

Hutton + Rostron Environmental Investigations Limited

Mindel House, Manchester: Plaster condition survey

Site note 4 for 8 April and 27 July 2021, job no. 212.57
REVISION B - 25.04.22

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1 INTRODUCTION

1.1 AUTHORITY AND REFERENCES

Hutton + Rostron Environmental Investigations Limited carried out a site visit to Mindel House, Manchester on the 8 April and 27 July 2021 in accordance with instructions from Manchester Design and Building Ltd by purchase order, dated 6 January 2021 reference 390 and by purchase order 746, dated 8 June 2021. Drawings provided by Beech Design & Build, Ref 061 were used for the identification of structures. For the purpose of orientation in this report, the elevation facing Bloom Street was taken as facing north-west

1.2 AIM

The aim of this survey was to investigate original lime plaster finishes and lath and plaster linings to ascertain their condition, vulnerability and service life as well as to identify composition and any defects relevant to the planned refurbishment

1.3 LIMITATIONS

This survey was confined to the accessible structures. Only demolition or exposure work can enable the condition of plaster to be determined with certainty, and this destroys what it is intended to preserve. Specialist investigative techniques are therefore employed as aids to the surveyor. No such technique can be 100 per cent reliable, but their use allows deductions to be made about the most probable condition of materials at the time of examination. Structures were not examined in detail except as described in this report, and no liability can be accepted for defects that may exist in other parts of the building. We have not inspected elements which are covered, unexposed or inaccessible and we are therefore unable to report that any such part is free from defect. The contents of this report do not imply the adoption of the role of Principal Designer by H+R for the purposes of the Construction Design and Management (CDM) Regulations 2015. No formal investigation of moisture distribution was made

2 STAFF ON SITE AND CONTACTS

2.1 H+R STAFF ON SITE

Chris Whitfield

2.2 PERSONNEL CONTACTED

Neil Kelly

3 EXECUTIVE SUMMARY

3.1 LIME PLASTER

External walls were generally finished with lime plaster that included a thin gypsum-based skim coat. Where exposed, the brick substrate behind the plaster was generally free from earlier decorative schemes, suggesting the plaster was largely original. However, earlier paint schemes were identified in some locations indicating that areas of the existing plaster were non-original

The many layers of non-original decorative finishes including timber panelling, plasterboard, wood-based fibreboard boxing as well as the numerous layers of wallpaper and paint over the lime plaster limited a detailed investigation. However, where 'tap-tested', there were numerous localised areas of debonding identified in the lime plaster largely attributed to historical water penetration and inadequate preparation of the substrate prior to plastering

The lime plaster at Fourth Floor level and in areas of ongoing water penetration was in particularly poor condition and beyond salvage. Some remnants of plaster remained at Lower Ground Floor level but as the solid walls are below ground level/earth retaining the plaster had failed

Although the plaster was largely repairable, additional damage should be expected following the removal of non-original finishes and allowance should therefore be made for extensive repairs

3.2 LATH AND PLASTER

Many internal stud partitions and window reveals were lined with softwood lath and lime plaster but modern plasterboard applied to internal partitions concealed many of the finishes. Where examined, the lath and plaster were generally in fair condition with only localised areas of mechanical damage and failure. However, the lath and plaster in the 3 no. areas of ongoing water penetration were damp and/or decayed where abutting the damp walls

The lath and plaster ceiling over the Lower Ground Floor was probably original as there were no earlier decorative schemes to the underside of the floor joists. There was widespread mechanical damage to the plaster largely caused by the addition of services and suspended ceilings associated with the former nightclub. This additional stress on the plaster 'keys' had caused abundant cracking and failure and some sections of plaster had detached. There were also pockets of timber decay where finishes were in direct contact with the external walls

The condition of the ceiling at Fourth Floor level is discussed in H+R Site Note 1

4 OBSERVATIONS

Report should be read in conjunction with the Schedule of Photographs at Attachment A and Drawings at Attachment B

4.1 FOURTH FLOOR

See Figures 1-23 in the Schedule of Photographs

4.1.1 Ceiling

- 1 Lath and plaster: See H+R Site Note 1

4.1.2 External walls (high-level)

- 1 Plaster: The external walls were generally finished with a ≈20mm lime plaster which had been decorated with numerous layers of paint and wallpaper. Petrographic analysis identified that although the base coat of the plaster was lime-based the much thinner surface was gypsum-based (see Attachment C). Where investigated, the brick substrate was generally free from earlier decorative schemes apart from in the former office to the North corner (MS-401) where there was a blue paint layer. This suggested the plaster to MS-401 was not original. Window soffits and reveals were lined with early/original machine sawn lath and lime plaster. There was no cornice
- 2 Condition: The many layers of decorative finishes over the plaster constrained detailed investigation but where 'tap-tested', the original/early lime plaster was cracked/loose/defective and relatively large areas were at risk of debonding from the brick substrate. Deterioration of the plaster was largely attributed to historical water penetration but exposure of the brickwork also revealed that no formal 'key' had been prepared prior to plastering i.e. the mortar joints had not been raked-out. The lath and plaster soffits were generally in fair condition with only localised areas of failure. However, all plaster and lath and plaster finishes in areas of ongoing water penetration were damp and/or decayed and beyond salvage

4.1.3 External walls (low-level)

- 1 Plaster: A gypsum plaster had been applied to the lower ≈1m of the external walls from floor to window sill height. Earlier blue and gold paint schemes were present on the brick substrate and the gypsum plaster was therefore non-original
- 2 Condition: No formal 'key' had been prepared in the brickwork, which when combined with paint provided a very poor surface for plastering. As such, the gypsum plaster had largely debonded

