Outward leaning walls

by
John E M Macgregor
OBE, FSA, FRIBA

Society for the Protection of Ancient Buildings

Technical pamphlet 1

Contents

1 The principal cause of failure

2 Resulting damage

3 Restraining outward-leaning walls

4 Pulling back the wall

5 Leaning west towers

6 Eliminating the basic cause of defects

7 Summary of remedies proposed

All thick walls with shallow foundations have an inherent tendency to lean outwards. This is because the load-bearing quality of the soil that is repeatedly saturated by rain is inferior to that of the soil which is protected by the building itself. Consequently, the weight of the upper parts of a structure exerting a downward pressure causes the walls to lean outwards. Although this condition can, in principle at any rate, occur in any building, it is particularly prevalent in churches, where the often considerable height of a roof has to be borne by outside walls and the piers of the aisles.

This pamphlet has been written to explain to the owners of such buildings, incumbents and their architects, some of the ways in which this fault can occur, the destructive effects that it will give rise to, and, with the help of examples, to suggest some methods of repair.

This pamphlet is a record of John Macgregor's own experience in dealing with outward leaning walls. 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.

1 The principal cause of failure

All those who have experience in dealing with old buildings, especially churches, will know that one of the most noticeable and common defects in them is external walls that lean outwards. The defect may be attributable to one of several different causes – the thrust of an insecurely tied roof, an insufficiently buttressed internal arch – and similar causes, which are usually not difficult to recognise, and the methods of dealing with them well-known.

There are, however, many instances where there is no such obvious physical stress to account for the failure. It is not uncommon to find aisle walls leaning outwards, leaving roof timbers and tie beams behind. The result of this is often that there is little bearing left for the roof construction. Buttresses built against leaning walls to stabilise them are often found to have pulled away from the wall, or, when bonded into the original masonry, to have pulled the wall further over.

These defects may be due to the same basic cause. The foundations of massive medieval walls are usually relatively shallow, so that the moisture content of the soil beneath their outer part is affected by the alternate wetting and drying of the soil along the base of the wall. With most soils this alternating condition will result in corresponding expansion and contraction, so that it can be regarded as moving, in contrast to that of the soil with constant water content beneath the building which is relatively static. I consider, therefore, that soil, which is subject to intermittent saturation and therefore to constant movement, has inferior bearing qualities to static soil beneath the building. For this reason, the outer part of the wall sinks more than the inner. If this destructive process is recognised, and its effects appreciated, a number of structural defects in medieval buildings can be understood.

2 Resulting damage

The invisible stabilization of outward-leaning walls has been a continuous study of mine both in theory and in practice during my 50 years as an architect. During this time I have dealt with a large number of historic buildings of all types, from castles to almhouses, and many churches dating from Saxon times onwards. The defect occurs in practically every type of building, but most commonly in the medieval church where walls are massive and not deeply founded, such as the parish churches of Castle Hedingham, Ivinghoe, Edlesborough, Kilsby and Orby.

The effect of this destructive action is, however, not confined to external walls, as can be seen in Fig. 2. Over a period of centuries the force of the continuing defect is so great that the north and south walls of a church draw outwards (A), thus either reducing the bearing of the aisle roofs or, where these were anchored securely at the ends (B), transferring the stress to the nave arcade walls which in turn have been drawn apart (C). Where this has occurred either the nave roof bearings have been perilously reduced (D), or the nave roof structure has held the clerestory walls together so that they have buckled within their height (E).

