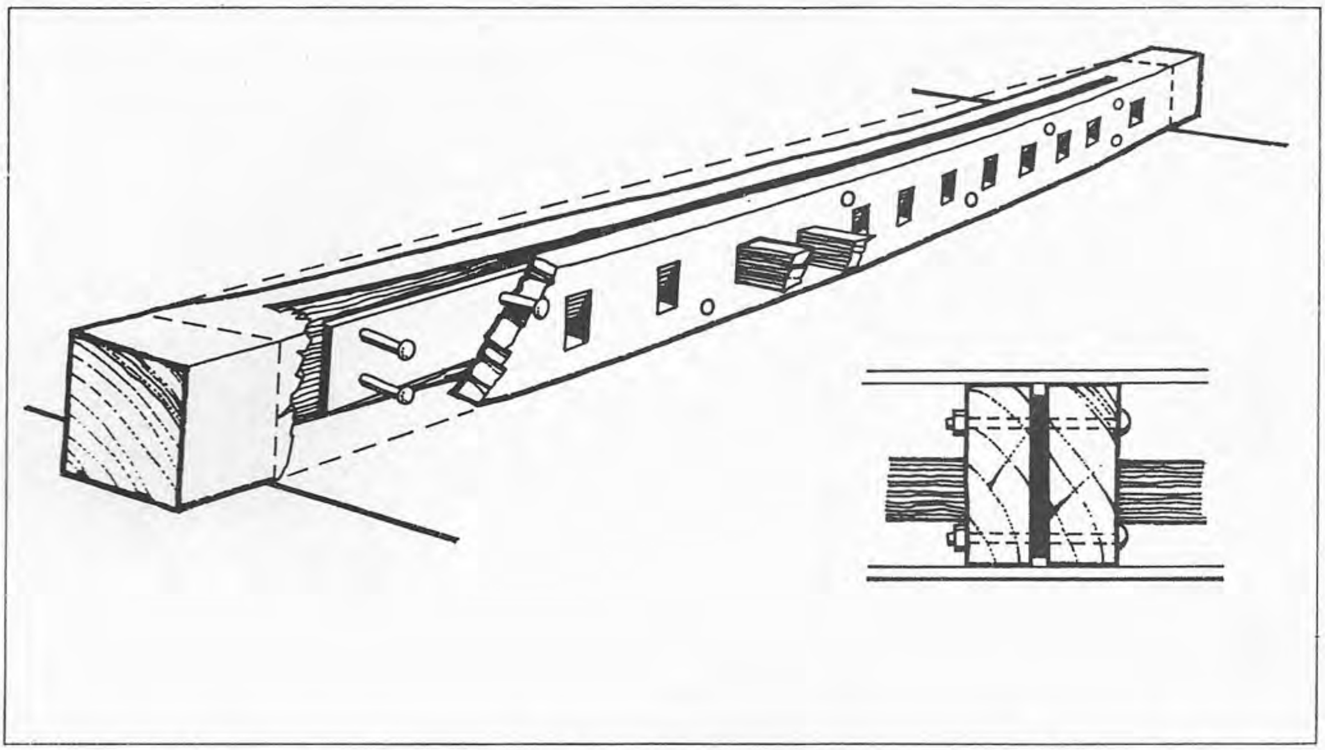
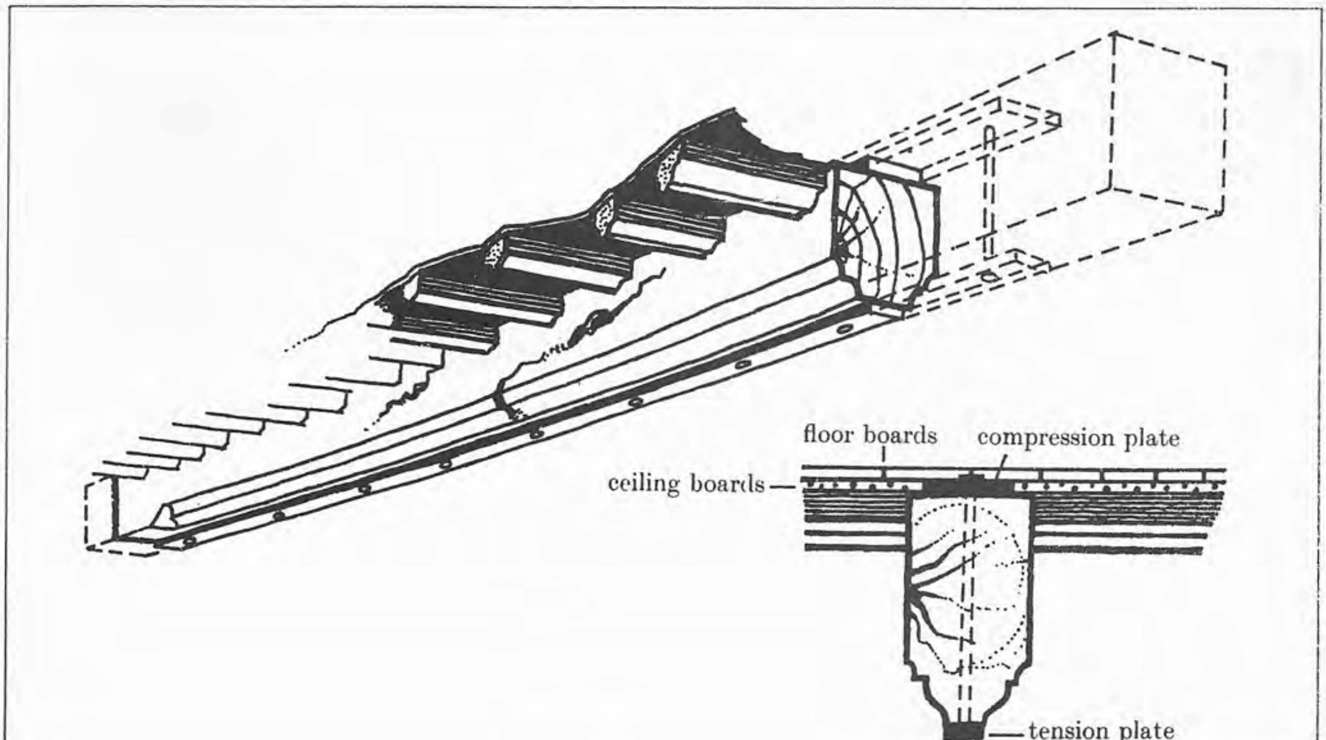


