masonclarkassociates
civil and structural engineering consultants

STRUCTURAL APPRAISAL REPORT
For
GRANGE FARM
NORTH STREET
ROXBY
NORTH LINCOLNSHIRE
DN15 0BN

Commissioned by R Elwes Fund of the Elwes Children's 1989 Settlement Fund

Report 20633-H-RP-001-R0
2 September 2022

STRUCTURAL APPRAISAL REPORT
for
GRANGE FARM
NORTH STREET
ROXBY
NORTH LINCOLNSHIRE

CONTENTS

ISSUE LOG FOR REPORT 20633-H-RP-001

Rev	*Date*	*Description*	*Author*	*Checked*
R0	2 September 2022	First Issue	MWG	MWG

Issuing office Mason Clark Associates (Hull). Refer to final page for full office details.

1 INTRODUCTION

1.1 Brief

1.1.1 This report has been prepared at the request of by R Elwes Fund of the Elwes Children's 1989 Settlement Fund, in order to determine the structural integrity of the farm complex, prior to proposed conversion into residential accommodation.

1.1.2 This report has been prepared for our client.

No liability is accepted to any third party for all or part of this report.

1.1.3 We have taken our brief as being to undertake the following assessment:

1.1.3.1 Carry out a visual internal and external structural survey of the building, to assess the integrity of the construction and identify key structural defects that are present.

1.1.3.2 Highlight any relevant structural issues noted during the survey that would affect the ongoing performance of the building.

1.1.3.3 Give recommendations for any 'opening up' of the building required, in order to vindicate our suspicions relating to the cause(s) of damage.

1.1.3.4 Undertake a Structural appraisal of the building and give conclusions as to the cause of recent movement and 'high level' recommendations for repairs.

1.1.3.5 N.B. No allowance is made for any detailed repairs or structural design of any strengthening required.

1.1.4 We do not intend to comment on every defect, only those which appear to be relevant to the structural integrity of the property at the time of our inspection.

Specialist surveys would be needed to determine the condition of the property with respect to services, damp penetration, timber infestation and contamination.

1.1.5 General references with regards to position relative to the property are given as follows:

1.1.5.1 Externally as viewing the elevation being considered.

1.1.5.2 Regarding room locations within the building, as viewed facing the front (approximately south) elevation of the farm complex.

1.1.5.3 Within a room as viewed from the centre of the room.

1.1.6 It was not possible to see concealed defects, which had they been visible may have indicated movement to the roof, walls and floors.

It must be appreciated that our initial examination does not cover those parts of the buildings that are concealed, inaccessible or unexposed.

1.1.7 The internal inspection has been made within the limits of ready accessibility and it is not normal practice to lift floor coverings or floorboards, remove panels of plaster or move heavier items of furniture. External inspection of the buildings has been carried out from ground level by visual and optical sighting and, without special access arrangements, we cannot confirm that obscured parts are free from defect.

1.1.8 Other areas of the property including detached outbuildings/garages etc. (as applicable) are not included within our report unless specifically stated.

1.1.9 If considered necessary, a visual inspection will be made of the manholes and drainage connections, where the cover is intact and able to be removed. We will only recommend tests of the drainage system to be made where there is evidence to suggest that structural damage to the property has been or may be caused by a faulty system.

1.1.10 This report does not constitute a House Buyers Report, Valuation or Schedule of Refurbishment and the lack of specific reference to any structural elements, material or type construction, does not infer compliance with the current British Standards Codes of Practice or Building Regulations and enquiries to the Local Authority have not been made.

1.1.11 An inspection was undertaken on Monday 22nd August 2022 during dry warm weather conditions.

2 SYNOPSIS

2.1 There appears to have been longstanding downward movement to the internal and external walls, as evidenced by the cracking, leaning to walls and general dilapidated condition of some of the buildings forming the farm complex.

2.2 With reference to BRE Digest 251: Assessment of Damage in Low Rise Buildings, the category of damage based on crack widths alone, generally falls into category 4.

2.3 In our opinion, the extent of the movement has not affected the overall stability of the majority of the buildings. However, the condition of buildings 1 and 2 and external stairway to Building 8 are of concern, and we cannot guarantee the short-term stability of these buildings.

2.4 The cause of downward movement to the load bearing walls generally, in our opinion, is due to one or a combination of the following.

2.4.1 As a result of historic differential consolidation settlement of the fill material immediately below the foundations and limited spread/projection to the footings provided

2.4.2 Climatic variations affecting clay sub-soils underlying the foundations. Although the subsoils encountered in the trial pits, revealed more granular rather than clayey subsoils, there may be other shrinkable clay deposits beneath, as indicated by the BGS site records.

2.4.3 From water escaping defective drains, however defects are widespread rather than localised.

2.6 Regarding the structural defects, we would recommend that the following are undertaken.

2.6.1 Carry out an asbestos survey and Damp/Decay survey of the buildings.

2.6.2 Carry out a CCTV survey on the drainage serving the farm complex.

2.6.3 Partially demolish Building 1 (rear section including deformed roof plate).

2.6.4 Review the residual structure or carefully demolish derelict Building 2.

2.6.5 Renew the first floor to Building 3. Investigate the integrity of the roof over Building 7.

2.6.6 Demolish the external stairway serving Building 8.

2.6.7 Repair all defective drainage and allow for testing on completion to confirm its integrity.

2.6.8 To address the possibility of clay subsoils, reduce the canopy volume of any adjacent trees.

2.6.9 Repair all cracks in masonry walls including Helibar reinforcement. Make good to any plaster.

2.6.10 Review any strengthening required to the roof structures following the Damp/Decay survey.

2.6.11 It is likely due to the many areas of limited foundations, that underpinning will be required. A structural design check is therefore recommended to determine the extent of this work.

3 BACKGROUND

3.1 Existing Building and Construction

3.1.1 The subject structure is a single/two storey farm complex.

3.1.2 The construction of the buildings comprises of traditional construction, with a tiled/sheeted coverings supported by timber roof structures.

3.1.3 The roofs are supported by solid brick masonry external walls, which are approximately 440mm thick.

3.1.4 Ground floors were provided, are of ground bearing concrete construction.

3.1.5 Internal walls appear to be solid masonry construction throughout.

3.1.6 Details of the superstructure and foundation construction to each of the buildings 1 to 9 inclusive, are recorded in our observations.

3.1.7 Based on information extracted from the BGS website the prevailing ground conditions at the site are made ground over clay with limestone, siltstone and shale.

4 INSPECTION

4.1 Building 1 Internal

4.1.1 We noted a 20mm plus vertical crack in the northwest corner and a 5mm wide vertical crack in the north wall. The north wall leans in at a gradient of 25mm in 1 metre.

The west wall is reasonably plumb, but we noted loose stonework at the base of the wall.

In the southwest corner, there is a 30mm + separation in the masonry. Loose stonework was visible in the base of the south wall which was measured at being 420mm thick. The walling adjacent to this was seen to be very loose.

The south wall leans out at a gradient of 37mm in 1 metre.

The floor is partial concrete but of a very rough quality.

The east elevation is partially open, and we noted 590mm square blockwork piers built off 780mm square piers.

The masonry at low level appears to be weathered but plumb.

4.1.2 An inspection of the roof structure revealed a timber collared construction comprising of 70 x 70mm common rafters at 460mm centres spanning onto 70 x 90mm purlins.

The purlins are received by a double 70 x 80mm truss rafter, with 260 x 35mm mid height collar and 170 x 50mm low level collars/ties which are disposed randomly along the roof.

There are dragon ties to the roof corners.

We noted that the purlins are heavily bowed to the east pitch as are the common rafters.

The cast iron column propping the east pitch wall plate has a heavy outward lean.

4.2 Building 1 External

4.2.1 We noted the heavy outward lean on the southeast corner.

4.2.2 There are longstanding cracks to the stonework on the south and west elevations.

We noted missing roof tiles to the west elevation.

4.2.3 A single trial pit TP5 was excavated adjacent to the front southeast corner.

This exposed the foundations and underlying subsoils to the property in this location.

4.2.4 The existing foundation is very limited and without a projection from the outside face of the external wall.

4.2.5 The underside of foundation is located at 490mm below ground level.

4.2.6 The foundation is seated in a fill over a brown made ground/fill material.

Shear Vane testing was not possible due to the subsoil's characteristics.

4.3 Building 2 Internal

4.3.1 Not inspected as in a derelict condition (we were advised by the owner of a previous fire?)

4.4 Building 2 External

4.4.1 Not inspected as in a derelict condition.

Large parts of the roof covering are missing, and the roof timbers are deformed and in poor order. There is much vegetation growth in evidence.

However, a cursory viewing revealed 10mm + cracking to the feature brick of the residual northeast corner adjacent to the stonework.

4.4.2 A single trial pit TP6 was excavated adjacent to the rear northeast corner.

This exposed the foundations and underlying subsoils to the property in this location.

4.4.3 The existing foundation is poorly constructed stone blocking is without a projection from the outside face of the external wall.

4.4.4 The underside of foundation is located at 530 mm below ground level.

4.4.5 The foundation is seated in a brown made ground/fill material.

Shear Vane testing was not possible due to the subsoil's characteristics.

4.5 Building 3 Internal

4.5.1 An inspection of the left side room revealed a 10mm wide vertical crack to the northeast corner.

The west wall is plumb. The north wall leans out at 15mm in 1 metre.

We measured the front wall as being 440mm thick.

4.5.2 The first-floor area comprises of 180 x 60mm joists at 460mm centres supported by a 180 x 170mm spine beam.

4.5.3 In the adjoining storeroom, the rear wall leans out at 40mm in 1 metre and there is a 30mm wide vertical crack in the northeast corner. The front wall is damp but plumb.

The rear end of the spine beam has pulled out of the wall.

4.5.4 The first-floor area is as the left-hand room except for a 200mm square timber spine beam spanning front to back, is as before.

4.5.5 In the right had side room we noted loose stonework in the central room division wall and there is a 2mm wide vertical crack in the southwest corner.

4.5.6 First floor construction in the right-side room matches that recorded elsewhere.

4.5.7 Ground floors are typically a poor concrete covering throughout.

4.5.8 First floors are affected by woodworm.

4.5.9 There is a cobbled floor in the central lobby area adjacent to Building 4.

4.5.10 We inspected the roof construction, and this comprises of timber scissor trusses with a 260 x 70mm principal rafter and 75mm square cross braces with bolted connections.

140 x 75mm purlins span between trusses and receive, 80 x 50mm common rafters at 460mm centres. There is a heavy lean evident in the rear (north) wall and consequently the rear pitch purlin is bowed in profile.