fig 1 (above): Edlesborough church, Buckinghamshire

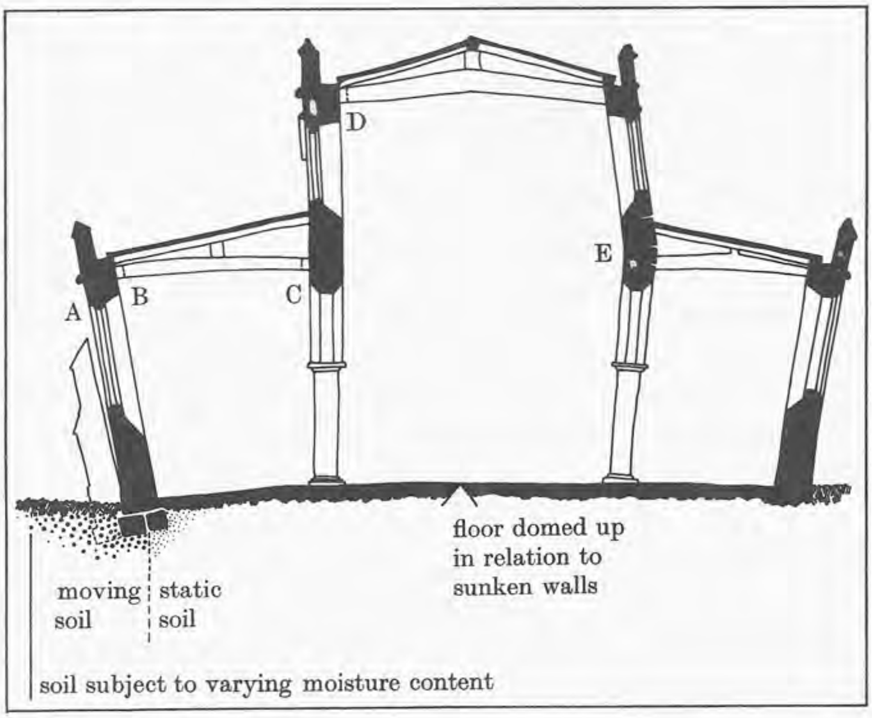


fig 2 (right): The effects of intermittent saturation of the soil

3 Restraining outward-leaning walls

In 1913 I was carrying out repairs to *Orston church*, Nottinghamshire, under Mr William Weir, who in my opinion was the finest exponent and practitioner of the Society's methods. He pointed out to me the aesthetic and functional failings of external buttresses. The job was being conducted by direct labour methods. He made it clear that, not only do these buttresses mar the appearance of the building, they also fail in their purpose by falling away from the wall (Fig. 3), or even make the defect worse by pulling the wall further out of plumb. For these reasons, the addition of external buttresses should be scrupulously avoided wherever possible (Fig. 4). What, then, are the alternatives?

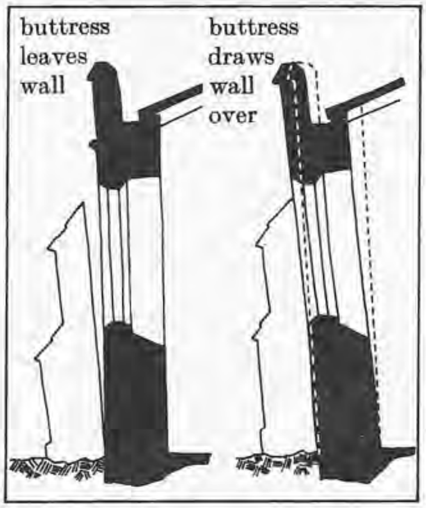


fig 3: The failure of an external buttress

fig 4: Buttress failure at All Saint's church, Maltby le Marsh, Lincolnshire

At Orston church, the fine three-feet-thick, 13th-century north wall of the north aisle was leaning about 18 inches out of plumb. Mr Weir instructed me to remove the masonry about two feet down from the wall plate from the inside, cutting back almost to the outer facing stones, thoroughly brushing out the loose mortar and moistening the stonework, and then to fill up with concrete behind, shuttering on the inside face and embedding reinforcing rods. This concrete wall-head was inserted in sections of three or four feet, with the rods hooked together for the full length of the wall and returned along the east and west walls, thus using them as restraining buttresses (Fig. 5). When the shuttering was removed, the wall was plastered with lime mortar, so that the work was entirely invisible. I visited the church half a century later and found the structure perfectly sound, despite the external surface scars of the war damage that had occurred in the interval. It is worth noting that the advantage of far greater leverage is obtained by restraining a leaning wall at the top, horizontally, than vertically at the base.

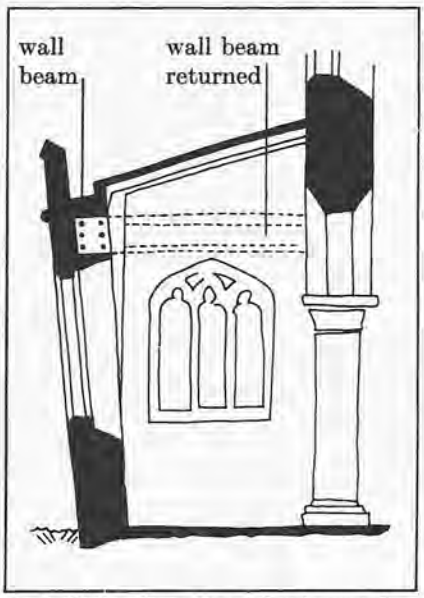


fig 5: Wall-top beam inserted and returned along the end walls. The wall-top beam must be anchored securely to the surrounding masonry.

At *Kilsby*, Northamptonshire, Mr Weir anchored the aisle tie beams into the north and south walls and linked them with tie rods across the nave (Fig. 6). This form of wall-top restraint is now common practice, but the basic principles of horizontal strengthening can be applied using other materials and in different types of buildings. For instance, when the Society itself moved to 55 and 57 Great Ormond Street, London, in 1938, the front wall was already bulged and a two-inch crack separated it from the party wall in the centre of the two houses. The main Committee Room was formed by inserting a steel portal frame which replaced the party wall between the two first-floor front rooms. The front wall was then stabilized by an angle iron fixed as a string course below the first floor window sills, anchored to the portal frame in the centre and to flat ties behind the panelling taken back some five feet along the end party walls.