Fig. 2: The flitch plate can be slotted into the timber beam and bolted horizontally (approved practice by the Department of the Environment).

Fig. 3: Lullingstone Castle, Kent, where a 15th-century beam was supported by top and bottom plates.

Fig. 4 The compression and tension plates are bolted vertically, and the steel takes the place of a rolled-steel joist.



1 The main causes of failure

There are many reasons why a floor is sloping or springy. The fault may be due to the failure of the supporting sub-structure, and in this case the whole floor may be brought back to its original position without any dismantling, if this structural problem is overcome. On the other hand, it may be found that the failure is in the floor itself, and frequently can be attributed to a single beam or system of beams, which has caused wholesale distortion. Such beams may have either subsidiary beams or the joists themselves framed into them, so that their replacement or even repair would entail great disruption of the whole construction, including the old floorboards and the ceiling beneath, which may have an original painted or moulded soffit.

Apart from failure due to decay or beetle infestation, timber beams are usually weakened by overloading. The standard I section rolled-steel joist may be considered as the simplest form of beam design, in which the three main structural elements are clearly demonstrated: the compressional upper flange; the tensible bottom flange; and the web that holds the top and bottom apart as far as possible and resists the diagonal stresses between them. The medieval timber beam with its joist mortices cut half way up on either side is fundamentally the same conception.

Timber beams always fracture first on the under-side (Fig. 1), showing that it is the tensile portion of the beam that is weakest. Bearing this in mind the following methods for dealing with a fractured or sagging beam can be considered.

2 The flitch plate

This method of strengthening a timber beam was commonly used in the last century and consists of a metal plate set vertically between two timbers and the three bolted together at suitable distances and at varying heights. The strength is that of the web of a steel joist without top or bottom flange, which is prevented from buckling by the timber on either side. The method can be used where timber beams span in the thickness of a floor supporting joists framed in between them on either side.