4.6 Building 3 External

4.6.1 An inspection of the south elevation revealed longstanding cracks and erosion to the stonework together with weathered brickwork. The roof profile is uneven over the west aspect.

4.6.2 There is weathered masonry to the north elevation stonework, with a 10mm + stepped crack over the west door brick arch. The roof tiles/guttering are in a dilapidated condition in this location.

4.7 Building 4 Internal

4.7.1 The main storeroom was inspected. This revealed rot to purlin ends embedded in the west division wall where pockets were noted in the masonry. The wall appears to be reasonably plumb although we noted 25mm plus tapered (at top) vertical cracks at its junction with the front and rear walls.

The rear wall is plumb but there is a 5mm wide tapered (at top) vertical crack in the southeast corner.

The east wall is plumb, but there is a 3mm wide stepped crack near the front (south) wall.

The front wall was measured as being 450mm thick and this leans in at 10mm in 1 metre.

4.7.2 the roof construction comprises of a timber king post truss arrangement with 100 x 50mm battens laid flat and 100 x 50mm rafter supporting the assumed asbestos roof sheeting.

There are 175 x 75mm purlins received by 135 x 100mm king posts truss rafters.

Internal braces are 100 x 75mm with 225 x 100mm truss tie and 180 x 100mm post.

All connections appear to be made with cast iron strap plates.

There are longitudinal splits in the truss tie.

4.8 Building 4 External

4.8.1 An inspection of the north and south walling revealed general weathering to the brickwork/stonework.

4.8.2 A single trial pit TP4 was excavated adjacent to the front, near Building 3 lobby.

This exposed the foundations and underlying subsoils to the property in this location.

4.8.3 The existing foundation is 200mm thick stone blocking which has a 200mm projection from the outside face of the external wall.

4.8.4 The underside of foundation is located at 700mm below ground level.

4.8.5 The foundation is seated in a hard brown sandy/gritty clay strata.

Shear Vane testing was not possible due to the subsoil's characteristics

4.9 Building 5 Internal

4.9.1 The north storeroom was inspected and revealed reasonably plumb external walls.

4.9.2 To the main stable there are 115mm diameter cast iron columns to the open west elevation.

We noted a heavy outward lean on the central south column.

We viewed the long east wall, and it is apparent that there is rot to the roof wall plate.

The wall generally leans in at a gradient of 20mm in 1 metre.

4.9.3 The roof construction over the stables matches that recorded over Building 4, except the roof tiles are received by 100 x 50mm rafters at 350mm centres.

4.9.4 We inspected the south end store. This has a dished profile cobbled floor and the external walls were measured as 450mm thick.

All walls were seen to be reasonably plumb albeit uneven. There is much vegetation growth that is penetrating the building envelope.

We noted a 10mm wide vertical crack to the northeast corner and a 2mm wide stepped crack to the northeast corner.

4.9.5 The roof construction is hip ended.

There are 275 x 40mm timber hip rafters receiving common rafters (100 x 50mm) disposed at 360mm centres.

There is a king post hip truss with 135 x 100mm truss rafter, 100 x 75mm internal braces, 225 x 100mm truss tie and 160 x 100mm king post supporting 175 x 75mm purlins.

Woodworm was visible to the common rafters and wall plate.

4.10 Building 5 External

4.10.1 An inspection of the west facing roof revealed areas of missing tiles.

There is vegetation growth around the south store, to the north, west and south elevations.

An inspection of the south store walling revealed general weathering to the brickwork/stonework. There is a 5mm wide stepped crack at low level to the southeast corner of the south store.

4.10.2 A single trial pit TP3 was excavated adjacent to a cast iron outer column supporting the roof. This exposed the foundations and underlying subsoils to the property in this location.

4.10.3 The existing foundation is a poorly constructed loosely jointed brick pad.

4.10.4 The underside of foundation is located at 350mm below ground level.

4.10.5 The foundation is seated in a brown sandy/gritty clay strata.

Shear Vane testing was not possible due to the subsoil's characteristics.

4.10.6 A single trial pit TP2 was excavated adjacent to the front south storeroom.

This exposed the foundations and underlying subsoils to the property in this location.

4.10.7 The existing foundation is poorly constructed stone blocking and without a projection from the outside face of the external wall.

4.10.8 The underside of foundation is located at 340mm below ground level.

4.10.9 The foundation is seated in a yellow sandy/gritty clay.

Shear Vane testing was not possible due to the subsoil's characteristics.

4.11 Building 6 Internal

4.11.1 To the northwest corner of the main store there is a 5mm wide tapered (at top) vertical crack with a 10mm wide vertical crack to the southwest corner. The west wall is plumb.

The stonework to the east wall is weathered, although plumb.

The rear (north) wall is plumb.

Inspection of the front (south) wall revealed loose stonework to the vent reveals and a 25mm + tapered (at top) vertical crack to the southeast corner. The wall is approximately 500mm thick and leans out at an approximate gradient of 50mm in 1 metre.

The floor is formed from rough cast concrete with longstanding cracking evident.

4.11.2 The roof construction over the main store comprises of 100x 50mm common rafters at 360mm centres laid in 140 x 75mm purlins. The purlins and 225 x 40mm hip rafters with dragon ties and are received by collared trusses.

The trusses comprise of 100 x 110mm truss rafters, 225 x 35mm mid height collar and 170 x 100mm ceiling tie.

We noted four trusses to five bays with connecting ridge ties.

4.11.3 Inspection of the small rear store revealed a timber rafter and purlin constriction.

There is a 10mm wide vertical crack to the southwest wall junction.

4.12 Building 6 External

4.12.1 An inspection of the northeast corner revealed gaps of greater than 20mm in the walling near the brickwork/stonework interface, together with an approximately 10mm wide vertical crack.

The roof tiles appeared to be in reasonable order.

There is evidence of weathering to the brickwork/stonework.

4.12.2 Inspection of the south elevation revealed general weathering to the brickwork/stonework.

There are cracks and voids noted in the stonework.

4.12.3 A single trial pit TP1 was excavated adjacent to the rear northwest corner.

This exposed the foundations and underlying subsoils to the property in this location.

4.12.4 The existing foundation is very poor and without a projection from the outside face of the external wall.

4.12.5 The underside of foundation is located at 550 mm below ground level.

4.12.6 The foundation is seated in a dark yellow cobbly, sandy/gritty clay.

Shear Vane testing was not possible due to the subsoil’s characteristics.

4.13 Building 7 Internal

4.13.1 No internal access was possibly (private tenant area).

4.14 Building 7 External

4.14.1 There is a noticeable belly in the roof tiles suggesting and over deflected supporting timber roof structure. There is vegetation in the guttering.

We noted tall mature (Lombardy Poplar?) trees immediately adjacent to the southwest corner.

4.14.2 The rear (north) wall is 470mm thick and leans out at 10 – 15mm in 1 metre.

There is general weathering and erosion to the facing brickwork.

4.14.3 The west gable wall leans out at 15mm in 1 metre and there is a 10mm wide vertical crack through this cill below the first-floor loft door.

4.14.4 Inspection of the south elevation revealed general weathering to the brickwork/stonework.

There are cracks and voids noted in the stonework near the southwest corner. There is a 10mm vertical crack between the stonework and facing brick corner, and stepped cracking over the brick arch to the east window.

The front (south) wall leans out at 20mm in metre.

4.15 Building 8 Internal

4.15.1 An inspection of the first-floor small loft store revealed a 3mm wide stepped crack to the southeast corner. To the south wall we noted 450mm thick wall construction and a 1mm wide vertical crack over the left side window.

The division wall to the main store is plumb however, the brickwork forming the chimney structure is in very poor order and unbonded near the top of the stack.

The east external wall leans out at a gradient of 15mm in 1 metre, and there is a 5mm wide vertical crack to the northeast corner.

4.15.2 In the main front floor storeroom there is a 3mm wide stepped vertical crack to the southeast corner in the division wall together with a 5mm wide stepped crack. There is evidence of previous repointing suggesting longstanding movement.

To the division wall, a 2mm wide vertical crack was detected and the rear (north) wall leans in at 20mm in 1 metre.

The west gable wall is reasonably plumb, but we noted a 2mm wide diagonal/stepped crack to the door location.

On the front wall there is 2mm wide cracking over the window and a 2mm wide horizontal crack near floor level near the west wall. The front wall leans in at 20mm in 1 metre.

4.15.3 First floor joists were seen to span front to back and the floor decking is in poor condition.

4.15.4 The timber construction comprises of 100 x 50mm common rafters at 350mm centres received by 175 x 75mm purlins spanning onto collared trusses. The trusses include a 110 x 100mm mid collar, 130 x 100mm truss rafter, 75 x 100mm braces and 225 x 100mm ceiling tie.

There are further 225 x 35mm collars at third positions in between the trusses.

4.15.5 Internal access into the ground floor facilities was not possible as all doors were locked.

4.16 Building 8 External

4.16.1 The northwest (rear) corner and west wall, appeared to be reasonably plumb. The brick/stone first floor lofts area stairs are in very poor condition and made trafficking precarious. The front wall leans out at 15mm in 1 metre over the southwest corner.

There are open joints in the stonework in evidence, together with weathered brickwork.

We noted stepped cracking over the southwest double door brick arch.

4.16.2 To the recessed area, we saw through a crack in the rear door/frame, that the small rear door is packed full of stored goods.

On the left-hand corner of the recess adjacent to the front (south) wall, the solider course has failed leaving a 25mm + tapered (at bottom) vertical crack to the front wall and a further 3mm wide tapered (at top) stepped crack over the door. To the opposite corner, again the soldier course over the door has failed and a 10mm wide vertical crack was present in the front wall near this location.

To the lean to store window, the masonry over and around the window is poor with 10mm + vertical cracking in evidence here.

4.16.3 An inspection of the north elevation revealed general weathering to the stonework.

4.16.4 A single trial pit was TP8 excavated adjacent to the first-floor stairway.

This exposed the foundations and underlying subsoils to the property in this location.

4.16.5 The existing poorly constructed stone blocking foundation is without a projection from the outside face of the external wall.

4.16.6 The underside of foundation is located at 500mm below ground level.

4.16.7 The foundation is seated in a very hard sandy/gritty clay.

Shear Vane testing was not possible due to the subsoil's characteristics.

4.17 Building 9 Internal

4.17.1 We noted vegetation growth to the west wall with collision damage to the rear of the blockwork walling. Consequently, there is a 3mm wide vertical crack through the blocks and random cracking to the northwest corner.