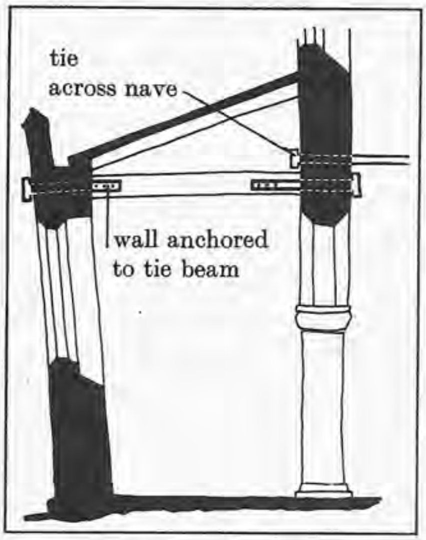


fig 6: Tie rod across the church aisles and nave

The efficiency of the method was proved when the street in front was bombed during the last war, and all the window frames blown in. The brickwork and the structure was generally unaffected. Some years later, however, a further bulge in the front wall was noted, and by temporarily removing the panelling a reinforced concrete beam and stanchions were chased into the brickwork to restrain the front behind the replaced panelling.

At *Castle Hedingham*, Essex, where the long thin north brick wall was leaning outwards alarmingly at its centre, a reinforced concrete wall-top beam anchored at the ends only was considered insufficient. I devised, therefore, an internal concrete buttress halfway along the wall in the form of a floor beam cranked up into the centre of the wall and linked to the wall top beam, and with its toe nicked under an arcade pier. No sign of cracks or other movement was visible when the building was inspected 15 years later.

When chases are formed for internal buttresses, they should be cut to provide irregular projections into the masonry on either side and taken back nearly to the external

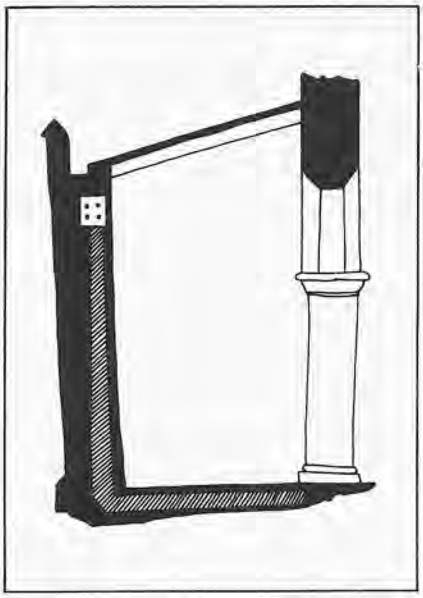


fig 7: Wall-top beam restrained by an internal buttress at Ivinghoe church, Buckinghamshire

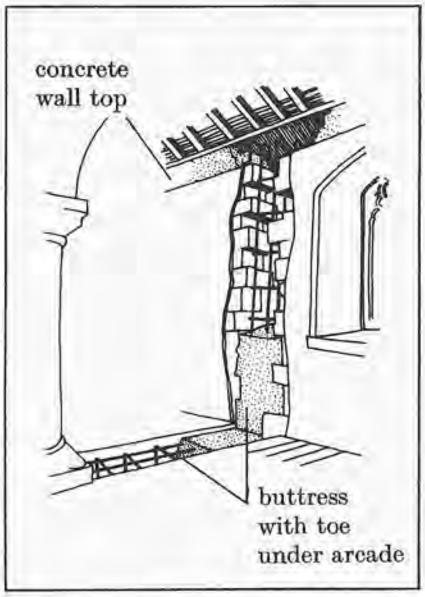
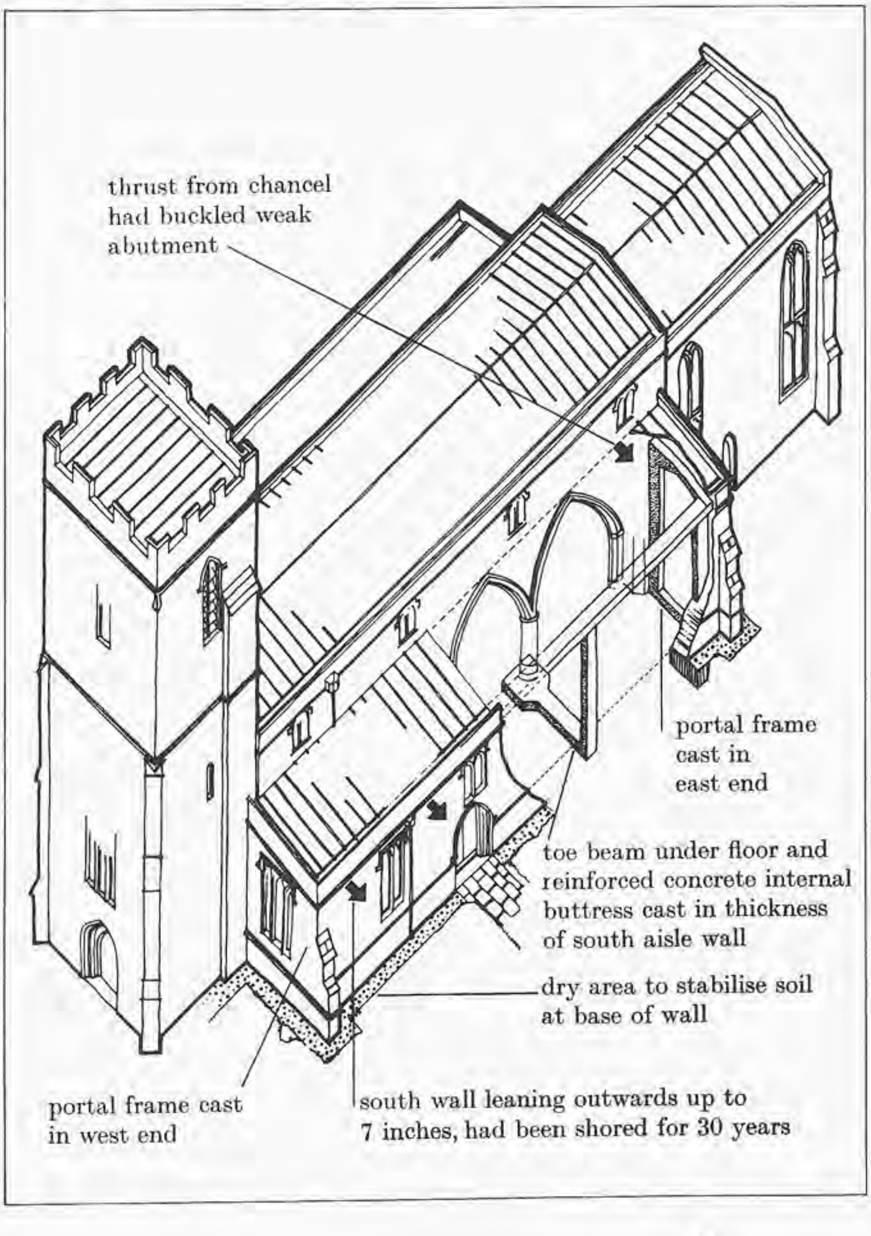