The great advantage is that the framing of the joist is not interfered with, but it entails sawing vertically through the full length of the beam twice, so that the flitch plate can be dropped into position and then cross bolted (Fig. 2).

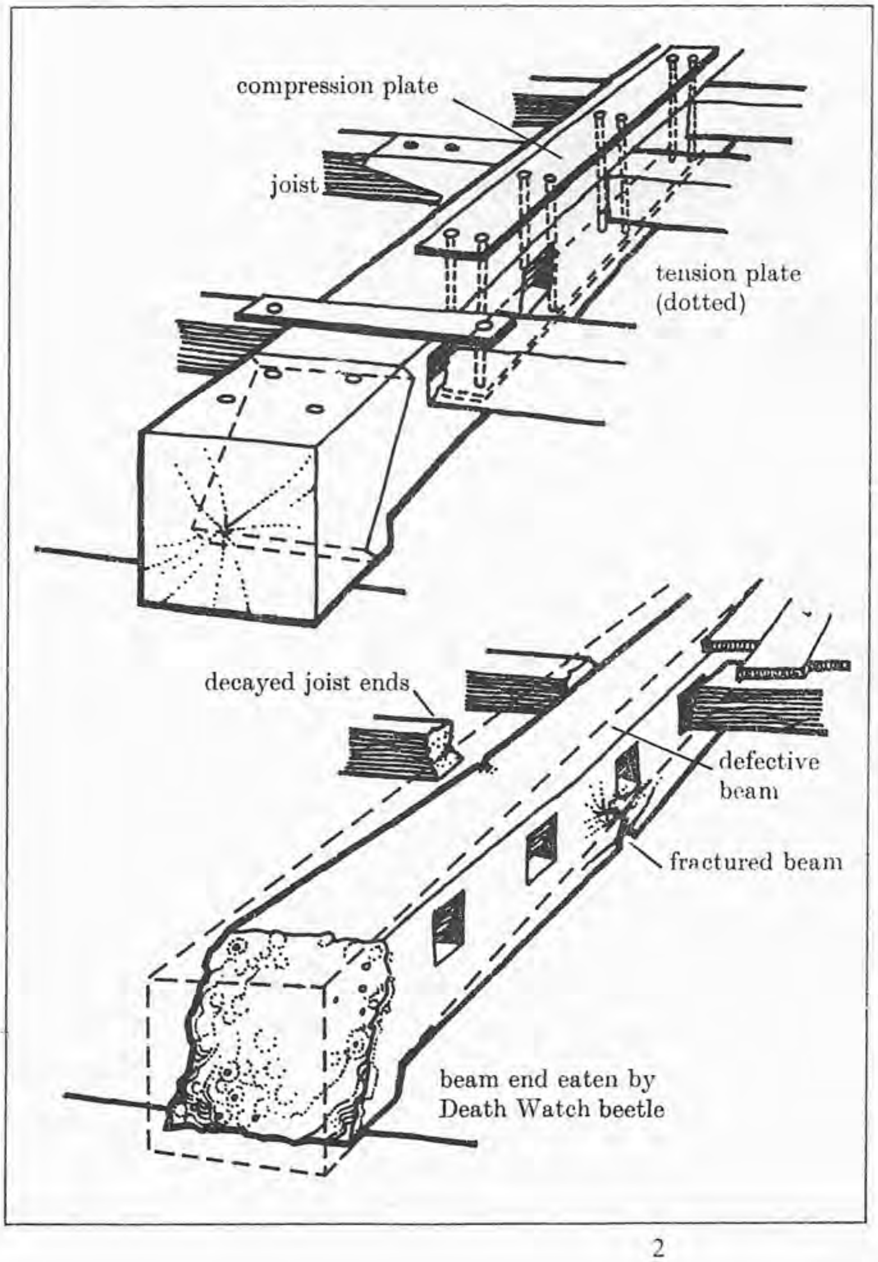


Fig. 1: Inserting a tension plate to support a beam that has fractured

3 Top and bottom plates

This method consists of placing metal plates beneath and on top of the sagging or fractured beam and then bolting vertically, so that steel takes the place of the top and bottom flanges of the rolled-steel joist, and the timber acts merely as the web.