4.17.2 The main framing supporting the asbestos roof sheeting is of precast concrete portal framed construction.

There are precast ‘L’ purlins spanning between tapered ‘Tee’ section portal rafters with taper haunch at eaves position and 250 x 150mm precast concrete portal columns.

The frames have plated/bolted connections.

4.18 Building 9 External

4.18.1 An inspection of the roof sheeting revealed light mossing.

4.18.2 A single trial pit TP7 was excavated adjacent to the front southwest corner.

This exposed the foundations and underlying subsoils to the property in this location.

4.18.3 The existing foundation is a 600mm thick, rough cast concrete padwith a 200mm projection from each face of the supported column.

4.18.4 The underside of foundation is located at approximately 800mm below ground level.

4.18.5 The foundation is seated in a hard brown sandy/gritty clay strata.

Shear Vane testing was not possible due to the subsoil’s characteristics.

5 DISCUSSION ANALYSIS AND CONCLUSION

5.1 Pattern of Movement

5.1.1 There appears to have been longstanding downward movement to the internal and external walls, as evidenced by the cracking and leaning walls and general dilapidated condition of some of the buildings forming the farm complex.

5.1.2 There is evidence of damp and material defects to the roof timbers.

5.2 Severity

5.2.1 With reference to BRE Digest 251: Assessment of Damage in Low Rise Buildings, the category of damage based on crack widths alone for the defects highlighted generally falls into the category 4, as they are typically circa 15-25mm in width.

A competent building contractor will be required to undertake the required repairs to the affected structural elements.

5.2.2 In our opinion, the extent of the movement has not affected the overall stability of the building.

5.2.3 However, the condition of buildings 1 and 2 and the external stairway to Building 8 are of concern, and we cannot guarantee the short-term stability of these buildings.

5.3 Cause

5.3.1 The cause of general cracking and downward movement in the load bearing walls, in our opinion, is due to one or a combination of the following.

5.3.1.1 As a result of differential consolidation settlement of the sub-soils (possibly a thin band of fill) underlying the foundations to the property and limited spread/projection to the footings provided.

However, based on the age of the property we would have expected that the major part (95%) of any movement due to this, to have taken place.

5.3.1.2 Climatic variations affecting the moisture content of clay sub-soils underlying shallow foundations to the property. This would result in cyclic shrinkage and swelling of the clays causing seasonal movement of the foundations. During prolonged periods of dry climate, moisture levels within the founding strata would be depleted further.

Very dry climatic conditions have been experienced during 2018.

NHBC standards chapter 4.2 April 1995 recommends a foundation depth of 900mm for soils of medium volume change potential, this being in the absence of any vegetation.

However, the subsoils encountered at early depth are partially non cohesive in nature, although it must be noted that there may be other shrinkable clays beneath these deposits, as indicated by the BGS site records extracted.

5.3.1.3 Resulting from water escaping from the defective leaking gully/drains and into the sub-soils underlying the foundations causing a washing out of the fines or softening of these materials leading to subsidence of the building at these locations.

However, the defects are widespread rather than in isolated locations.

6 RECOMMENDATIONS

6.1 Further Investigations and Short-Term Action Required

6.1.1 All asbestos in the property to be confirmed following specialist survey and report.

6.1.2 It would be prudent in our opinion, to arrange a Damp/Decay specialist survey, in order to determine the extent of any loss of integrity to the structure and to give advice on the required repairs.

The survey should consider all aspects of the construction to the building but in particular, the timber roof and upper floor structures.

The source of any outbreak should be clearly identified, together with the likely extent of contamination.

The report should give clear advice on the nature and extent of any remedial actions deemed necessary, in order to counter defects highlighted, together with costs for the work required.

6.1.3 It would be prudent to undertake a CCTV survey on the drainage system serving the property in order to confirm its condition and clarify any defects present. Submit a supplementary report commenting on the findings of the exercise giving recommendations for any further investigations or remedial works required and advising on the following.

6.1.3.1 all defects encountered

6.1.3.2 probable cause(s) of defects encountered

6.1.3.3 repairs required to restore integrity to any area of defect likely to be leaking water or affecting the performance on the drainage system.

6.1.4 Partially demolish Building 1 (rear section including deformed roof plate).

6.1.5 Demolish the external stairway serving Building 8.

6.1.5 Review the residual construction or carefully demolish derelict Building 2.

6.1.6 Investigate the integrity of the roof over Building 7.

6.1.7 It is likely due to the predominantly limited foundations to the buildings, that underpinning will be required so that the residual structures are able to sustain the loadings from the new development.

A structural design check is therefore recommended to determine the extent of this work.

6.2 Walls (Long Term)

6.2.1 To the defective areas of masonry identified, rake out masonry mortar joints 25mm, dust off, slightly wet, adjacent masonry to avoid early shrinkage of new mortar and repair in 1:6 plasticised mortar to match existing colour, texture and profile.

6.2.2 Where applicable, locally rebuild masonry using cleaned up salvaged existing masonry units bedded in 1:6 plasticised mortar above damp proof course level and 1:3 plasticised mortar below damp proof course, colour, profile and texture to match existing.

6.2.3 Replace severely weathered masonry with units of matching colour, profile, texture and strength.

6.2.4 Reset any dropped external soldier courses following provision of support to all structural elements above using Acrow or Strongboy supports with head/sole plates.

6.2.5 Provide replacement or renew defective lintels with precast concrete or galvanised mild steel units.

6.2.6 Undertake repairs to masonry to include for the installation of HeliBar reinforcement into the bed joints to the walling at the location of the prominent cracking to the walls.

Repairs to be affected as follows:

6.2.6.1 Rake out or cut slots into mortar bed joints across cracks in masonry, 500mm past each side of the crack. Depth of slot to be 25-35mm for single leaf wall and 35-45mm for solid wall. Clean out slots and apply HeliBond primer or flush with water. Inject a bead of HeliBond to the back of the slot. Push HeliBar into the grout to obtain good coverage. Insert a further bead of HeliBond over the exposed HeliBar finishing 10-15mm from the face and "iron" into the slot.

6.2.6.2 Repoint mortar bed. Make good the vertical crack with a weatherproof filler, i.e., Crackbond TE or similar approved. Spacing of HeliBars to every fourth course of masonry.

6.2.6.3 Helibars to be fitted into bed joints so that bars cross the line at the line of the original crack and hence 'stitch' the walling either side together. Bars to be 1000mm long in order that the bar extends 500mm past the line of the crack.

6.2.6.4 Spacing to be at 450mm centres (maximum) or as determined by adjacent features.

6.2.6.5 Where horizontal / vertical cracks have been formed, which are in excess of fine in width, stitch drill and repair masonry to full line of former crack as follows.

6.2.6.6 Rake out loose mortar from cracked joints, dust off, slightly wet.

6.2.6.7 Clean cracks with wire brush or compressed air to remove all loose particles /debris dust, grease etc. Drill 6.5mm diameter injection ports into cracks in masonry and along cracks in mortar, with holes 30mm deep. Holes to be drilled at 150mm centres.

6.2.6.8 Starting at the lowest hole, carefully inject Helifix CrackBond resin TE into each hole and allow to flow until visible. Allow resin to gel and then make good the surface of the full crack line. All in strict accordance with manufacturer's instructions.

6.3 External and Internal Finishes (Long Term)

6.3.1 To the defective areas of any render/plaster, hack off any loose and cracked plaster/render, rake out any cracked mortar joints behind, prepare and repoint. Make good plaster. Include for fixing galvanized mild steel expanded metal reinforcement over existing cracks.

NB: All broken bricks encountered, to be replaced with units of similar size, quality and strength. Vee out and seal cracks/gaps in cracked but intact plaster with proprietary filler. Colour to match surround.

6.3.2 Carefully cut out and replace defective debonded panels to the existing ceilings.

6.3.3 Include for fixing galvanized mild steel expanded metal reinforcement over existing cracks.

6.3.4 Consideration should be given to the use of specialist render/plaster in areas of damp or absent wall plaster.

6.3.5 NB: All broken bricks blocks encountered to be replaced with units of similar size, quality and strength.

6.4 Timbers

6.4.1 Renew the first floor to Building 3.

6.4.2 Review the strengthening required to any element of roof structure to be retained following the Damp/Decay survey.

6.5 Trees

6.5.1 To address the possibility of clay subsoils withing influence of the existing vegetation.

Severely reduce the canopy volume of any specimen of vegetation lying in close proximity to the buildings and regularly maintain it in order to prevent increased water demand in the future.

6.5.2 This applies to the vegetation on boundaries to the building, although we appreciate that you will need to acquire the owner's cooperation to proceed in this manner.

6.5.3 Kill the root bulb to any remaining tree stumps with a suitable translocating poison or grub out the root bulb and remove all debris off site to tip.

6.6 Drainage

6.6.1 Following the CCTV survey, repair all defects in the drainage.

6.6.2 Allow for testing all drainage on completion, to confirm its integrity prior to installing the surround and backfilling.

7 LIMITATIONS

7.1 Our inspection and report are concerned with the structural aspects of the building such as foundations, walls and floors. We have not concerned ourselves with the condition of items such as doors, windows, and other fittings; or items such as timber infestation / decay, dampness, and testing of services to the property, unless specified in the report.

7.2 Sampling and testing of materials is beyond the scope of this report.

7.3 We have not inspected woodwork or other parts of the structure which are covered, unexposed or inaccessible and we are therefore unable to report that any such part of the property is free from defect.

7.4 This report is applicable to the condition and state of the building at the time of inspection. The building may be subject to deterioration in the future and the opinions expressed in this report may need to be revised accordingly.

7.5 This report is limited to the property under consideration. It does not consider the effects that adjoining properties may have, unless with prior agreement, a detailed inspection of all adjoining properties can be made.

7.6 The above recommendations do not constitute a full list of works to be carried out, but refer to the main areas of work associated with structural aspects of the building, based on a visual inspection only and under the limitations of our inspection.

7.7 All building and construction works are covered by the requirements of the CDM regulations. Owners/Clients have legal responsibilities to engage persons and companies with appropriate level of skills knowledge and experience to ensure that the requirements of the CDM regulations are met. The works required will be covered by the CDM regulations 2015 and you should understand your obligations and act accordingly.

7.8 Unless specifically mentioned no comment is made in the report as to the presence of new or old mine workings or tunneling, heavy metals, chemical, biological, electromagnetic or radioactive contamination or pollution, or radon methane or other gases, underground services or structures, springs and water courses, sink holes or the like, noise or vibratory pollution, mould, asbestos and asbestos products.