4.1.4 Internal wall to southern staircase

- 1 Plaster: The non-original brick wall was finished with gypsum plaster
- 2 Condition: The plaster was in fair condition with only localised areas of mechanical damage and failure

4.1.5 Central good lift

- 1 Plaster: The brickwork was largely concealed by modern plasterboard but the plaster is almost certainly of lime (as described at 4.1.2 (1) above)
- 2 Condition: As the area was subject to ongoing water penetration the concealed

plaster is almost certainly wet and largely debonded from the brick substrate

4.1.6 Internal partitions

- 1 Construction: The internal partitions were of softwood stud form, lined with modern plasterboard and timber skirting boards. However, the plasterboard to the partitions either side of staircase MS-414 concealed earlier vertical softwood t&g panelling with a softwood skirting board. It is worth noting that the skirting board to the external walls of MS-412 and MS-413 is of the same profile and therefore almost certainly not original
- 2 Condition: The plasterboard linings impeded investigation but the timber panelling and skirtings were wet and partially decayed where abutting the external wall due to ongoing water penetration

4.2 THIRD FLOOR

See Figures 24-40 in the Schedule of Photographs

4.2.1 External walls

- 1 Plaster: The external walls were generally finished with lime plaster with lath and plaster to window soffits (as described at 4.1.2 (1) above). The softwood skirting board to MS-301–MS-309 was of the same era as the plaster but the vertical softwood t&g dado panelling to MS-312–MS-320 was not original and concealed the skirting board. There were no earlier paint schemes to the brick substrate behind the plaster. There was no cornice
- 2 Condition: The lime plaster was 'tap-tested' revealing numerous areas of debonding, primarily at low-level. Lath and plaster, skirting boards and panelling were similarly in fair condition. However, all plaster and timber finishes in areas of ongoing water penetration were damp and/or decayed and beyond salvage

4.2.2 Internal wall to southern staircase

- 1 Plaster: As per 4.1.4 (1)
- 2 Condition: As per 4.1.4 (2)

4.2.3 Central good lift

- 1 Plaster: As per 4.1.5 (1)
- 2 Condition: As per 4.1.5 (2)

4.2.4 Internal partitions

- 1 Construction: The internal partitions either side of the staircase MS-302 were generally lined with lath and lime plaster but with some use of a hessian 'scrim' fibrous plaster. The lath and plaster as well as its softwood skirting board appeared to be original to the staircase
- 2 Condition: Other than localised mechanical damage (presumably caused by the recent R&D Asbestos Survey) the finishes were generally in a fair condition and where visible the plaster 'keys' were sound. However, plaster and timber finishes were damp and partially decayed where abutting the damp external wall

4.3 SECOND FLOOR

See Figures 41-56 in the Schedule of Photographs

4.3.1 External walls

- 1 Plaster: The external walls were generally finished with lime plaster and a softwood skirting board (as described at 4.1.2 (1) above). These early/original finishes were partially concealed by reproduction softwood panelling in MS-205 and plasterboard dry lining around the chimney to MS-218. The dry-lining appears to have been applied around the chimney to disguise the effects of hygroscopic salt to the lime plaster. There were no earlier paint schemes to the brick substrate behind the plaster. There was no cornice
- 2 Condition: The lime plaster was 'tap-tested' revealing numerous areas of debonding. Skirting boards were generally in fair condition. However, all plaster and timber finishes in areas of ongoing water penetration were damp and/or decayed and beyond salvage

4.3.2 Internal wall to southern staircase

- 1 Plaster: As per 4.1.4 (1)
- 2 Condition: As per 4.4.3 (2)

4.3.3 Central good lift

- 1 Plaster: As per 4.1.5 (1)
- 2 Condition: As per 4.1.5 (2)

4.3.4 Internal partitions

- 1 Construction: A proportion of the internal partitions were of non-original studwork lined with plasterboard. However, there was earlier lath and plaster either side of the staircase MS-202 and to the rear of the cupboard at MS-216. Softwood skirting boards appeared to be contemporaneous with these linings
- 2 Condition: The finishes were generally in a fair condition and where visible the plaster 'keys' were sound. However, plaster and timber finishes were damp and partially decayed where abutting the damp external wall in both of these areas

4.4 FIRST FLOOR

See Figures 57-74 in the Schedule of Photographs

4.4.1 External walls

- 1 The external walls were generally finished with lime plaster and a softwood skirting board (as described at 4.1.2 (1) above). These early/original finishes were largely concealed by reproduction softwood boxing and panelling in MS-117. This room also included a plasterboard ceiling on softwood battens fixed to the underside of the millboards that concealed the earlier wallpaper. The plasterboard ceiling included a non-original cornice/coving. A gypsum plaster had also been applied over the lime plaster near the loading doors to MS-110
- 2 Condition: The lime plaster was 'tap-tested' revealing numerous areas of debonding. Skirting boards were generally in fair condition. However, all plaster

and timber finishes in areas of ongoing water penetration were damp and/or decayed and beyond salvage. The condition of the lime plaster to MS-117 could not be confirmed but is likely representative of other areas

4.4.2 Internal wall to southern staircase

- 1 Plaster: As per 4.1.4 (1)
- 2 Condition: As per 4.1.4 (2)

4.4.3 Central good lift

- 1 Plaster: As per 4.1.5 (1)
- 2 Condition: As per 4.1.5 (2)

4.4.4 Internal partitions

- 1 Construction: The internal partitions to the staircase at MS-119 and MS-117 were lined with early/original lath and lime plaster. Softwood skirting boards appeared to be contemporaneous with these linings. The timber glazed screen to MS-101 was non-original and evidence of this can be seen where the joinery has been cut around the profile of an earlier skirting board to the side of the fireplace
- 2 Condition: The finishes were generally in a fair condition and where visible the plaster 'keys' were sound. However, plaster and timber finishes were damp and partially decayed where abutting the damp external wall in both of these areas. Other than localised mechanical damage and inadequate restraint there were no significant damp and/or decay related defects affecting the glazed timber screen