A richly moulded 15th-century beam at Lullingstone Castle, in Kent (Fig. 3), which was split and fractured completely in many places and had rich, moulded oak joists on both sides, was recently dealt with successfully in this manner (Fig. 4). The only visible effect is a 3 in x $\frac{1}{2}$ in plate on the under side, which, when tinted to the colour of the oak, is hardly noticed.

At Watford one of the two main beams in a 16th-century floor, which was carrying three billiard tables, had fractured, and the whole floor was so distorted that total renewal was contemplated. On opening up, however, it was found that the fracture was a clean one, and by jacking up, and fixing plates about 6 ft long buried in the thickness of the floorboarding and plaster ceiling, the whole floor was saved.

5 Side rods

On occasions it is impractical to get at and strengthen the underside of a beam, and some other device is called for. Such a problem was met at Moor Park, Rickmansworth (Fig. 7), where the floor over the great salon was sagging and springy. As the building was being opened to the public, concern was felt about the floor on account of the world-famous painted ceiling beneath.

In order not to disturb the ceiling, the floorboards above were removed, the beam was drilled through just above the ceiling, and two substantial steel-bearing tubes inserted. Angle irons were notched into the upper side at either end and cranked steel tie rods were inserted through the end of the angle irons and under the projecting ends of the bearing tubes with nuts and washers at the ends with left-and-right-threaded union in the centre (Fig. 8). On tightening, the sag was reduced without appreciable effect on the painted ceiling.

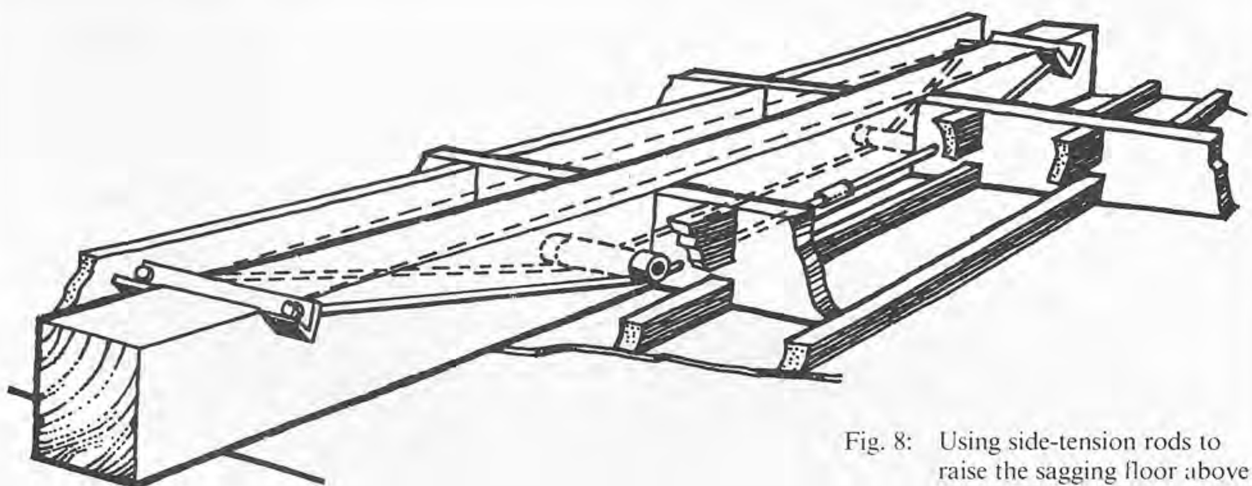


Fig. 8: Using side-tension rods to raise the sagging floor above the painted ceiling at Moor Park, Rickmansworth

6 Joist strengthening

A sagging floor is found occasionally to be constructed with its joists running lengthwise, and it is desirable to strengthen it in its thickness by breaking the joist span in the centre in a transverse way. This problem arose in the adaptation of 55 and 57 Great Ormond Street, in London, for use as the offices of the Society for the Protection of Ancient Buldings. It was overcome by removing two or three floorboards, measuring and drawing a section through the joists on which was plotted a sagging suspension line. In accordance with this line a series of holes was bored through each joist and a steel cable threaded, the ends of which were anchored to a flat steel plate passing on top of the joists and into the walls at either end (Fig. 9). By stressing this cable each joist is carried in the centre of its span as if on a cross beam.