7.9 The report has been prepared for the client alone and no third party should rely on it. For the avoidance of doubt, the Contracts (Rights of Third Parties) Act 1999 shall not apply to this contract.

7.10 The inspection and report will not include any liability in respect of Advice/Design in fire safety to the structure and/or any liability whatsoever in respect of any losses (whether direct or indirect) arising from combustibility of cladding in delivery of our Services. We shall not be liable for that part of any claim which relates to loss of profits, loss of use, loss of production, loss of contract, liquidated damages or for any cost of decamping or rehousing.

7.11 Possible deleterious materials have been noted during the survey. Any prospective purchaser should acquire specialist advice on the appropriate actions for dealing with these materials. In addition, we would highlight that, for all non-domestic properties and communal areas, any materials containing asbestos must be managed and or removed in accordance with the current Asbestos Regulations. We recommend that specialist report be undertaken to clearly identify these materials and management/removal requirements.

7.12 This report is limited to structural matters. The client should obtain their own advice on any specialist surveys that need to be undertaken.

7.13 This report relates to the building in its original layout. We have not been involved in the refurbishment works and therefore cannot comment on the effects of any changes to the structure of the building. It is the responsibility of those involved in the refurbishment; to ensure the buildings present stability is not compromised, and its future stability is ensured.

7.14 Short of the whole structure involved being dismantled, an appraisal can only ever be based on the areas investigated, in the belief they are representative.

DEFINITIONS

1. General reference to the building and its surrounds are given as viewed facing the front elevation of the property.

2. Specific references to individual parts of the property are given as viewed directly at that part.

3. Where reference to cracks are made, the following classification is used:

Hairline	:	up to 0.1 mm wide
Fine	:	over 0.1 mm up to 1 mm wide
Slight	:	over 1 mm up to 5 mm wide
Moderate	:	over 5 mm up to 15 mm wide
Severe	:	over 15 mm up to 25 mm wide
Very Severe	:	over 25 mm wide

4. Where reference to movement is made, the following classification is used:

Slight	:	up to 10 mm/metre
Moderate	:	10 mm to 25 mm/metre
Severe	:	over 25 mm/metre

APPENDIX A

Selected Photographs

Plate 1 – Building 1

Plate 2 – Building 1

Plate 3 – Building 1

Plate 4 – Building 1

Plate 5 – Building 2

Plate 6 – Building 2

Plate 7 – Building 2

Plate 8 – Building 2

Plate 9 – Building 3

Plate 10 – Building 3

Plate 11 – Building 3

Plate 12 – Building 3

Plate 13 – Building 4

Plate 14 – Building 4

Plate 15 – Building 4

Plate 16 – Building 4

Plate 17 – Building 5

Plate 18 – Building 5

Plate 19 – Building 5

Plate 20 – Building 5

Plate 21 – Building 5

Plate 22 – Building 6

Plate 23 – Building 6

Plate 24 – Building 6

Plate 25 – Building 6

Plate 26 – Building 7

Plate 27 – Building 7

Plate 28 – Building 7

Plate 29 – Building 7

Plate 30 – Building 8

Plate 31 – Building 8

Plate 32 – Building 8

Plate 33 – Building 8

Plate 34 – Building 8

Plate 35 – Building 8

Plate 36 – Building 9

Plate 37 – Building 9

Plate 38 – Building 9

Plate 39 – Building 9

APPENDIX B

BRE Digest 251

BRE Digest

Concise reviews of building technology

Digest 251
Revised 1995

CI/SfB (X)

Assessment of damage in low-rise buildings

with particular reference to progressive foundation movement

This Digest discusses the assessment and classification of visible damage resulting from structural distortion. The assessment is based on a description of work considered necessary to repair the building fabric; classification into six categories is recommended, taking into account the nature, location and type of damage.

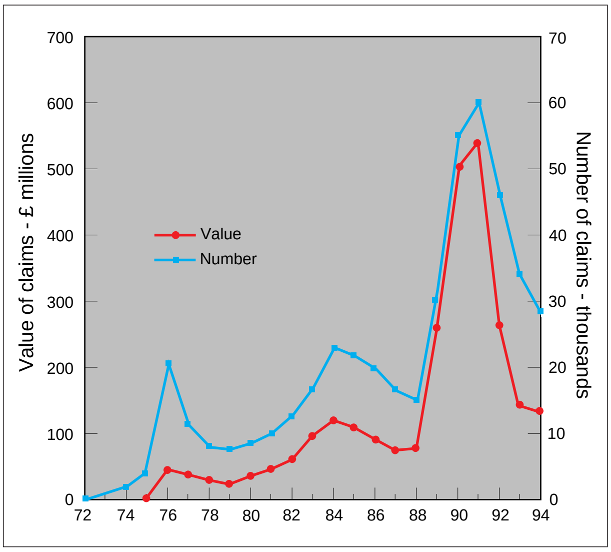
The most common causes of damage are discussed. It is concluded that for damage of Category 2 or less, cracking may result from a combination of causes which are difficult to identify and the cost and effort involved in carrying out an identification would be disproportionate to the scale of the damage, except for circumstances where the movement is likely to be progressive. It is rare for damage to progress beyond Category 2; when it does ground movement is usually the cause. The various causes of ground movement giving rise to damage are described briefly and emphasis is placed on the identification of conditions where the movement might lead to progressive deterioration.

This Digest will assist building professionals, property valuers and insurance advisors both in putting building damage into its true perspective and in determining necessary action, either in the form of seeking expert advice or in recommending simple repairs.

The severe droughts of 1975/6 and 1989/90 brought to the public's attention the fact that low-rise buildings are susceptible to cracking of the materials from which the buildings are constructed. That widespread publicity and some alarm were generated reflects not so much the severity of the damage as the general ignorance of both causes of damage and the amounts which masonry structures can tolerate. It is important to realise that very few buildings, if any, exist without some form of damage. How much can be tolerated depends on a number of factors: the type of building, the function it is to perform, the location and nature of the damage, the expectations of the user and the cost of repair work in relation to the value of the building. Many of the ways in which cracking can be produced in buildings are discussed in Digests 359 and 361.

One of the many causes of damage is foundation movement resulting especially from the drying shrinkage of clay subsoil. This is not a new phenomenon and has been experienced many times in the past. However, the 1975/76 drought, whilst admittedly being more extensive than previous dry spells,

Fig 1 Annual value of insurance claims for subsidence and heave damage to housing
Note the substantial increase following 1989 and 1990 – dry years



Building Research Establishment

Technical enquiries to:
BRE Advisory Service
Garston, Watford, WD2 7JR
Tel: 01923 664664 Fax: 01923 664098

initiated a spate of damage claims on insurance companies out of all proportion to its severity. Indeed, cases of damage, whilst being geographically more widespread, were no more severe than have been identified by the Building Research Establishment in previous dry spells, such as the dry summers of 1946 and 1947. The growth in claims for subsidence damage from 1971, when insurance against subsidence damage became widely available, is shown in Fig 1 which was produced from data supplied by leading household insurers and the Association of British Insurers.

In a two-year period following the end of the drought in August 1976, BRE examined 90 properties which suffered damage during and soon after the drought. These were cases specifically brought to the attention of BRE, largely by professionals, and probably they represent the worse end of the spectrum of subsidence damage. In addition, case records supplied by NHBC (20) and major household insurers (30) were examined. The ‘worst’ examples were requested. The overall sample size was, therefore, 140.

Examining the results of this survey it was apparent that one single factor had been responsible for the massive increase in damage claims: when house insurance cover had been enhanced in 1971 by insurance companies to indemnify against damage caused by ground subsidence, no qualifications had been placed on the amount of damage occurring. In consequence, many cases of damage hitherto regarded as of no great importance had become the subject of insurance claims. In addition, houses with cracks which would once have been disregarded were being significantly devalued unless expensive remedial measures were carried out.

It also became apparent that extensions to existing buildings and structural protrusions, such as bay windows and porches, were especially vulnerable to slight cracking where they joined the main structure. As will be discussed later, damage to extensions, usually ascribed to clay shrinkage, may well result from other causes.

The over-sensitivity of the housing market has also affected new construction. Local authority building inspectors are now much more cautious and it is evident that unnecessarily large sums of money are being spent on new foundations for no apparent reason other than in an attempt to prevent small cracks which, when they occur, may be totally unconnected with foundation movement. It is known, for example, that 3 m deep trench foundations have been used in a number of locations and even 5 m deep trench foundations have been reported for clay soils where 1 m deep trench foundations would have been regarded as adequate in the past.

During the course of the investigations it was concluded that inadequate attention was paid to describing building damage and that the essential first step in any assessment should be to ensure that all visible damage is properly recorded and classified in terms of an objective, widely accepted scale. The main purpose of this Digest is to discuss the recording and classification of damage to enable rational decisions to be made on such questions as severity of damage, its cause and appropriate remedial measures.

REPORTING DAMAGE

The reporting of damage is frequently less than satisfactory for assessing the severity and cause of damage. Statements like ‘extensive cracking to interior walls’ are often the only description of damage given for a property. Furthermore, the subjective judgement of individuals on the seriousness of damage varies considerably, so that properties with similar levels of damage brought about by similar events may undergo vastly different degrees of remedial work.

A prerequisite for the objective classification of damage in a building is a thorough, well-documented survey. A suggested procedure for carrying out such a survey consists of:

On a sketch of each damaged wall, draw the position and direction of any cracks

Distinguish where possible between tensile cracks, compressive cracks (indicated by small flakes of brick squeezed from the surface and by localised crushing) and shear cracks (indicated by relative movement along a crack of points on opposite side of it). Note the direction of any crack taper, crack widths, and the frequency of cracks if they are too numerous to record individually. If both external and internal crack patterns are plotted (as full and broken lines respectively) on the same elevation drawings, the mode of distortion and cause of movement can be better understood. An example of such a plot is shown in Fig 2. Generally, cracks produced by foundation movement are not widely distributed throughout a building, but tend to be concentrated in areas where maximum structural distortion and structural weak points coincide. In these areas, cracks are usually few in number so that recording of crack density is not onerous. Photographs provide a useful record of crack patterns and density; Figs 3 and 4 are typical cases. Any movement on one side of a crack in relation to the other in a direction out of the plane of the wall will also help to identify the mode of distortion (see Digests 343 and 344).