fig 8: Sketch showing method of inserting internal buttress and wall beam

fig 9 (below): Axonometric projection of Marston St Lawrence church, Northamptonshire, showing the strengthening of the aisle wall.



facing of the wall to obtain maximum bond behind the shuttering. The concrete should be in mass form of weak mix, say 8 to 1, and can be made up largely of the material removed from the wall.

The same method was used at *Ivinghoe*, Buckinghamshire, just after the last war. First, an internal buttress was inserted in the north wall (Fig. 7), and two other similar buttresses in the south wall were carried right through the wall and up behind the flint facing.

At *Marston St. Lawrence*, Northamptonshire, I recommended the insertion of internal buttresses in the south wall. Some nine years later I inspected the building again, on behalf of the Historic Churches Preservation Trust, and repeated my recommendation. After a further period of years, during which other methods of repair were considered and discarded, my suggestions have been included in a programme of work that has now been carried out most economically by Donald Insall and Associates (Fig. 9).

At *Edlesborough*, Buckinghamshire, the north and south aisle walls bulged outwards causing serious vertical fractures in the west wall on either side of the tower. A reinforced concrete tie was inserted in the thickness of the wall in short linked lengths, which, as it was faced inside and out in good ashlar, had to be burrowed from point to point. This tie started at the south-west corner of the church, was carried up in the west wall, over the tower arch and down to the north-west corner (Fig. 10, over)

Where the outward lean in the centre of a wall is only very slight, it can be restrained simply by fixing a flat iron strap along the outer face of the wall top, anchored securely at its ends and provided with stressing bolts in its length to form the tensile of the horizontal beam, the masonry or brickwork itself taking the compression. This method was satisfactorily adopted at *St. George's* church, Esher, in Surrey.

At *Kempley* church, Gloucestershire, the barrel-vaulted chancel, which is covered internally with 13th-century frescoes (Fig. 11), had sunk at the crown and was in a perilous condition. I recommended that a reinforced concrete floor beam should be laid and carried through the walls and up in the form of buttresses outside. The repair was carried out satisfactorily (Fig. 12).