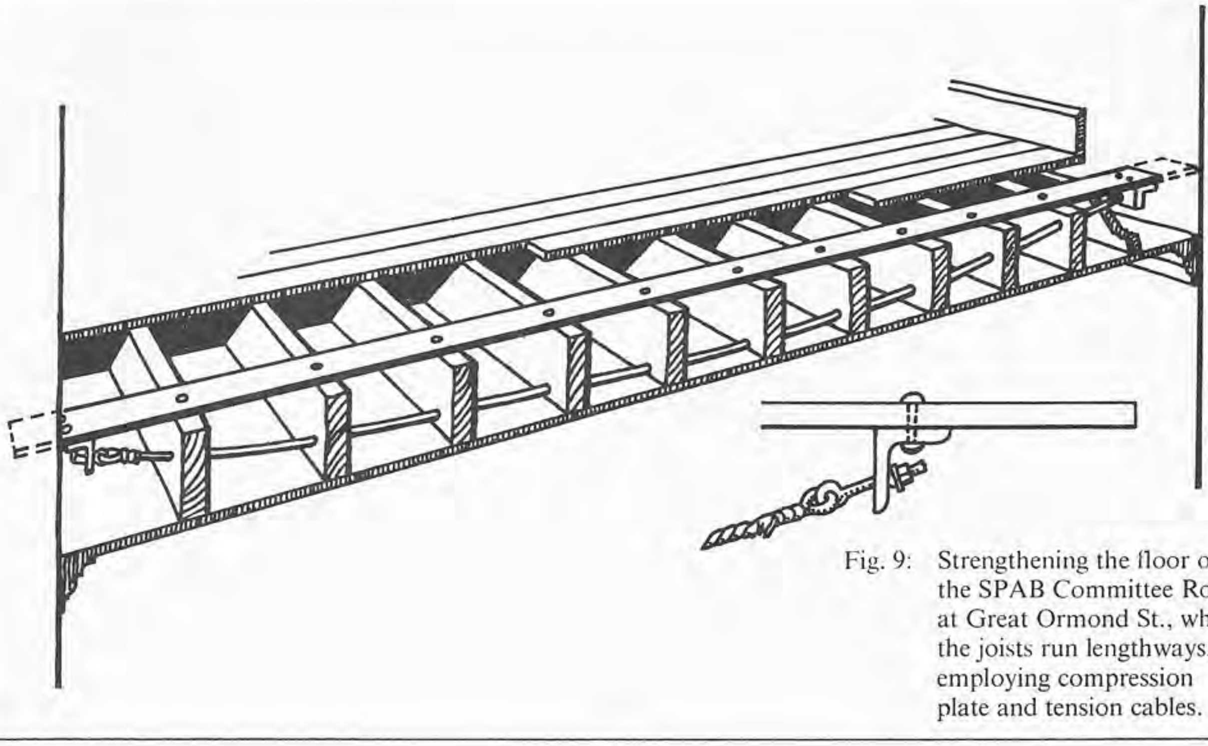


Fig. 9: Strengthening the floor of the SPAB Committee Room at Great Ormond St., where the joists run lengthways, by employing compression plate and tension cables.

4 Trussed girder

At the Wren Library, Trinity College, Cambridge (Fig. 5), the floor beams were suffering excessive sag and spring. Over-stressed from the first by the heavy load of books above, attempts to strengthen the beams began as early as 1685, when inclined compressional struts were housed in their sides. But these in turn eventually caused further weakness by splitting the beams along their grain at the internal strut pressure points. Wrought-iron hangers then added above also failed, because they could not be sufficiently anchored in the outside walls.

The problem was solved in 1970 by adding inverted trussed griders below the beams, housed entirely in the hollow plaster beam casings of the underlying cloister ceiling. Akin to the chassis beams of railway carriages, the girders consist of pairs of 3 in x $\frac{3}{8}$ in mild steel flats, coach screwed to both sides of each beam end. From these points they rake downwards to a level some 3 in below the beam centres, where they are fabricated as angles, set flange inwards. The flanges carry oak blocking pieces crosswise below the beam centres and are wedged up to them with folding oak wedges, driven from each side. The beams were thus effectively and invisibly stiffened causing no damage or disturbance to the marble floors of the Library above (Figs. 5, 6).