Fig 2 Crack plotting on building elevation

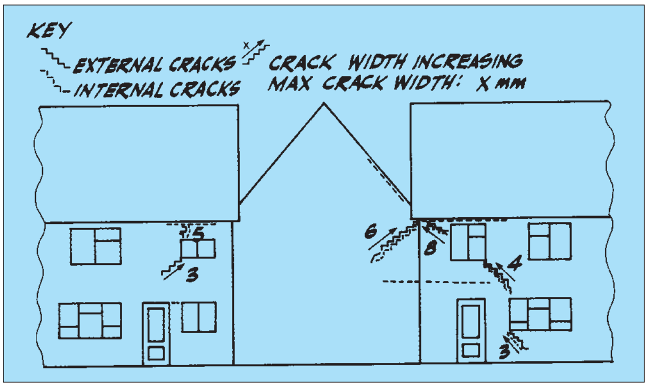


Fig 3 Category 2 subsidence damage
studs are used to monitor crack width

Fig 4 Category 3 damage
movements predominantly rotational and horizontal

Try to determine the approximate age of the cracks

This can be done by questioning the occupants on the date of discovery and by examining the fracture surfaces, particularly of external cracks, for signs of age. For instance, recent cracks in brickwork have a clean appearance, whereas older cracks show signs of dirt accumulation.

Where possible, measure or estimate the magnitude of any distortion and movement of the building

Examples are tilt and bulge of walls, slope of floors and slip on damp-proof course (Digest 344). The plotting of such values on a drawing of the building can be very helpful; Fig 5 shows a plot of the results of plumbing of walls. A series of level readings on a course of brickwork near ground level can provide an indication of both the direction of vertical movement and the part of the structure where it is concentrated. Figure 6 shows an example of a plot of relative levels around a building. Of course, care is necessary in interpreting such measures as the brick courses may not have been horizontal at the time of construction. Ideally, a series of measurements at different dates should be taken to show if movements are continuing. While this will not usually be practicable for full surveys of level and verticality (Digests 344, 386), it may be possible to obtain a series of measurements with time of the widths of cracks (Digest 343). Many cases of alleged subsidence damage take considerable time to be resolved so that such a series of measurements, over say six months to a year, may well be practicable and of immense value in determining cause. Evidence of building distortion is often hidden in lofts; the ends of roof joists and purlins should be examined to establish the extent of any movement. Movement in roofs can also be detected by observing gaps between tiles.

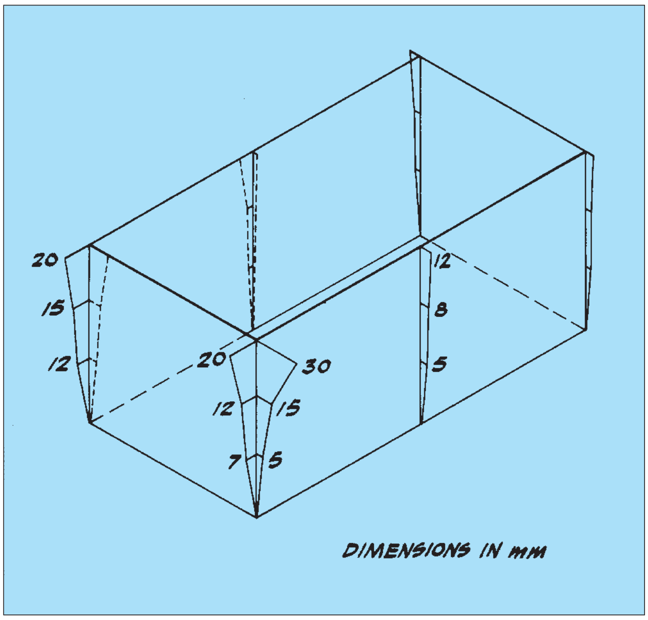


Fig 5 Verticality plot for a pair of semi-detached houses

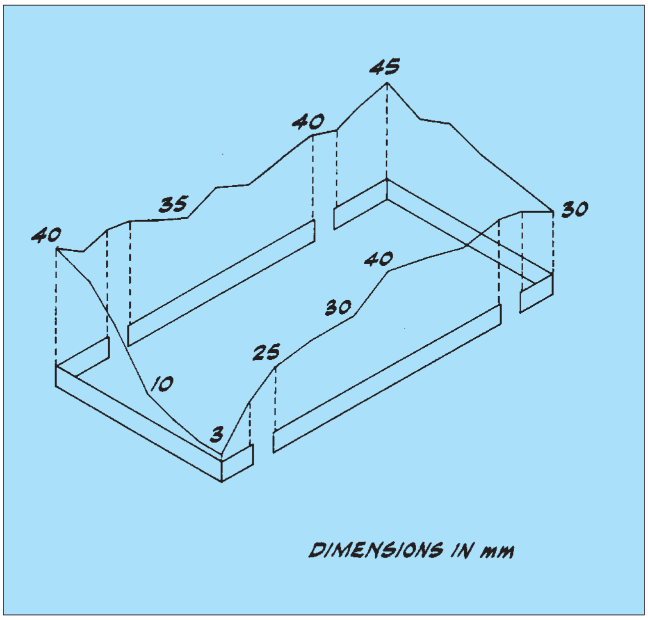


Fig 6 Level plot for a pair of semi-detached houses

Describe how the serviceability of the building has been impaired
For example, doors and windows jamming, window panes cracked, draughts and rainwater penetrating cracks, and service pipes fractured.

Give a thorough description of the materials of walls and finishes and their condition, especially that of mortar
Information of this type can often enable the identification of causes other than ground movement, for example shrinkage of concrete products, or differential thermal expansion of dissimilar materials, as well as assisting in the selection of suitable methods of structural repair.

Record details of the construction
This can have a very significant effect, on both degree and location of structural cracking. Every effort should be made to establish basic information about the structure, for example whether it has solid or cavity walls and the way in which the floor has been constructed. Whether or not the floor slab has been carried off the inner leaf, for example, or is floating (see Fig 7) can affect significantly the response of the structure to foundation movement, the way in which damage may occur and the form of remedial works.

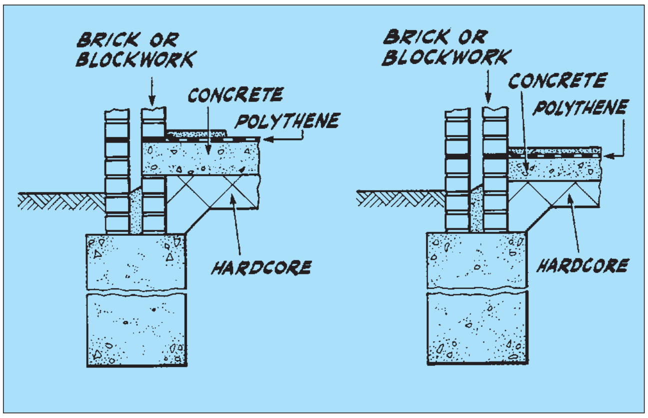


Fig 7 Alternative forms of floor construction

Where the cause of damage is believed to be foundation movement, additional factors may need to be considered depending on the scale of the damage sustained
It may be necessary to carry out a thorough examination of the foundations in the area of most movement and also to determine the nature of the underlying ground (see *Assessing the possibility of severe damage due to progressive ground movement*). In both these cases it may be necessary to call for the services of a suitably qualified civil or structural engineer.

CLASSIFICATION OF DAMAGE
Three broad categories of damage should initially be considered: ‘aesthetic’, ‘serviceability’ and ‘stability’. The first comprises damage which affects only the appearance of the property. The second includes cracking and distortion which impair the weathertightness or other function of the wall (eg sound insulation of a party wall may be degraded), fracturing of service pipes and jamming of doors and windows. In the third category are cases where there is an unacceptable risk that some part of the structure will collapse unless preventative action is taken. Very often when damage is described, no distinction is made between these three categories, making it impossible to gauge the severity of the problem.

It is only a short step from the three, general descriptions of damage to the more detailed classification shown in Table 1; this defines six categories of damage, numbered 0 to 5 in increasing severity.

The classification is based on the ease of repair of visible damage to the building fabric and structure and has been derived from a number of previous studies[1–5]. In order to classify visible damage it is, therefore, necessary when carrying out the survey to assess what type of work would be required to repair the damage both externally and internally. The following points should be noted:

- The classification applies only to brick or blockwork and is not intended to apply to reinforced concrete elements.

- The classification relates only to visible damage at a given time and not its cause or possible progression which should be considered separately.

- Great care must be taken to ensure that the classification of damage is not based solely on crack width since this factor alone can produce a misleading concept of the true scale of the damage. It is the ease of repair of the damage which is the key factor in determining the overall category of damage for the whole building.

- It must be emphasised that Table 1 relates to visible damage and more stringent criteria may be necessary where damage may lead to corrosion, penetration or leakage of harmful liquids and gases or structural failure.

For most cases, Categories 0, 1 and 2 can be taken to represent ‘aesthetic’ damage, Categories 3 and 4 ‘serviceability’ damage and Category 5 ‘stability’ damage. However, these relationships will not always exist since localised effects, such as the instability of an arch over a doorway, may influence the categorisation. Judgement is always required in ascribing an appropriate category to a given situation.

CAUSES OF DAMAGE

So far, only the reporting of damage and its classification have been discussed. However, it is the cause of the damage and whether it will be progressive that is of great concern. There are many causes of damage brought about by differential movements. Broadly, they can be divided into those associated with the structure itself, and those associated with the ground beneath the structure.

Table 1 Classification of visible damage to walls with particular reference to ease of repair of plaster and brickwork or masonry

Crack width is one factor in assessing category of damage and should not be used on its own as a direct measure of it.

Category of damage	Description of typical damage *Ease of repair in italic type*
0	Hairline cracks of less than about 0.1 mm which are classed as negligible. *No action required.*
1	Fine cracks which can *be treated easily using normal decoration*. Damage generally restricted to internal wall finishes; cracks rarely visible in external brickwork. Typical crack widths up to 1 mm.
2	*Cracks easily filled. Recurrent cracks can be masked by suitable linings.* Cracks not necessarily visible externally; *some external repointing may be required to ensure weather-tightness.* Doors and windows may stick slightly and *require easing and adjusting*. Typical crack widths up to 5 mm.
3	Cracks which *require some opening up and can be patched by a mason. Repointing of external brickwork and possibly a small amount of brickwork to be replaced.* Doors and windows sticking. Service pipes may fracture. Weather-tightness often impaired. Typical crack widths are 5 to 15 mm, or several of, say, 3 mm.
4	Extensive damage which *requires breaking-out and replacing sections of walls*, especially over doors and windows. Windows and door frames distorted, floor sloping noticeably*. Walls leaning or bulging noticeably*, some loss of bearing in beams. Service pipes disrupted. Typical crack widths are 15 to 25 mm, but also depends on number of cracks.
5	Structural damage which *requires a major repair job, involving partial or complete rebuilding*. Beams lose bearing, walls lean badly and require shoring. Windows broken with distortion. Danger of instability. Typical crack widths are greater than 25 mm, but depends on number of cracks.