4.5 UPPER GROUND FLOOR

See Figures 75-91 in the Schedule of Photographs

4.5.1 External walls

- 1 The external walls were generally finished with lime plaster (as described at 4.1.2 (1) above). However, non-original low-level boxing/panelling of plasterboard, fibreboard and chipboard concealed much of the plaster below window sill height. The central portion of the south-west wall had undergone numerous phases of rebuilding and alteration and subsequently there were no plaster finishes. Lath and plaster and/or softwood joinery had been applied to many of the window reveals and these finishes are thought to be original/early. There was no cornice
- 2 Condition: The lime plaster was 'tap-tested' revealing numerous areas of localised debonding. All plaster and timber finishes in areas of ongoing water penetration were damp and/or decayed and beyond salvage. The condition of the low-level lime plaster behind the boxing could not be confirmed. The lath and plaster and timber window reveals were generally in fair condition with only localised areas of failure and mechanical damage of the joinery

4.5.2 Internal wall to southern staircase

- 1 Plaster: As per 4.1.4 (1)
- 2 Condition: As per 4.1.4 (2)

4.5.3 Central good lift

- 1 Plaster: As per 4.1.5 (1)
- 2 Condition: As per 4.1.5 (2)

4.5.4 Internal partitions

- 1 Construction: The internal partitions to the staircase at MS-UG01 and northern Entrance Lobby were lined with early/original lath and lime plaster. The lath and plaster finishes were largely concealed by numerous non-original finishes including plasterboard, timber panelling and a flecked paint wall finish that probably dates from the 1980's. There was also a decorative barrel ceiling over the entrance lobby with curved coffered panel moulds but this was partially concealed by a non-original suspended ceiling. A small section of lath and plaster remained directly behind the central goods lift but this was also concealed by plasterboard
- 2 Condition: The condition of lath and plaster could not be ascertained due to the retained non-original finishes but they are likely to be largely free from significant defect. However, plaster and timber finishes were almost certainly damp and partially decayed where abutting the damp external wall of the entrance lobby and central goods lift. There was no significant damp or decay related issues identified in the decorative ceiling over the entrance lobby

4.6 LOWER GROUND FLOOR

See Figures 92-95 in the Schedule of Photographs

4.6.1 Ceiling

- 1 Lath and plaster: Lath and plaster had been applied to the underside of the upper ground floor joists and remained in the north-eastern bays (gridlines no. 1-4). Where visible, the softwood joists above were undecorated suggesting that this ceiling may be original. It is worth noting that the majority of the floor joists at this floor level were painted with white paint and there was no evidence that a ceiling existed in these areas before. There was no cornice
- 2 Condition: The lath and plaster ceilings were damp and laths were decayed where abutting the external walls. This had resulted in localised failure notably in the eastern corner. Cracking was also widespread throughout the plaster largely a result of services and suspended ceilings associated with the former nightclub that had been hung directly from the ceiling. As a result of this, plaster 'keys' have been overstressed and the ceilings were at risk of failure and some relatively small areas of localised failure had already occurred

4.6.2 External walls

- 1 Plaster: As the solid masonry walls are largely below ground, they are susceptible to damp and unsuitable for direct plastering. Some small areas of plaster remained but the plaster was wet and had debonded from the brick substrate

4.6.3 Internal walls

- 1 Construction: All walls are of solid material. No lath and plaster finishes were identified to the walls

4.7 PETROGRAPHIC EXAMINATION

- 1 Sampling: In all 6 no. small specimen samples of plaster were removed from Mindel House for petrographic analysis by Sandberg Consulting Engineers. The samples were all taken from what appeared to be original/early plaster and are thought to be representative of the building. The sample locations are listed below and identified on the attached drawings:

Sample no.	Floor	Location
1	Fourth floor	External wall
2	Fourth floor	External wall
3	Third floor	External wall
4	Second floor	External wall
5	Fourth floor	Ceiling
6	Fourth floor	Ceiling

- 2 Results: See 'Report on the petrographic examination of six plaster samples' at Attachment C

5 RECOMMENDATIONS

5.1 FOURTH FLOOR

- 1 Ceiling: See H+R Site Note 1
- 2 Walls: The plaster was largely beyond salvage and H+R recommend complete removal back to the brick substrate. Although the lime plaster to the upper walls was generally original, the gypsum plaster to the lower walls was not and the client may therefore wish to consider the design options available to them as it may be favourable to leave the brickwork exposed or reinstate a dry lining