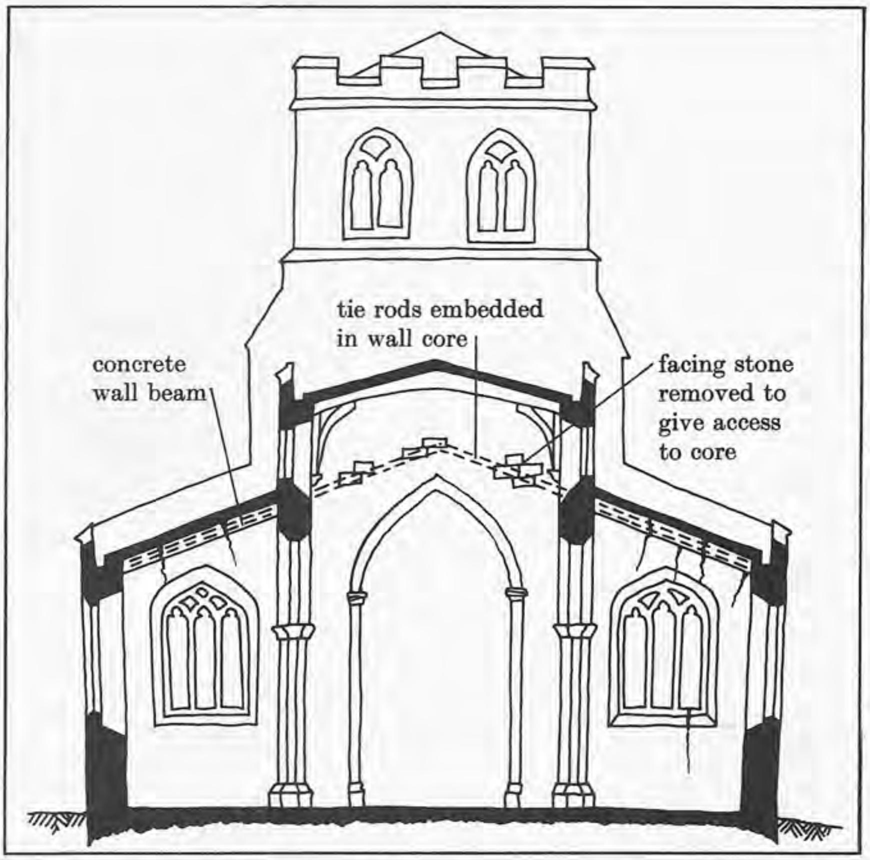


fig 10: Outward leaning north-west and south-west corners restrained by reinforcement in core of west wall linking wall tops, at Edlesborough church, Buckinghamshire

fig 11: The barrel-vaulted chancel of Kempley church showing the 13th-century frescoes (Country Life)

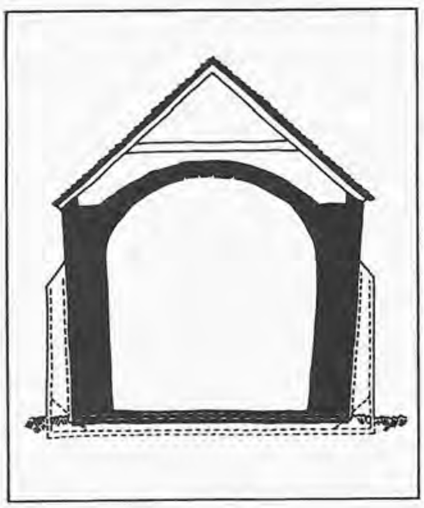


fig 12: Outward-thrusting vault restrained by buttresses linked by a floor beam

4 Pulling back the wall

So far, all the methods and cases instanced have shown how a leaning wall may be invisibly restrained. This, however, only preserves the status quo. Sometimes the architect is confronted with a building which is so badly distorted that for aesthetic and structural reasons this treatment must be ruled out. At the same time, the building is so important that its original form, detail, texture and even the subsequent addition and alteration justifies every effort to reinstate it.

If the wall is, for instance, built of plastered rubble or the stone roughly hewn, but the doorways and windows have carefully wrought jambs and tracery, it can be carefully dismantled and re-erected with fairly satisfactory results. Even so, some historic textural quality may well be lost.

Ashlar-faced structures can also sometimes be treated in this way, but there is an alternative which is well worth considering. That is to draw the whole, or the greater part of the wall back to the vertical and retain it there. Two cases may be instanced. At *Newtown*, in the Isle of Wight, the 17th-century Town Hall stands on clay soil, and the ground falls away steeply westwards. The whole west gable was hanging over more than one foot in 12 above ground-floor level (Fig. 13). Below this the basement masonry was in fair condition and was easily repaired. It was decided to cut a chase along the inside face of the gable wall at ground-floor level to form a hinge, and then to pull the whole wall above this back to the vertical. The wall had been temporarily supported by raking shores.