** Local deviation of slope, from the horizontal or vertical, of more than 1/100 will normally be clearly visible. Overall deviations in excess of 1/150 are undesirable.*

Causes associated with the structure include such items as:

- material shrinkage and creep;
- corrosion or decay;
- differential thermal movements in dissimilar materials;
- poor detail design or workmanship.

It is rare for damage due to such causes to exceed or to deteriorate beyond Category 2 in Table 1, except perhaps very locally in a building.

Causes associated with the ground include:

- ground subsidence and heave due to volume changes in clay soils;
- settlement and heave of floor slabs on unsuitable or poorly-compacted in-fill beneath the slab;
- instability of sloping ground;
- movement due to consolidation of poor ground or made-ground;
- mining subsidence;
- movement caused by nearby excavations;
- chemical attack on foundation concrete or erosion of fine soil particles due to the passage of water, for example from a leaking pipe.

Also included is differential settlement induced by unequal foundation pressures arising from such factors as extensions added to existing buildings or concentrations of load, for example under chimneys. Damage from these causes can fall within any of the categories described in Table 1.

Thus Category 2 damage can result from a variety of causes which are frequently very difficult to identify. Indeed, at this level damage may result from a combination of the above factors. If damage exceeds Category 2 it is often much easier to identify the cause (which is frequently associated with ground movement) and hence prescribe a suitable remedy.

Category 2 defines the stage above which repair work requires the services of a builder. For domestic dwellings, which constitute the majority of cases, damage at or below Category 2 does not normally justify remedial work other than the restoration of the appearance of the building. For the cause of damage at this level to be accurately identified it may be necessary to conduct detailed examinations of the structure, its materials, the foundations and the local clear ground conditions. Consequently, unless there are clear indications that damage is progressing to a higher level it may be expensive and inappropriate to carry out extensive work for what amounts to aesthetic damage.

Cases of progressive damage are rare and since they are mainly associated with ground movement a brief discussion of the factors involved follows. It should, however, be emphasised that it is a highly specialised topic usually requiring the advice of an expert structural or civil engineer. The aim of this discussion is to give advice on when to call in such an expert.

ASSESSING THE POSSIBILITY OF SEVERE DAMAGE DUE TO PROGRESSIVE GROUND MOVEMENT

Two questions frequently confront those examining a damaged property: is the damage due to foundation movement, and will it get progressively worse?

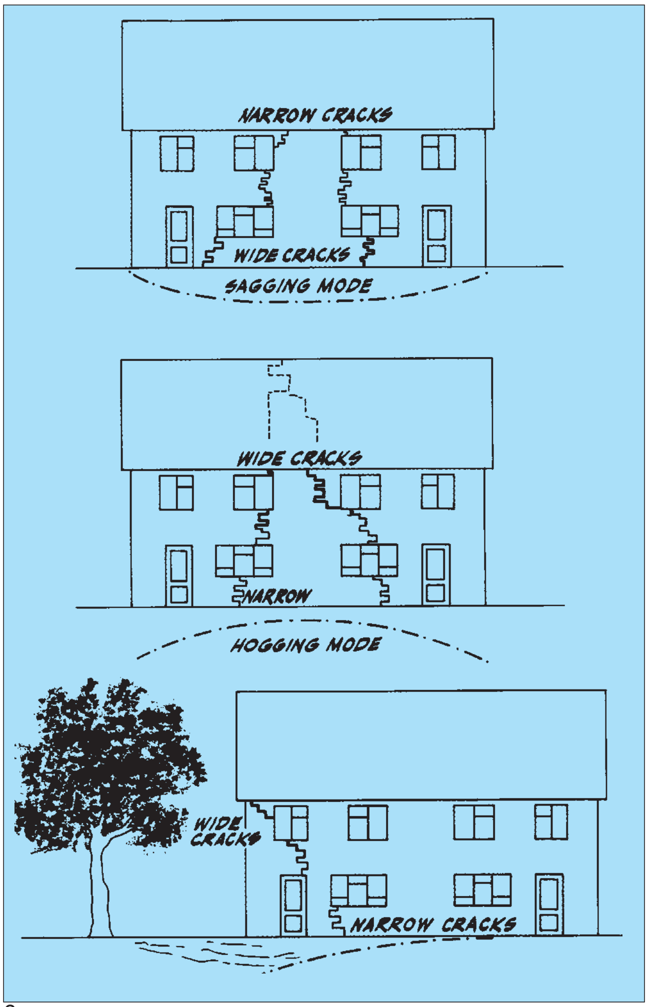
Damage due to foundation movement

It is essential to carry out a thorough survey, described in *Reporting damage*, from which records of damage and distortion should be seen to be reasonably consistent with foundation movement. The following observations would indicate such movement:

- Cracks usually show externally and internally and may extend through the dpc and down into the foundation, though this is unlikely for Category 2 damage or less.
- Crack tapers should be consistent with differential foundation movement; see, for example, Fig 8.
- Crack patterns should be reasonably consistent with observed or measured distortions (see *Reporting damage* and Fig 8).
- Floors slope, walls tilt, window and door openings distort producing uneven clearance and jamming.

The survey summarised in Figs 2, 5 and 6 points to foundation settlement at the near corner of the building.

Fig 8 Crack patterns associated with different modes of distortion



Progressive movement

If the damage is reasonably consistent with foundation movement it is then necessary to assess the likelihood of it becoming progressively worse. The main causes of foundation movement are listed in *Causes of damage*; some comments on the more common ones are:

Clay soils

A major factor discussed in detail in *Shrinkage and heave due to clay soils.*

Floor slab movement (See Table 2)

This is a common cause of damage and results from inappropriate or poorly compacted under-floor fill. Damage is generally confined to the slab and the junctions between it and external walls and also to internal partitions carried on the slab. The problem usually manifests itself early in the life of the building although it may not be discovered at the time it occurs; if not serious at this stage it is unlikely to give rise to long-term progressive deterioration.

Chemical attack

Attack by sulphates (Digest 363) or acid substances in the natural ground is rarely, if ever, sufficiently destructive to cause significant damage to the shallow foundations of low-rise buildings since these are usually sited above groundwater level. However, attack by aggressive chemical compounds in fill material (Digest 276) has resulted in numerous cases of disintegration and expansion of ground bearing slabs and foundation brickwork, particularly where burnt colliery shale has been used as under-floor filling. How far any damage will progress depends on the depth and nature of the fill material.

Instability of sloping ground

Ground movement due to slope instability usually results in cracking of roads, garden walls, services etc as well as the building itself. If progressive movement of sloping ground is thought to be the cause of damage the advice of a suitably qualified civil or structural engineer should be obtained.

Consolidation of poor ground or made ground

This problem usually manifests itself within the first ten years of the life of the building, in the form of progressive damage. If it is suspected as the cause of the damage the advice of an expert civil or structural engineer should be obtained. It is helpful to assemble all readily obtainable information about the history of the site such as the geological map and current and old Ordnance Survey maps. Aerial photographs are particularly valuable in revealing previous uses of the site. Local residents can often provide useful historical information about past activities on or near the site. These sources of information are easily obtainable and can be extremely valuable in assessing whether the site has been in-filled or whether soft marshy conditions prevailed earlier (Digests 318 and 348). If the available evidence points to a risk of progressive settlements, it will usually be necessary to carry out a ground exploration with trial pits and/or borings located in the areas of greatest movement.

Table 2 Classification of visible damage caused by ground floor slab settlement

The classification below attempts to quantify the assessment of floor slab settlement damage in a way similar to that for superstructure damage, given in Table 1. It has not yet been used extensively to determine its applicability. It should be noted that the categorisation may be qualified by the possibility of progression to a higher category; this should arise only when examination has revealed the presence of voids or areas of loosely compacted fill (or degradable material) beneath the floor slab such that more settlement can be expected.

Category of damage	Description of typical damage	Approximate (a) crack width (b) gap *
0	Hairline cracks between floor and skirtings	(a) NA (b) up to 1 mm
1	Settlement of the floor slab, either at a corner or along a short wall, or possibly uniformly, such that a gap opens up below skirting boards which can be masked by resetting skirting boards. No cracks in walls. No cracks in floor slab, although there may be negligible cracks in floor screed and finish. Slab reasonably level.	(a) NA (b) up to 6 mm
2	Larger gaps below skirting boards, some obvious but limited local settlement leading to a slight slope of floor slab; gaps can be masked by resetting skirting boards and some local rescreeding may be necessary. Fine cracks appear in internal partition walls which need some re-decoration; slight distortion in door frames so some 'jamming' may occur, necessitating adjustment of doors. No cracks in floor slab although there may be very slight cracks in floor screed and finish. Slab reasonably level.	(a) up to 1 mm (b) up to 13 mm
3	Significant gaps below skirting boards with areas of floor, especially at corners or ends, where local settlements may have caused slight cracking of floor slab. Sloping of floor in these areas is clearly visible; (slope approximately 1 in 150). Some disruption to drain, plumbing or heating pipes may occur. Damage to internal walls is more widespread with some crack filling or replastering of partitions necessary. Doors may have to be refitted. Inspection reveals some voids below slab with poor or loosely compacted fill.	(a) up to 5 mm (b) up to 19 mm
4	Large, localised gaps below skirting boards; possibly some cracks in floor slab with sharp fall to edge of slab; (slope approximately 1 in 500 or more). Inspection reveals voids exceeding 50 mm below slab and/or poor or loose fill likely to settle further. Local breaking-out, part refilling and relaying of floor slab or grouting of fill may be necessary; damage to internal partitions may require replacement of some bricks or blocks or relining of stud partitions.	(a) 5 to 15 mm but may also depend on number of cracks (b) up to 25 mm
5	Either very large, overall floor settlement with large movement of walls and damage at junctions extending up into 1st floor area, with possible damage to exterior walls, or large differential settlements across floor slab. Voids exceeding 75mm below slab and/or very poor or very loose fill likely to settle further. Risk of instability. Most or all of floor slab requires breaking out and relaying or grouting of fill; internal partitions need replacement.	(a) Usually greater than 15 mm but depends on number of cracks (b) greater than 25 mm

* *'Gap' refers to space — usually between the skirting and finished floor — caused by settlement after making appropriate allowance for discrepancy in building, shrinkage, normal bedding and the like.*

Mining subsidence

In districts where mining subsidence is anticipated, it is advisable to seek the help of experts in mining subsidence.