5.2 THIRD FLOOR- UPPER GROUND FLOOR

5.2.1 Preparation and detailed investigation

- 1 Survey limitations: H+R recommend that all non-original finishes including non-original joinery, plasterboard, cornices, fibreboard, wallpaper, gypsum plaster and paint etc. are carefully removed from the external walls and internal partitions. Only then can full investigation of plaster condition be undertaken and quantitative information gained. H+R recommend early discussion with Paul Butler Associates to clarify existing permissions with regard to removal of non-original finishes
- 2 Methodology for removing wallpaper/woodchip: The 'steaming off' of wallpaper is not recommended as this can result in further damage to the lime plaster. Instead, wallpapers should be dampened down with water from a low pressure mist spray and sponge aided by a good quality flat scraper. The glues of the older wallpapers are likely to be starch-based and this method is likely to be the most appropriate in removing the finishes back to the earlier paintwork
- 3 Areas of ongoing water penetration: The lime plaster to the external walls subject to ongoing water penetration should be removed back to the brick substrate. Ideally, at this stage, any damp masonry should be left exposed as long as necessary to allow adequate drying before re-plastering. Lath and plaster in these areas should be carefully cut back to sound material. Allowance should be made for additional decay in the laths and the softwood studwork whilst water penetration continues and whilst residual moisture remains in the structure. Lime plaster should only be reinstated to these areas following drying. H+R can undertake drying monitoring at an appropriate stage in the redevelopment, if instructed. Alternatively, ventilated dry-linings could be considered
- 4 Detailed investigations: Following the removal of non-original finishes allowance should be made for a detailed 'tap-test' of all lime plaster to locate areas of debonding and 'mark-up' the full extent of repairs required. H+R recommend that this element is undertaken by the plasterer appointed to undertake the repairs. The plasterer should be trained and experienced in conservation plastering including the methodology of application and management of drying etc. and H+R recommend that sample panels are done. Allowance should be made for extensive repairs to the plaster at each floor level

5.2.2 Repair and reinstatement

- 1 Preparation: Areas of defective, loose and salt-damaged plaster should be carefully cut back to the sound plaster or brick substrate. The brick substrate should be hand cleaned by wire brush to remove debris and any salts and prepared for application by raking out the mortar joints to a depth of around 10mm to provide a 'key' for the new plaster. Remove any built-in bonding timbers and brick-up/fill with lime mortar

- 2 Lime plaster to masonry walls: The methodology should be agreed by the conservation plasterer and the reinstated lime mix be characteristic of that identified in the petrographic analysis (see Attachment C)
- 3 Lath and plaster to partitions and window reveals: Decayed or damaged laths should be replaced with new machine sawn laths and lime plaster reinstated as per above
- 4 Barrel vaulted ceiling: It may be necessary to temporarily remove the First floor floorboards above to enable detailed inspection of the decorative ceiling from above and to provide access to undertake repairs. Any decayed or damaged laths should be replaced with new and any damaged lime plaster reinstated as per above. Any sections of damaged moulding should also be replicated to match the existing profile. Extent of repairs to be confirmed following detailed condition assessment by the conservation plasterer
- 5 Redecoration: Redecorate only when the plaster has dried out. Note: Drying /shrinkage cracks may appear where the new plaster adjoins the existing plaster. These can be filled during decoration. The lime plaster should be decorated with a highly vapour permeable decorative finish. Lime paint, lime wash, distemper and casein paints are traditional finishes for new work

5.2.3 Joinery repairs

- 1 Skirting boards and timber window reveals: Carefully release the timbers from the areas subject to ongoing water penetration to avoid further decay. The timbers should be referenced and stored in a dry and ventilated environment to await inspection for salvage. Damp and/or decayed or mechanically damaged sections of timber should be replaced to match the existing profile in a suitably specified softwood timber species. All reinstated joinery should be isolated from direct contact with the masonry using strips of dpm, plastic wedges and screw fixings etc. rather than timber grounds

5.3 LOWER GROUND FLOOR

- 1 Ceiling: Allowance should be made for extensive repairs to the lath and plaster following a detailed assessment by a conservation plasterer. This would require removal of the floorboards from the floor above so that the plaster 'keys' can be inspected. Alternatively, given the widespread damage to the existing ceiling it may be advantageous to remove the existing and reinstate with new traditional lath and lime plaster
- 2 Walls: Any remnants of plaster and paint should be removed from the external brick walls. H+R recommend that a 'Type C' waterproofing system is applied to the external walls and this should be formally designed and installed with drainage by a specialist

6 H+R WORK ON SITE

- 6.1** H+R inspected original/early plaster and lath and plaster, as necessary, so as to ascertain condition, vulnerability and service life

7 PROPOSED ACTION BY H+R

- 7.1** H+R will advise on repair and conservation of timber elements, so as to minimise the risk of decay after refurbishment if instructed
- 7.2** H+R will advise on remedial detailing, so as to minimise the risk of damp and decay problems after refurbishment if instructed
- 7.3** H+R will advise on conservation of original fabric with regard to damp, decay and salt damage, as necessary and if instructed
- 7.4** H+R will review proposed remedial details as these become available if instructed
- 7.5** H+R will return to site to inspect sample remedial details if instructed
- 7.6** H+R will liaise with conservation and historic building authorities, if instructed, so as to ensure the cost-effective conservation of original fabric
- 7.7** H+R will liaise with building guarantors, as necessary, so as to ensure the issuing of collateral warranties and building guarantees at practical completion, if required
- 7.8** H+R will return to site to inspect other buildings on site for structurally significant decay; and advise on timbers at risk of decay during the latent defect period due to water penetration before and during refurbishment if instructed

8 INFORMATION REQUIRED BY H+R

- 8.1** H+R require up-to-date copies of project programmes, as these become available
- 8.2** H+R require copies of up-to-date lists of project personnel and contact lists as these become available
- 8.3** H+R require copies of proposed remedial details for comment as these become available
- 8.4** H+R should be informed as a matter of urgency if further significant water penetration occurs onto site; so that advice can be given on cost-effective remedial measures, to minimise the risk of cost or programme overruns and so as to minimise the risk of damp or decay problems during the latent defect period

9 ADMINISTRATION REQUIREMENTS

- 9.1** H+R require formal instructions for further investigations and consultancy on this project
- 9.2** H+R require confirmation of distribution of digital and printed copies of reports and site notes

Attachment A



Fig 1:

Fourth Floor, MS-401; showing wet and largely debonded lime plaster in the area of ongoing water penetration

Note that the low-level timber boxing had been removed revealing that the brickwork behind was previously painted blue and gold