Fig. 7: The Great Salon at Moor Park, Rickmansworth

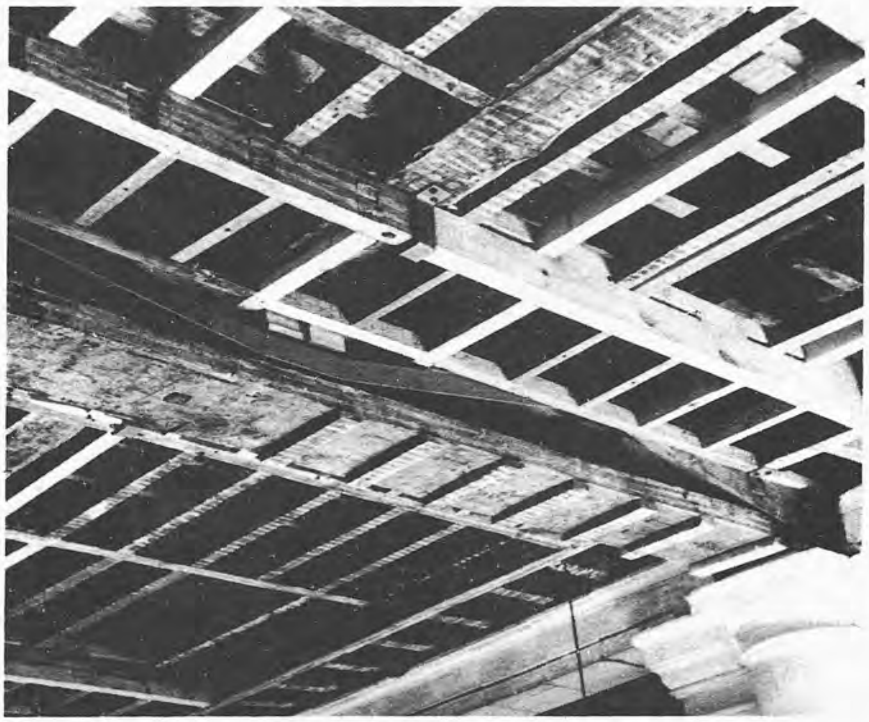


Fig. 5: (above) The cloisters below the Wren Library at Trinity College, Cambridge.

Fig. 6: (Left)
The floor beams of the Wren Library were sagging. Inverted trussed girders were inserted and wedged up.

7 Loss of compressional strength

A common cause of floor-weakening is produced by the insertion of heating or other service pipes notched down into the joists or supporting beams. This may not be serious if it is close to the bearings. If, however, it is in the centre of the span, it can be disastrous. At Montacute House several of the beams previously referred to had been further weakened in this way. The trouble was remedied by the insertion of wedges in the incision in the beams above the pipes.

Normal deal joists carrying the moulded and coloured ceiling of one of the London Livery Company halls had suffered similarly, but owing to the absence of space between the pipes and the floorboards folding wedges could not be used. By placing a flat iron plate slighty curved up in the centre, with its ends notched into the top of the joist and then screwed down in the centre to flatten them, the notched end thrust outwards thus restoring the weakened compressional portion (Fig. 10).

8 Decayed joist tenons

It is frequently found that decay or shrinkage has destroyed the bearing of the oak tenon joists in the mortices of a central beam. By fixing short iron plates across the beam, the joist ends can be supported from above without disturbing them in any way (Fig. 11).