A timber framework was erected against the facade, from the top of which steel cables were carried through the whole length of the building through the east window and attached with tightening gear to timbers against the outside face. The disintegrated brickwork and stone quoins of the two south-west corners were taken down, and the whole west wall gently drawn back to the vertical (Fig. 14, over).

fig 13 (left): Newtown Town Hall, Isle of Wight (National Trust)

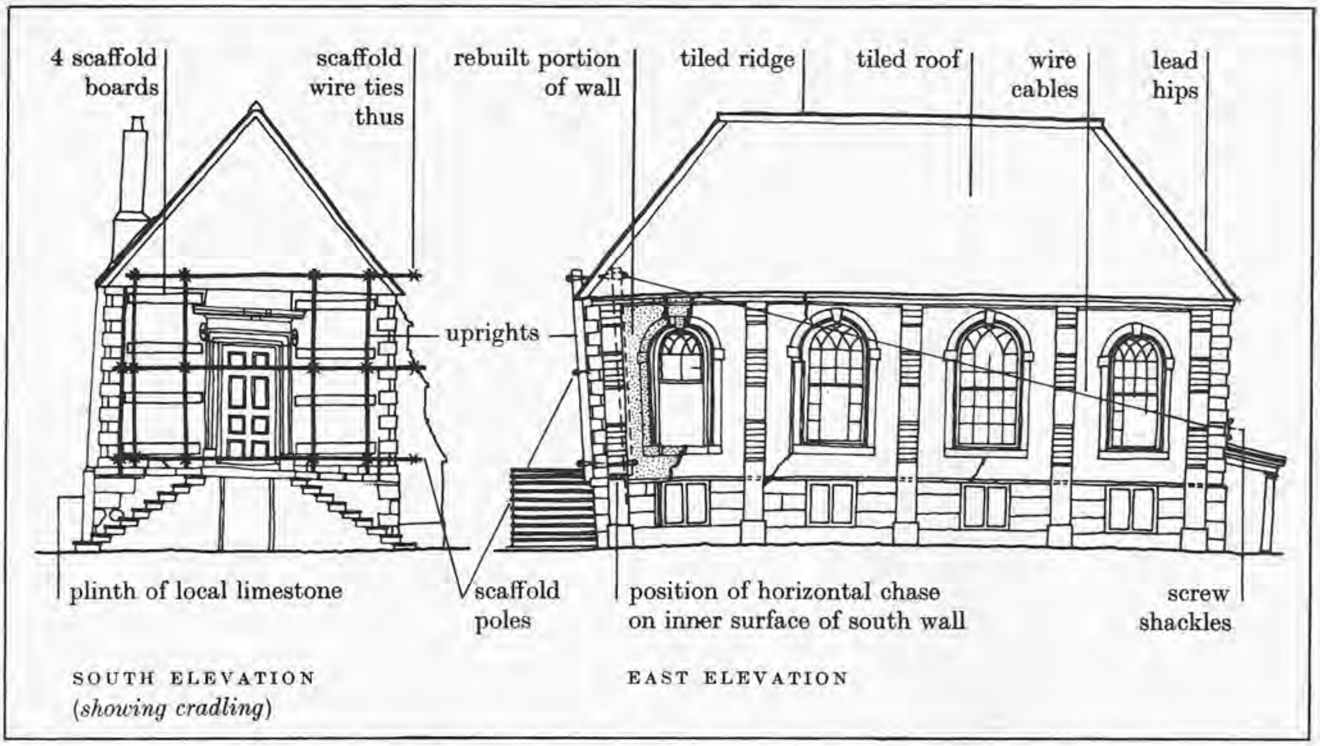


fig 14: Drawing back the west wall of Newtown Town Hall, Isle of Wight

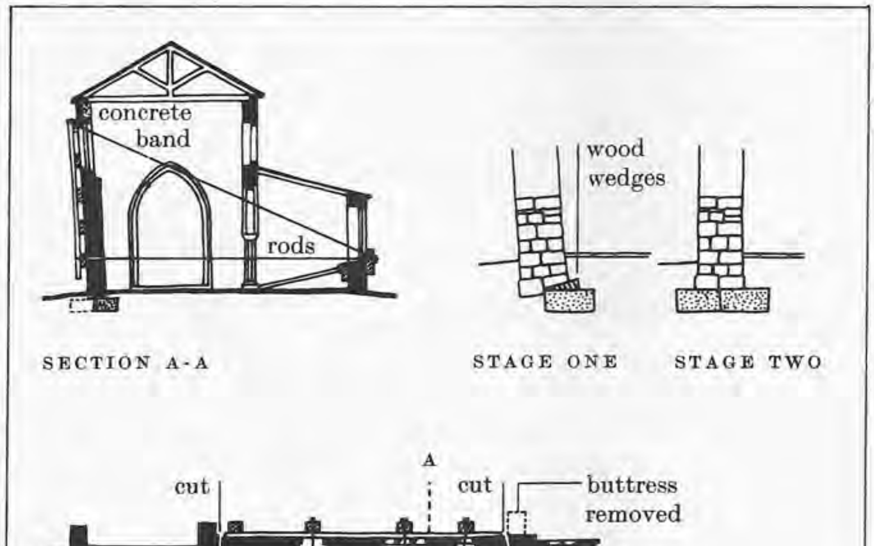
At *Orby*, Lincolnshire, the whole north wall, about 50 feet long and 30 feet high, was pulled back in a similar way. In this case, the fenestration was quite unique. Above the 13th-century two-light windows is a range of 14th-century ones bearing little relative positioning to those below. The thickness of the wall was reduced by an internal off-set from about three feet to two at the upper window sills, thus placing the centre of gravity of the upper part beyond that of the lower, and adding to the natural tendency of the wall to lean out.