Lowering the water table by the action of brine pumping can also cause ground subsidence.

Soil erosion

In silty, sandy soils a leaking water or drain pipe can, over many years, bring out localised subsidence damage by slowly washing fine particles from the soil. Pressure and acoustic testing can readily identify the source of the problem and repairs of the broken pipe will stop the subsidence.

Shrinkage and heave due to clay soils

(Digests 240, 241 and 242)

This is the major cause of damage due to foundation movement, but in the majority of cases the damage is only of Category 2 magnitude or less. (Of the 140 cases described earlier, about 70% fell within Category 2 or less). If clay subsoil is suspected of being the cause of damage the following three distinct situations must be recognised:

1 open ground away from major vegetation;

2 buildings near existing trees;

3 buildings on sites newly cleared of trees.

In all these situations the following investigations are recommended:

- *Record the damage;*
- *Establish that it is consistent with foundation movements;*
- *Investigate the subsoil by means of trial pits which must reveal the depth of foundations, the presence of clay and, in the case of (2) and (3) above, the presence of fine roots below the foundations;*
- *Ascertain the history of the site (including previous vegetation), building and dates of observed movement and damage;*
- *Record the position, species and approximate age of all nearby trees and shrubs;*
- *Record the position and condition of nearby drains;*
- *Monitor.*

Open ground

For foundations less than about 1 m deep in clay soils, seasonal foundation movements take place which may give rise to slight cracks which open and close seasonally. Though sometimes unsightly, these cracks are easily masked.

Buildings near existing trees *(Digest 298)*

Where the action of existing trees has been identified as the principal cause of foundation subsidence, care and experience are required in assessing the likelihood of progressive movement and hence in planning remedial action.

The following factors should be noted:

- *Where the trees have reached or are close to maturity*, although seasonal shrinkage and swelling movements can be anticipated, larger movements are likely to occur only in exceptional spells of dry weather. Felling of such trees can lead to worse damage due to swelling of the clay. Tree pruning may offer an acceptable way of reducing the influence of the tree
- *If the trees are still far from mature* there is a possibility that progressive foundation movement will take place giving rise to increasingly severe damage. Specialised advice on remedial action should be obtained and it may be necessary to consider pruning or felling the trees that are positively identified as the cause of the movement. Small alterations in the environmental conditions such as the repair of a leaking drain can lead to further root growth and the possible effects should be considered.

For buildings damaged by shrinkage of clay the likelihood of recurrence of damage (not necessarily progressive) in very dry weather may depend on whether or not structural damage extends down into the foundations. If a foundation is completely fractured, a hinge can develop at the point of fracture which may produce recurrence of structural damage in the future. However, such a foundation fracture is unlikely to occur for damage of Category 2 or less.

Building on sites recently cleared of trees *(Digest 298)*

When trees and shrubs are removed from a shrinkable clay site, any deep zone of desiccated clay induced by the roots will tend to absorb moisture and the ground will swell. Sometimes the swelling may continue for many years. If damage is consistent with foundation movement, there is a risk of progressive movement if there is evidence of previous large vegetation on the site and trial pits reveal desiccated clay with fine roots beneath the foundation; specialist advice from a structural or civil engineer should be obtained.

Despite the qualifications mentioned above, in the light of long experience at BRE over several droughts and the examination of the 140 cases arising from the 1975/76 drought, it can be said that progressive subsidence damage is most uncommon. Only seven of the cases were regarded as involving progression extending beyond the duration of the drought; of these, three or four involved tree removal which has been clearly identified as a situation where progression can occur. Consequently, any precipitate action by interested parties on a case of subsidence damage due to clay shrinkage, whether this action be in the form of removal of suspect trees or underpinning of the affected area of the structure, would be unwise for levels of damage of no more than Category 2. The only certain way of confirming the progression of damage is to take a series of measurements with time.

Acknowledgement

The Building Research Establishment is grateful to Professor J B Burland, Imperial College of Science and Technology, for his valuable contribution to this Digest.

References

1 **Tomlinson, M J; Driscoll, R M C; Burland, J B.** Foundations for low-rise dwellings. *The Structural Engineer,* 1978, Part A, 56 A (6), 161 - 173.

2 **Burland, J B; Broms, B; De Mello, V B F.** Behaviour of foundations and structures: State of the Art Report. *Proc 9th Int Conf on Soil Mech and Found Eng. Session II. Tokyo. 1977.*

3 **Jennings, J E; Kerrich, J E.** The heaving of buildings and the associated economic consequences, with particular reference to the Orange Free State Goldfields. *The Civil Engineer in South Africa,* 1962, Vol 5, No 5, 122.

4 **National Coal Board.** Subsidence Engineers' Handbook, 1975.

5 **Institution of Structural Engineers.** Structure – soil interaction: A State of the Art Report, 1977.

Other BRE Digests

240 Low-rise buildings on shrinkable clay soils: Part 1
241 Low-rise buildings on shrinkable clay soils: Part 2
242 Low-rise buildings on shrinkable clay soils: Part 3
276 Hardcore
298 The influence of trees on house foundations in clay soils
313 Mini-piling for low-rise buildings
315 Choosing piles for new construction
318 Site investigation for low-rise building: desk studies
343 Simple measuring and monitoring of movement in low-rise buildings. Part 1: cracks
344 Simple measuring and monitoring of movement in low-rise buildings. Part 2: settlement, heave and out-of-plumb
348 Site investigation for low-rise building: the walk-over survey
352 Underpinning
359 Repairing brick and block masonry
361 Why do buildings crack?
363 Sulphate and acid resistance of concrete in the ground
386 Monitoring building and ground movement by precise levelling

APPENDIX C

Archive Information

SE91 NW/9

SE 91 NW 9281 1726

249

4. Well at Roxby Grange.

		Ft.	in.
	Soil	2	0
[Lower Estuarine Series]	Gravelly stuff (probably broken rock)	9	0
	Shale	4	0
	Greystone, very hard	0	6
		15	6

TDM SE91/3

see also ... p. 56

See Analyses, p. 200.

... analysis of this water. * O.D. : c.t 97.

* 6" f.s. shows B.M. 98·6 on the side of building near the well.

O.D. taken as 98 ft. ...

Lines 11 NW·W.

Sitteldon 6" ...

⊙ W.D.E.

Published in

'Water Supply of

Lincolnshire.'

Page 147

6" Quarter Sheet

1" N.S. Geol. Map

1" O.S. Geol. Map

Whether Confidential

Name and Number of Shaft or Bore given by Geological Survey:

Name and Number given by owner (if different from above): Hole No. M. 508.

Town or Village: Risby. Date of sinking: 7th October, 1942.

Exact site: Lat. 100 / Dep. 3868. / Lines. X1.J

A sketch-map or tracing from a large-scale map is desirable.

Purpose for which made: Prospecting Frodingham Ironstone Bed.

Level at which bore commenced relative to O.D.: 98.7 If not down bore, state if horizontal or up: —

Made by: Appleby-Frodingham Steel Co. Ltd for Messrs. A.F.S. Co. Ltd.

Information from: Mines Dept. A.F.S. Co. Ltd. Date received: 6.3.43.

Specimens: Dip of strata:

Geological Classification	Description	Thickness (m)	Thickness Ft.	Thickness Ins.	Depth (m)	Depth Ft.	Depth Ins.
	Made up ground	2.44	8	0	2.44	8	0
	Yellow clay	2.44	8	0	4.88	16	0
	Siltstone nodule	0.30	1	0	5.18	17	0
	Chocolate shale	9.75	32	0	14.94	49	0
	Marlstone	1.22	4	0	16.15	53	0
	Grey clay and nodules	15.24	50	0	31.39	103	0
	Pecten bed	1.22	4	0	32.61	107	0
	Blue-grey clay and nodules.	26.52	87	0	59.13	194	0
	Ironstone	8.53	28	0	67.67	222	0
	Blue clay	0.61	2	0	68.28	224	0

Top of F.I. -95

ORE MINING BRANCH
of
THE UNITED STEEL COS. LTD.
Colsterworth/Scunthorpe

92911729

EXPLORATION RECORD

SE 91 NW / 127

Hole No. DM.53

O.S. Sheet Ref. | Lease Elwes | Area Dragonby U.G. | Date Started 6/10/64.

Position 9292 1729 North side of Road due east of Roxby Grange Farm | Date Completed 7/11/64.

GEOLOGICAL LOG

Depth Feet From	To	Thick. Ft.	Description	Geological Horizon
0.0	1.83 6.0	1.83 6.0	Yellow Clay)	
1.83 6.0	2.29 7.5	0.46 1.5	Brown brocken limestone) Inferior Oolite	
2.29 7.5	3.51 11.5	1.22 4.0	Grey Clay)	
3.51 11.5	4.88 16.0	1.68 5.5	Brown limestone & Clay)	
4.88 16.0	5.64 18.5	0.76 2.5	Grey & Brown Limestone	
5.64 18.5	16.61 54.5	10.97 36.0	Grey clay & shale	
16.61 54.5	18.29 60.0	1.68 5.5	Marlstone	
18.29 60.0	33.22 109.0	14.94 49.0	Grey clay with rock bands	
33.22 109.0	34.44 113.0	1.22 4.0	Pecten	
34.44 113.0	60.96 200.0	26.52 87.0	Grey clay with rock bands	
60.96 200.0	68.99 226.3	8.03 26.3	F.I. bed	
68.99 226.3	71.60 234.9	2.62 8.6	Blue bind with rock bands	

8.03 at 6096 / 3114 / -2982   6096 / 3322 / 2774 (1.22)   6096 / 1661 / 4435 (1.68)

Hole plugged at 200.0'

DRILL LOG

CROWNS USED

Size	No.	Feet
131	6067B	18.0
131	F.B.	36.0
116	F.B.	136.0
116	Cbd	4.0
101	642333	34.4