Fig 2:

Fourth Floor, MS-401; showing a typical example of the damp and decayed lath and lime plaster soffit over MS-4W06



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Fig 3:

Fourth Floor, MS-401; showing modern plasterboard lining to stud partition



Fig 4:

Fourth Floor, MS-401; showing earlier vertical t&g panelling with a softwood skirting board behind. Timbers were damp and partially decayed in the area of ongoing water penetration



Mindel House, Manchester

Photographs
8 April and 27 July 2021

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Fig 5:

Fourth Floor, MS-401; showing previous blue and gold paint schemes to the upper brick wall behind the non-original lime plaster



Fig 6:

Fourth Floor, MS-402; showing the separation line between the upper lime plaster and lower gypsum. Note that there is no earlier decorative finish behind the lime plaster



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Fig 7:

Fourth Floor, MS-402; showing the softwood skirting board that was fixed to timber blocking. The skirting board appears to have been applied at the same period as the gypsum i.e. it is non-original



Fig 8:

Fourth Floor, MS-402; showing the profile of a removed section of softwood skirting board. This reversible/dual purpose moulding is of mid-late 20th century



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Fig 9:

Fourth Floor, MS-402; showing a typical example of debonded lime plaster caused by historical water penetration between MS-4W19 and MS-4W20



Fig 10:

Fourth Floor, MS-402; showing localised mechanical damage to the lath and lime plaster soffit over MS-4W20



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Fig 11:

Fourth Floor, MS-402; showing the non-original internal wall that was finished with gypsum plaster



Fig 12:

Fourth Floor, MS-405; showing the separation line between the upper lime plaster and lower gypsum plaster



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Fig 13:

Fourth Floor, MS-406-MS-411;
showing extensive deterioration of the
plaster finished in the area of ongoing
water penetration



Fig 14:

Fourth Floor, MS-412; showing the
separation line between the upper lime
plaster and lower gypsum plaster

Note that the softwood skirting board
was applied over the non-original
gypsum plaster



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Fig 15:

Fourth Floor, MS-412; showing an area of removed gypsum plaster. Note that a 'key' had been prepared to the brickwork prior to application of the plaster. Also note that there was no previous decoration to the brickwork



Fig 16:

Fourth Floor, MS-404; showing a non-original internal partition that was lined with plasterboard. Note that the skirting board applied over the plasterboard was the same as in MS-412 i.e. non-original



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Fig 17:

Fourth Floor, MS-404; showing a close-up of the plasterboard that was applied to either side of this stud partition



Fig 18:

Fourth Floor, MS-404; showing a non-original internal partition that was lined with plasterboard. Note that the skirting board applied over the plasterboard was the same as in MS-412 i.e. non-original



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Fig 19:

Fourth Floor, MS-404; showing a close-up of the plasterboard that was applied to either side of this stud partition



Fig 20:

Fourth Floor, MS-413; showing an area of water penetration. All wall finishes were damp and decayed



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Fig 21:

Fourth Floor, MS-414; showing an area of water penetration. All wall finishes were damp and decayed. The timber panelling to the stud partitions were also damp and partially decayed where abutting the external wall



Fig 22:

Fourth Floor, MS-414; showing an area of water penetration. All wall finishes were damp and decayed. The timber panelling to the stud partitions were also damp and partially decayed where abutting the external wall



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Fig 23:

Fourth Floor, Goods lift; showing largely non-original plasterboard linings around the central goods and passenger lift shafts. The lime plaster behind was largely damp and had debonded from the substrate



Fig 24:

Third Floor, MS-301; showing the area of water penetration. The lime plaster was wet and the softwood skirting board was partially decayed in this area



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Fig 25:

Third Floor, MS-305-MS-308; showing early/original lime plaster to the external wall. Plaster was generally in fair condition with localised areas of debonding at low-level



Fig 26:

Third Floor, MS-305-MS-308; showing a typical example of where the lime plaster had cracked and debonded from the brick substrate



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Fig 27:

Third Floor, MS-309; showing an area of significant debonding of the plaster caused by historical water penetration



Fig 28:

Third Floor, MS-309; showing that the lime plaster pre dates the construction of the internal brick wall



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Fig 29:

Third Floor, MS-312-MS-320; showing deterioration of the wall finishes in the area of water penetration



Fig 30:

Third Floor, MS-312-MS-320; showing extensive damp and decay of the softwood vertical t&g panelling and saturation of the lime plaster behind



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Fig 31:

Third Floor, MS-320; showing lime plaster finish with non-original t&g boarding at low-level



Fig 32:

Third Floor, MS-320; showing earlier softwood skirting board and wallpaper to the lime plaster behind the panelling



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Fig 33:

Third Floor, MS-320; showing an area of water penetration and deterioration of the wall finishes



Fig 34:

Third Floor, MS-320; showing the timber stud partition around MS-302 that was lined with lath and plaster as well as hessian 'scrim' fibrous lime plaster



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Fig 35:

Third Floor, MS-320; a close-up of the lath and plaster and hessian 'scrim' fibrous lime plaster



Fig 36:

Third Floor, MS-320; showing a removed section of hessian 'scrim' fibrous lime plaster



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Fig 37:

Third Floor, MS-302; showing deterioration of the external and internal wall finishes in the area of water penetration



Fig 38:

Third Floor, MS-302; showing the backside of the fibrous lime plaster on hessian 'scrim' panel



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Fig 39:

Third Floor, Goods lift; showing largely early/original lime plaster with a softwood skirting board



Fig 40:

Third Floor, Goods lift; showing significant debonding of the lime plaster caused by ongoing water penetration



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Fig 41:

Second Floor, MS-201; showing deterioration of the lime plaster in the area of ongoing water penetration. The softwood square-edge skirting board was also damp and partially decayed in this area



Fig 42:

Second Floor, MS-205; showing reproduction panelling formed of plasterboard and softwood timber that conceals original/early lime plaster



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Fig 43:

Second Floor, MS-204; showing lime plaster with a softwood skirting board to the external wall



Fig 44:

Second Floor, MS-204; showing a close-up of the numerous paint and wallpaper finishes over the early/original lime plaster



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Fig 45:

Second Floor, MS-204; showing a section of removed lime plaster. Note that there had been no previous decorative finishes to the brick substrate



Fig 46:

Second Floor, MS-207; showing localised debonding of the lime plaster in an area of historical water penetration



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Fig 47:

Second Floor, MS-213; showing deterioration of the lime plaster in an area of ongoing water penetration



Fig 48:

Second Floor, MS-215; showing deterioration of the lime plaster in an area of ongoing water penetration



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Fig 49:

Second Floor, MS-216; showing an area of lath and lime plaster used behind the cupboard of MS-218. The lath and plaster was damp and partially decayed where abutting the external wall

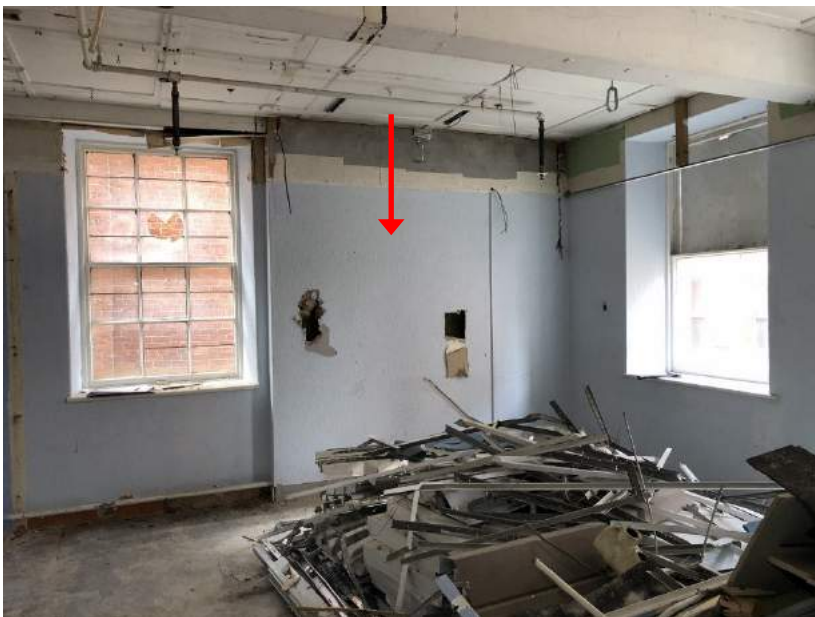


Fig 50:

Second Floor, MS-218; showing lime plaster with a softwood skirting board. Note that plasterboard had been applied around the chimney to hide penetrating salt



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Fig 51:

Second Floor, MS-218; showing lime plaster with an earlier paint scheme behind the plasterboard. Note cracking of the plaster associated with salt



Fig 52:

Second Floor, MS-218; showing numerous paint and wallpaper finishes over the lime plaster



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Fig 53:

Second Floor, MS-218; showing an area of ongoing water penetration that had caused deterioration of the lime plaster



Fig 54:

Second Floor, MS-218; showing a close-up of the lath and plaster finish to the separating partition to MS-202. Lath and plaster was damp and partially decayed in the area of ongoing water penetration



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Fig 55:

Second Floor, MS-202; showing deterioration of the wall plaster and lath and plaster in the area of ongoing water penetration



Fig 56:

Second Floor, Good lift; showing lime plaster. The plaster was wet and largely debonded from the brick substrate due to ongoing water penetration



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Fig 57:

First Floor, MS-101; showing deterioration of the lime plaster and partial decay of the softwood skirting board in the area of ongoing water penetration



Fig 58:

First Floor, MS-101; showing a close-up of the lath and lime plaster finishes to the internal partition between MS-119



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Fig 59:

First Floor, MS-101; showing the non-original timber and glazing partition. There was localised mechanical damage but the timbers were free from significant damp and decay



Fig 60:

First Floor, MS-101; showing the softwood skirting board that pre-dates the installation of the timber partition



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Fig 61:

First Floor, MS-102; showing lime plaster with a softwood skirting board. The plaster was generally in fair condition with localised areas of debonding



Fig 62:

First Floor, MS-106; showing the area of historical water penetration which had caused localised deterioration of the lime plaster and partial decay of the skirting board



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Fig 63:

First Floor, MS-1110 to MS115;
showing the area of ongoing water
penetration that had caused significant
deterioration of the plaster finishes



Fig 64:

First Floor, MS-1110 to MS115;
showing the use of gypsum plaster
over the earlier lime plaster. The
masonry was saturated and the plaster
had largely debonded in this area



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Fig 65:

First Floor, MS-116; showing an area of debonded lime plaster



Fig 66:

First Floor, MS-115; showing lath and lime plaster linings to the internal partition. The lath and plaster was damp and partially decayed where abutting the external wall



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Fig 67:

First Floor, MS-117; showing non-original timber boxing and panelling that concealed earlier lime plaster with a softwood skirting



Fig 68:

First Floor, MS-117; showing the earlier lime plaster and skirting board as viewed through the boxing



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Fig 69:

First Floor, MS-117; showing a small opening through the ceiling to determine construction



Fig 70:

First Floor, MS-117; showing non-original plasterboard supported on softwood battens fixed to the underside to the millboards. Note the earlier wallpaper to the underside of the millboards