The wall overhung by almost two feet in the centre, and tall buttresses had been built against it, the one at the west having fallen away. Owing to the irregularity of the fenestration and the thinness of the upper part of the wall, the insertion of an internal buttress was impracticable. It was decided, therefore, to strut up the roof, cut and disconnect the full height and thickness of the wall at either end of the leaning portion, and pull it back in one piece. The procedure was comparable to that followed at Newtown, a rough cradle being erected against the outside, and the iron rods, subsequently used as reinforcement in the concrete wall top, slung across the aisles and nave to timbers set against the outside of the south aisle (Fig. 15).

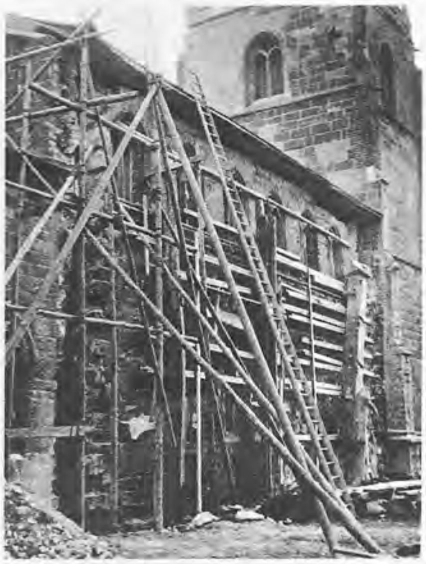
fig 15 (right): Straightening the north wall of the nave of Orby church, Lincolnshire

The masonry at the base of the wall was removed on the inside up to its centre, and a new concrete foundation inserted in short lengths in its place. Folding wedges were placed temporarily beneath the masonry above. When this had been completed for the full length, the wedges were carefully removed, and the weight of the sagging rods was sufficient to draw the wall back to the vertical. It was then a straightforward job to insert the outer part of the new foundation, form a concrete wall top, re-bond the drawn-back portion to the masonry on either side, and pick up the roof. Now that the buttress has been removed, there is little sign of the operation.

The three photographs (Figs. 16, 17 and 18) show the north wall before, during and after the operation, the overhanging eaves indicating the amount the wall was pulled back beneath the roof.



On visiting *Baginton*, in Warwickshire, on behalf of the Historic Churches Preservation Trust, to inspect the subsidence of the east end of the north aisle, I recommended the pulling in of the east wall as at *Orby*, and this has since been carried out.



figs 16, 17 and 18: The progress of the work of pulling back the north wall of Orby church

5 Leaning west towers

Western church towers frequently suffer in the same way as outside walls and fall away from the bulk of the church. The reason for this is that the east side of the tower abuts the nave, and the soil beneath is therefore protected from the moisture. The soil on the other three sides, however, is subject to intermittent saturation.

It may be that the west wall of such a tower overhangs as much as, or even more than, its thickness at its base, and so, if considered as an entity, would be deemed perilously unstable. But if this wall forms an homogeneous mass with the tower, there is no threat of instability. Naturally, if there is any sign of disintegration in the tower itself, this must be dealt with.

It is common to find that a western tower leant over early in its life, and that after a certain amount of foundation shrinkage stability was reached. In such a case, it is folly to interfere with it. At *Puttenham*, Hertfordshire, the tower went over early in its life in one mass, drawing the impost of the nave arcades over with it (Fig. 19). Some 40 years ago alarm was felt, and temporary shoring was carried out that consisted of raking shores against the west walls of the aisles, and centring placed in the western arches of the arcades. The trouble had apparently been diagnosed quite wrongly, the assumption being that the nave arches had thrust the tower over, whereas in fact the tower had pulled the arch.

The stability was simply and economically attained by disassociating the tower structure entirely from that of the arcades by the insertion of expansion joints. The thrust of the arches was restrained by a reinforced concrete beam inserted in the wall immediately above them which was carried down to the arch springing. Iron plates, with graphite as a lubricant between them, were inserted so that the impost beneath the abutments was free to move with the tower. An expansion joint was formed between the arcade wall and the tower with a concrete beam at eaves level projecting into the tower to give lateral stability.

The tower itself is perfectly homogeneous, and stability of bearing seems to have been achieved as the expansion joints do not appear to have opened.

An interesting demonstration of the progress of gradual stabilization is presented at *Warkworth* church, Northumberland. The original Norman church had a western door and no tower, and the west wall itself went over almost immediately after erection. This is demonstrated by the fact that the 13th-century tower embodied the west wall, and its inclination at this date is recorded by the joint between it and the north and south tower walls. The 13th-century tower, which had been apparently founded upon previously covered ground, in turn heeled over westward. The tower was raised about 20 feet in the 14th century and again went over slightly. In the 15th century, stability seems to have been reached, and the stone steeple which was then superimposed appears now to be still vertical.

fig 19: The effect of the drawing away of the tower on one of the nave arches at Puttenham church, Hertfordshire

6 Eliminating the basic cause of defects

It is the intermittent wetting and drying of adjacent soil that reduces its bearing qualities compared with the static soil beneath the building.