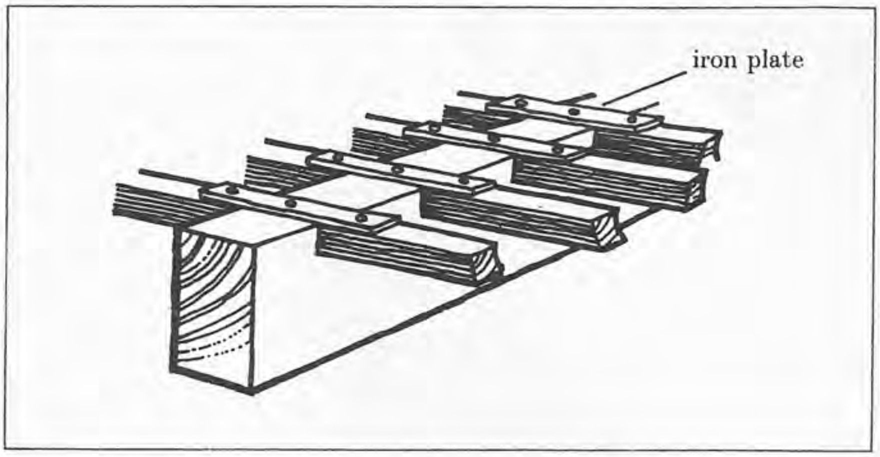


Fig. 11 (Above): Inserting iron plates to improve the bearing of tenon joists in the mortices of a central beam

Fig. 12 (Below): Supporting a beam, the end of which has rotted due to being pocketed in a damp wall

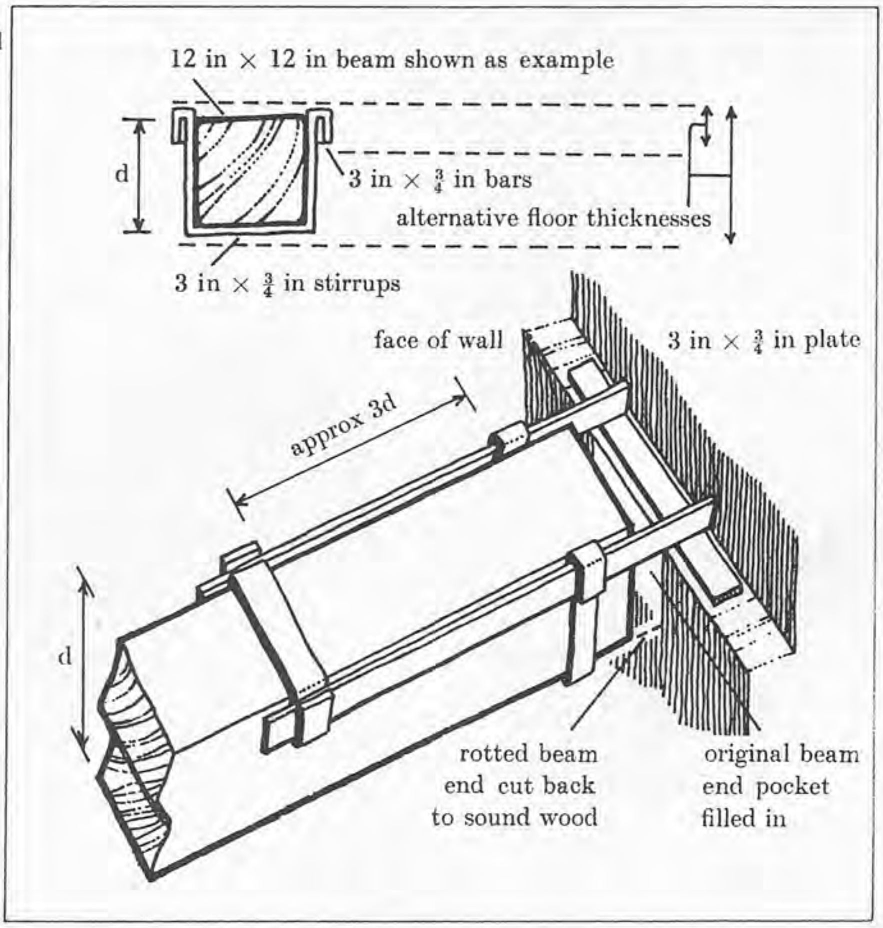
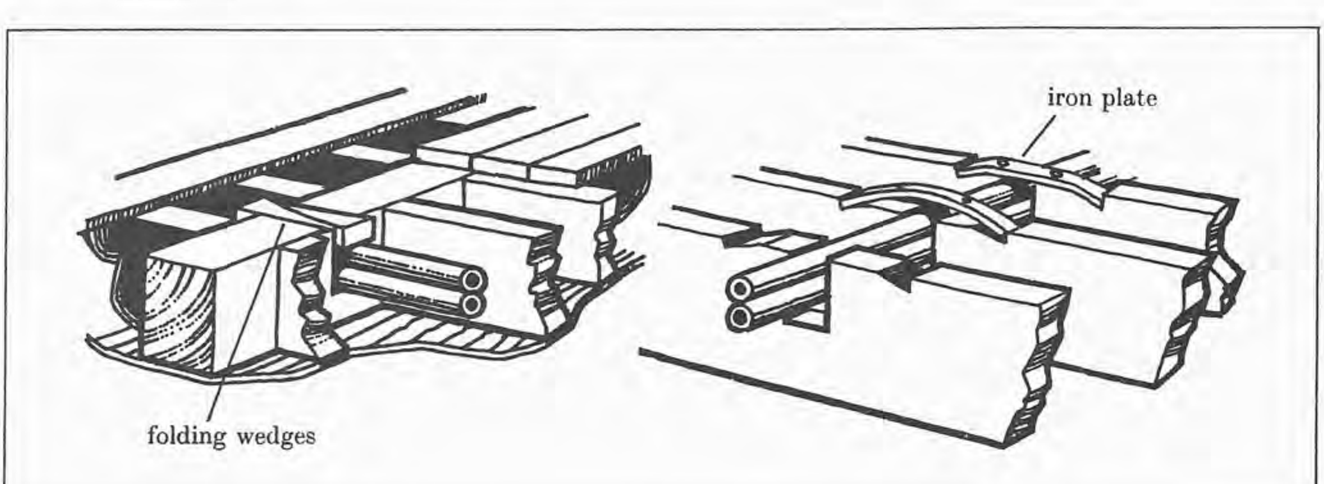