REAMERS USED

Size	No.	Feet

CASING USED

Size	Set (Ft.)	Recovered (Ft.)
143	6.4	6.4
128	60.9	60.9

Water Used 35,100

Rest Water Level

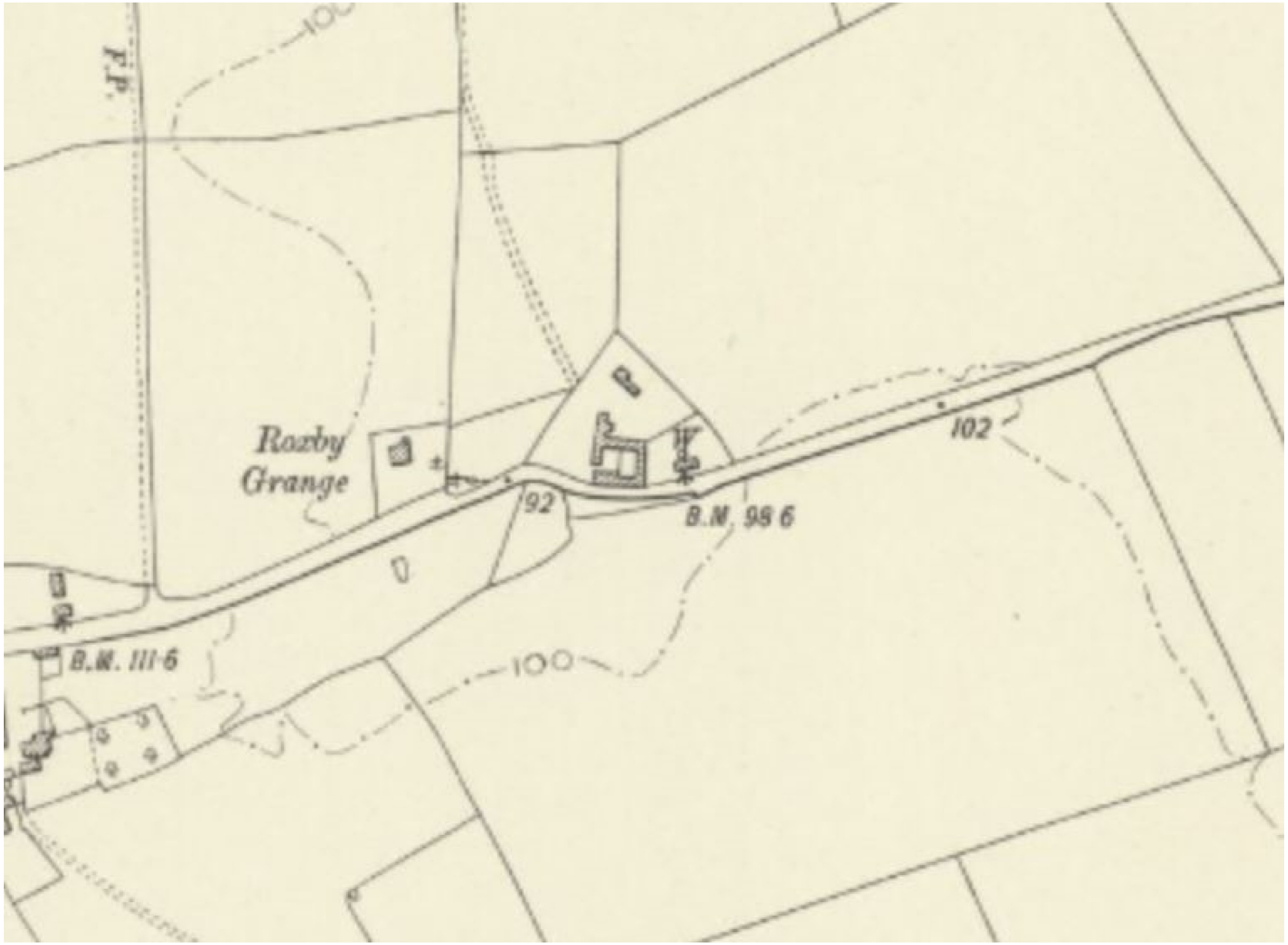
LEVELS 31.14

Surface	102.1
Top I'st.	
Bottom I'st.	

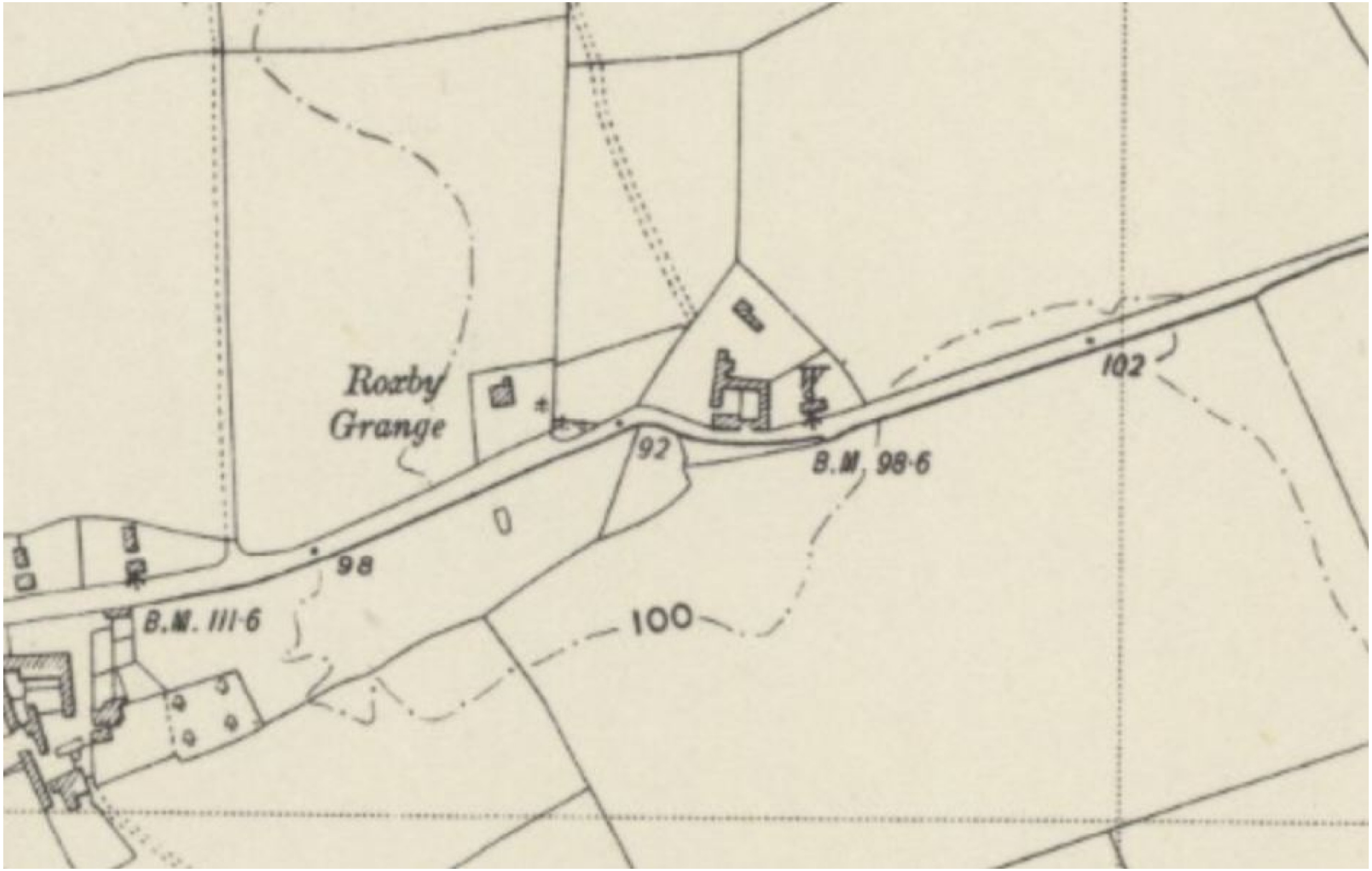
Signed [redacted]

P. & H. 2/60.

F.P.
Roxby Grange
92
93
94
98
100
102
B.M.98·6
B.M.111·6



F.P.
100
Roxby
Grange
92
B.M. 98.6
102
B.M. 111·6
100


Roxby
Grange
92
B.M. 98·6
102
98
B.M. 111·6
100

Hull (Registered Office)	**Leeds**	**York**
Church House	Unit E	Partnership House
44 Newland Park	Millshaw Business Living	Monks Cross Drive
Hull HU5 2DW	Global Avenue	Monks Cross
01482 345797	Leeds LS11 8PR	York YO32 9GZ
www.masonclark.co.uk	0113 2779542	01904 438005
consultants@masonclark.co.uk	www.masonclark.co.uk	www.masonclark.co.uk

CIVIL ENGINEERING
Bridge design, maintenance and construction
Wharfs, jetties and marine structures
Highway design and maintenance
Retaining wall and slope stability solutions
Land remediation advice

Road and sewer design to adoptable standards
Section 38 and 104 Agreements
Sewer requisitions and diversions
Section 98 and 185 Agreements

Flood Risk Assessments
Coastal erosion flood breach analysis
Flood risk management / prevention schemes

Underground drainage design
Stormwater attenuation
SUDS
Ponds, lakes and balancing ponds

PROJECT MANAGEMENT
QUANTITY SURVEYING & CONTRACT ADVICE
CDM SERVICES

BUILDING SURVEYING SERVICES
Design, Remedial Repair / Improvement Schemes
Contract Administration
Building Surveys
Professional Opinion Reports
Condition Surveys & Schedules of Condition
Measured Surveys
Dilapidation Claims
Party Wall etc. Act Representation
Disabled Adaptations

EXPERT WITNESS SERVICES
Civil & Structural engineering disputes
Project Disputes
Health and Safety Regulations

STRUCTURAL ENGINEERING
Residential and commercial building structures
Education and healthcare facilities
Heavy industrial development
Feasibility studies for development sites
Building Regulations and Planning Applications

Access and maintenance gantries
Modular building design
Blast design

Subsidence management and resolution
Temporary works design and specification
Site and soils investigation
Sulphate attack specialists
Confined spaces assessments

CONSERVATION ENGINEERING
Engineer Accredited in Building Conservation CARE
Registered Engineer
Heritage and conservation engineering
Listed Building refurbishment
Historic Parks and Gardens
Scheduled Ancient Monuments
Monitoring and investigations
Liaison with Local Conservation Officers
Buildings at Risk and Managed Ruins

3D LASER SCANNING AND DATA CAPTURE
Latest Generation 3D Laser Scanning
Measured Building Surveys
Topographical Surveys
Monitoring Surveys

3D modelling (Revit, CAD, Inventor, Solidworks)
M & E Modelling
Volumetric / Level analysis
Scan to BIM
Scan data cloud hosting
Hi-Def HDR photographic surveys