The variation may be very materially reduced, therefore, if the water level in the soil can be stabilised. Frequently the floor level of an old church is lower than the general ground level outside, and a common practice is to lower the soil immediately against the building and to form a paved dry area round it. This often produces a sloping bank outside the dry area which itself conducts the rainwater to the wall foundations. These dry areas are apt to crack and shrink away from the walls thus letting moisture seep down beneath the paving, which itself prevents upward evaporation.

If, instead of this excavation and paving, the soil is left at its natural level, but a narrow trench is dug to about one foot below the floor level with a porous agricultural land drain in it, and then covered with hard core and finished in shingle, ground moisture approaching the building is immediately trapped and led away by the field drain (Fig. 20). As the period of actual rainfall is so much shorter than the intervening dry periods, the hard core is never saturated, but acts almost continuously as a sponge drawing the moisture out of the wall. It is essential that the field drain is led to special soak-aways, and the rainwater from the down pipe is dealt with by a quite independent drainage system. The wall-top beam must be anchored securely to the surrounding masonry.

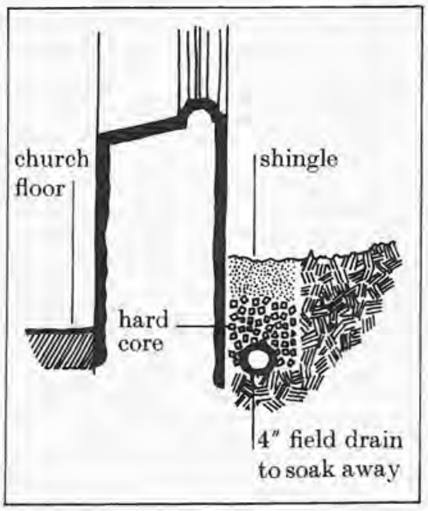


fig 20: Channelling ground moisture away from the building through a field drain: There is a tendency for the field drains to become blocked. The drain should therefore be provided with inspection chambers or be dug out and re-laid every ten to 15 years. Rainwater pipes should not be allowed to discharge into the drainage trench; they should be connected to separate drains that lead the water away from the building.

7 Summary of remedies proposed

Outward leaning walls

1 The addition of external buttress should generally be avoided, if possible.
Orby (Fig. 15)

2 Underpinning is satisfactory, if it is taken down below the saturation level.

3 Restraint by rods through the building, so that the external walls hold each other in.
Kilsby (Fig. 6)

4 Concrete wall top returned at either end.
Orston (Figs. 3, 4 and 5)

5 Concrete external buttresses linked by floor beam.
Kempley (Fig. 12)

6 Tensioning along external face.
Esher

9 Drawing back in one mass to original position.
Newtown (Figs. 13 and 14)
Orby (Figs. 16, 17 and 18)

Western towers

10 Ensure that the tower is still moving. If so, ensure that it is in one single mass, and then disassociate it from rest of building.
Puttenham (Fig. 19)

Technical pamphlets published by the SPAB

1. *Outward Leaning Walls* by John E M Macgregor OBE, FSA, FRIBA
2. *Strenthening Timber Floors* by John E M Macgregor OBE, FSA, FRIBA
3. *Chimneys in Old Buildings* by Gilbert Williams FRIBA
4. *Cleaning Stone and Brick* by John Ashurst DArch, RIBA
5. *Pointing Stone and Brick* by Gilbert Williams FRIBA
6. *Fire Safety in Historic Buildings* by Alan Parnell FRIBA, FSIAD, FIFE, Dip TP and David Ashford ACII
7. *Fire Safety in Historic Buildings - Part II* – To be published)
8. *Treatment of Damp in Old Buildings* by Andrew Thomas AA Dipl, RIBA
9. *Electrical Installations in Old Buildings* by Alistair Hunt RIBA

The Society for the Protection of Ancient Buildings . . .

Advises on all problems affecting old buildings, giving technical advice on their treatment and repair.

Investigates cases of buildings suffering from neglect or threatened by damaging treatment or with destruction.

Holds annual courses on the repair of ancient buildings for architects, surveyors and builders.

Administers scholarships, which enable architectural students to study old buildings and their repair.

Arranges public lectures on specific subjects dealing with old buildings.

Circulates a quarterly list of buildings for sale in need of repairs (available only to members).

Publishes a quarterly newsletter.

The first publication in 1971 of this pamphlet was made possible through the Rupert Gunnis Bequest to the SPAB.
Reprinted with amendments 1985.

The Society welcomes new members. Details of activities are available from:

The SPAB
37 Spital Square
London E1 6DY
Tel: 01-377 1644

S·P·A·B

Printed by Bishopsgate Press
37 Union Street, London SE1 1SE