Fig. 10 (Below): Restoring compressional strength to timbers weakened by the insertion of central-heating or other service pipes



9 Rotted end bearings

Frequently, the end of a beam, which is otherwise sound, has rotted, due to being pocketed into a damp wall. The beam end is, therefore, no longer providing the necessary support for the floor. It is possible to correct this fault by using a cradle of steel plates. The rotten end must be cut back to sound wood, and the pocket that originally held the beam end filled in. A3 in x ¾ in stirrup runs beneath the beam end, and a similar stirrup is laid across the top of the beam 3 ft to 4 ft from it. the stirrups are held by 3 in x ¾ in bars, their projecting ends resting on a steel plate or concrete padstone built into the masonry of the wall (Fig. 12). All the components in this method are held in position by gravity and do not need to be bolted or welded. The ends of the supporting bars can be bent round in the masonry for additional stiffness. This method, which has often been used at Knole in Kent, can only be employed where the beam, or its upper part, is concealed in the thickness of the floor (Fig. 13).

Fig. 13: A cradle of steel plates was used to support beams at Knole, in Kent

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Strengthening Timber Floors: A notice from the SPAB Technical Panel

Our attention has been drawn to the necessity to keep a regular check on some of the methods of strengthening timber floors and beams described in this pamphlet. Some of these methods utilise the strength of steel in tension and the strength of timber in compression. There is now some reason to suppose that over the years, either through timber shrinkage or by compression set in the timber, the compressive funciton of the timber is no longer playing its part. This, of course, can be remedied by tightening up the wedges, bottle screws or other means employed for tensioning the steel.

Owners of historic buildings are well aware of the need for continuing vigilance in maintaining regular inspections of roofs, gutters, downpipes etc., and we now wish to recommend equally strongly that wherever the strengthening methods in this pamphlet have been used, the tension devices just referred to above are included in regular maintenance inspections.
Sloping floors will not normally detract from an old building. It must always be verified that there is a current problem before remedial action is taken to correct these faults. A springy floor does not always indicate overstressing — merely exececssive deflections. Greater deflections can be allowed where there are no ceiling finishes than where these exist and would crack as a result of the deflections; the values for deflections given in codes of practice refer to cases with ceiling finishes.

Any of the methods of strengthening timber floors described in this pamphlet depends on the steel not being exposed to heat and fire. Experience has shown that unprotected steelwork, in repairs to timber, can distort and cause early failure in fires.

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