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Fig 71:

First Floor, MS-118; showing lath and lime plaster finish to the stud partition. There was no significant damp or decay in this area



Fig 72:

First Floor, MS-118; showing the area of ongoing water penetration. The lime plaster had deteriorated and the lath and plaster partition was damp and partially decayed where abutting the external wall



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Fig 73:

First Floor, MS-118; showing a close-up of the lath and plaster applied to the partition. The lath and plaster was generally free from significant defect



Fig 74:

First Floor, Goods lift; showing lime plaster applied to the brickwork. The lime plaster had debonded in areas of ongoing water penetration



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Fig 75:

Upper Ground Floor, MS-UG04;
showing non-original fibreboard boxing
with skirting board below window sills.
The upper walls were plastered with
lime



Fig 76:

Upper Ground Floor, MS-UG04;
showing a close-up of the non-original
fibreboard boxing at low-level



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Fig 77:

Upper Ground Floor, MS-UG08;
showing a close-up of the lath and
plaster to a window reveal concealed
by wood-chip wallpaper



Fig 78:

Upper Ground Floor, MS-UG09;
showing plasterboard dry lining
concealing windows MS-UGW15 and
MS-UGW16



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Fig 79:

Upper Ground Floor, MS-UG12;
showing non-original fibreboard boxing
with skirting board below window sills.
The upper walls were plastered with
lime. Note that the window reveals
were panelled with softwood timber

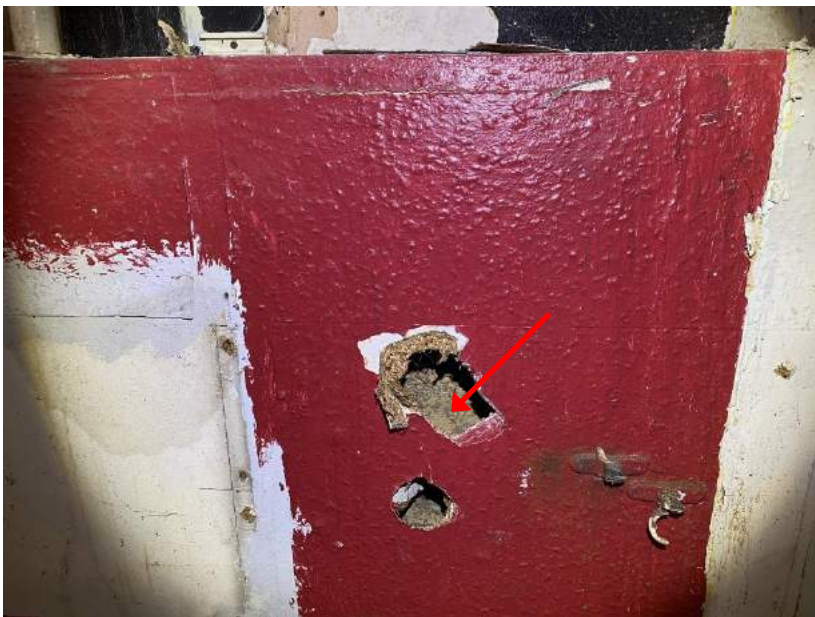


Fig 80:

Upper Ground Floor, MS-UG12;
showing a close-up of plaster visible
through an opening in the non-original
chipboard boxing



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Fig 81:

Upper Ground Floor; showing lime plaster applied to the non-original internal wall around the southern stairwell. Plaster here was generally in fair condition



Fig 82:

Upper Ground Floor; showing a general view of the area subject to water penetration at the centre of the south-west elevation. There were no retained original plaster finishes to this wall



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Fig 83:

Upper Ground Floor, MS-UG21;
showing non-original plasterboard
boxing at low-level. The wall behind
was plastered with lime



Fig 84:

Upper Ground Floor, MS-UG21;
showing lime plaster visible within the
plasterboard boxing. The plaster had
debonded from the brick substrate in
this location



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Fig 85:

Upper Ground Floor, MS-UG01;
showing lath and plaster to the partition
of the northern stairwell. A terrazzo
effect finish (possibly from the 1980's)
had been applied over a plaster skim



Fig 86:

Upper Ground Floor, MS-UG01;
showing a close up of the lath and
plaster visible behind the terrazzo
effect wall finish



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Fig 87:

Upper Ground Floor, MS-UG23; showing remnants of early wallpapered lath and plaster to the small store room. The plaster was largely mechanically damaged and partially decayed where abutting the external wall

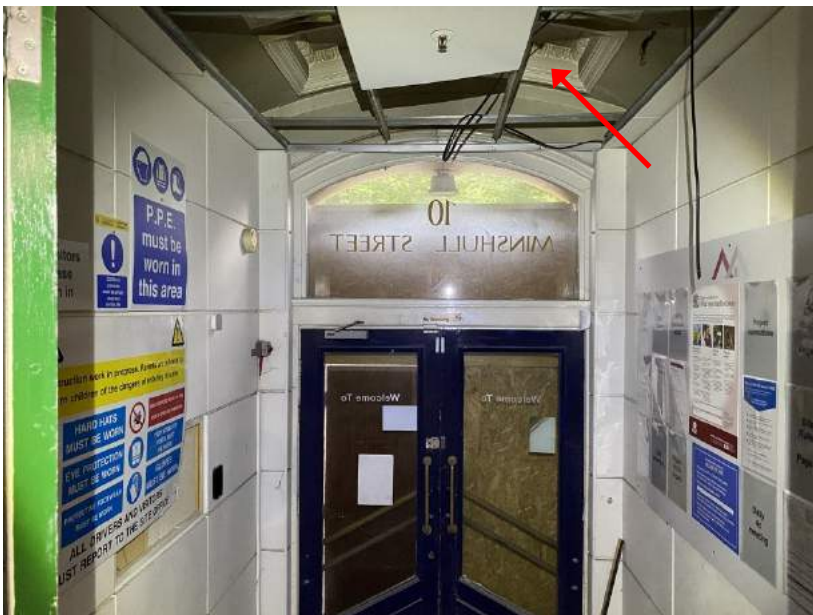


Fig 88:

Upper Ground Floor, Entrance lobby; showing an early/original ornamental barrel ceiling that appeared to be in good condition. The stud partitions either side of the lobby were lined with lath and plaster. However, non-original wall finishes concealed the lath and plaster



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Fig 89:

Upper Ground Floor, Entrance lobby;
showing lath and plaster visible behind
the numerous non-original wall finishes



Fig 90:

Upper Ground Floor, Goods lift;
showing a general view of the retained
non-original finishes that largely
conceal the lime plaster finishes of the
goods lift. A small partition of lath and
plaster also remained to the rear of the
goods lift (arrowed)



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Fig 91:

Upper Ground Floor, Goods lift;
showing the south west wall of the
goods lift. The lime plaster finishes
were largely damp and had debonded
from the brick substrate

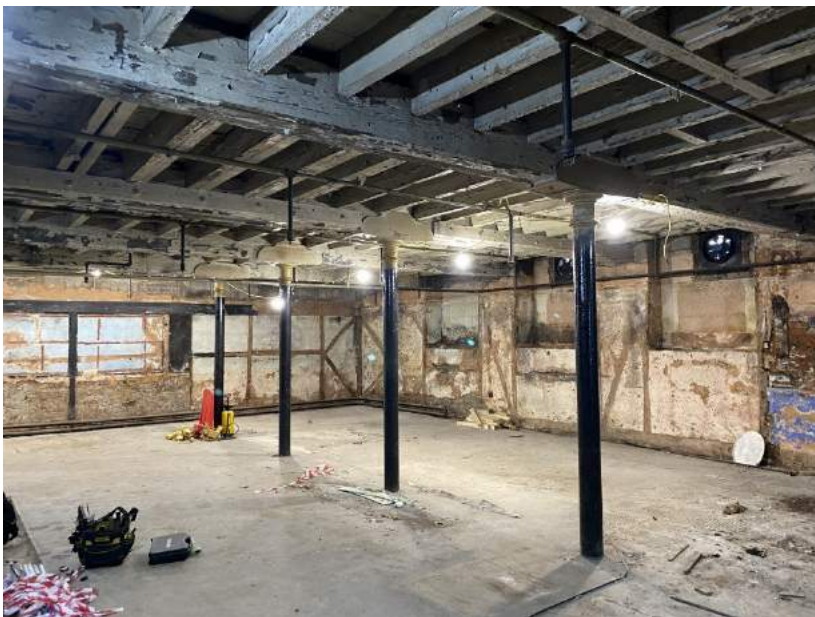


Fig 92:

Lower Ground Floor; showing a
general view of the external walls. As
the walls are below ground level they
are susceptible to damp and any
retained plaster had largely debonded.
The small amount of plaster that
remained was non-original



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Fig 93:

Lower Ground Floor; showing lath and plaster applied to the underside of the floor joists to the north-east bay. The addition of services had caused widespread mechanical damage to the lime plaster resulting in widespread cracking



Fig 94:

Lower Ground Floor; showing deterioration of the lime plaster and timber decay through the ceiling laths in the east corner



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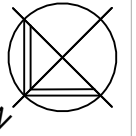
Fig 95:

Lower Ground Floor; showing an example of debonded ceiling plaster. Where visible, plaster 'keys' were in poor condition and additional areas of plaster were at risk of debonding



Mindel House, Manchester
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Attachment B



MS-402 - MS-405

Upper wall

Wall finish: Original/early lime plaster
Window soffit: Original/early lath and lime plaster

Plaster condition: Lime plaster largely debonded and generally in poor condition. Lath and plaster partially decayed in localised areas

Notes: No previous decorative finishes to brickwork behind the lime plaster

Lower wall

Wall finish: Non-original gypsum plaster to the lower 1m with non-original reversible softwood skirting board

Plaster condition: Inadequate 'key' to the brick substrate and largely debonded

Notes: Blue and white paint schemes to brickwork behind the gypsum plaster

MS-401 & MS-402

Upper wall

Wall finish: Non-original lime plaster with repairs in gypsum
Window soffit: Original/early lath and lime plaster

Plaster condition: Wet and largely debonded. Lath and plaster heavily decayed by wet rot in areas of water penetration

Notes: Blue paint scheme to brickwork behind the lime plaster

Lower wall

Wall finish: Non-original timber boxing recently removed

Notes: Blue and gold paint schemes to brickwork behind boxing

MS-414

Timber stud partitions: Modern plasterboard applied over vertical softwood t&g panelling and skirting

Timber condition: Timbers damp and partially decayed by wet rot against external wall

Internal wall

Wall finish: Gypsum plaster

Plaster condition: Generally in fair condition

Notes: This internal wall is non-original

MS-406

Wall finish: Lime plaster

Plaster condition: Wet and largely debonded

MS-412 - MS-414

Upper wall

Wall finish: Original/early lime plaster
Window soffit: Original/early lath and lime plaster

Plaster condition: Wet and largely debonded. Lath and plaster heavily decayed by wet rot in areas of water penetration

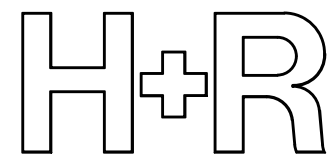
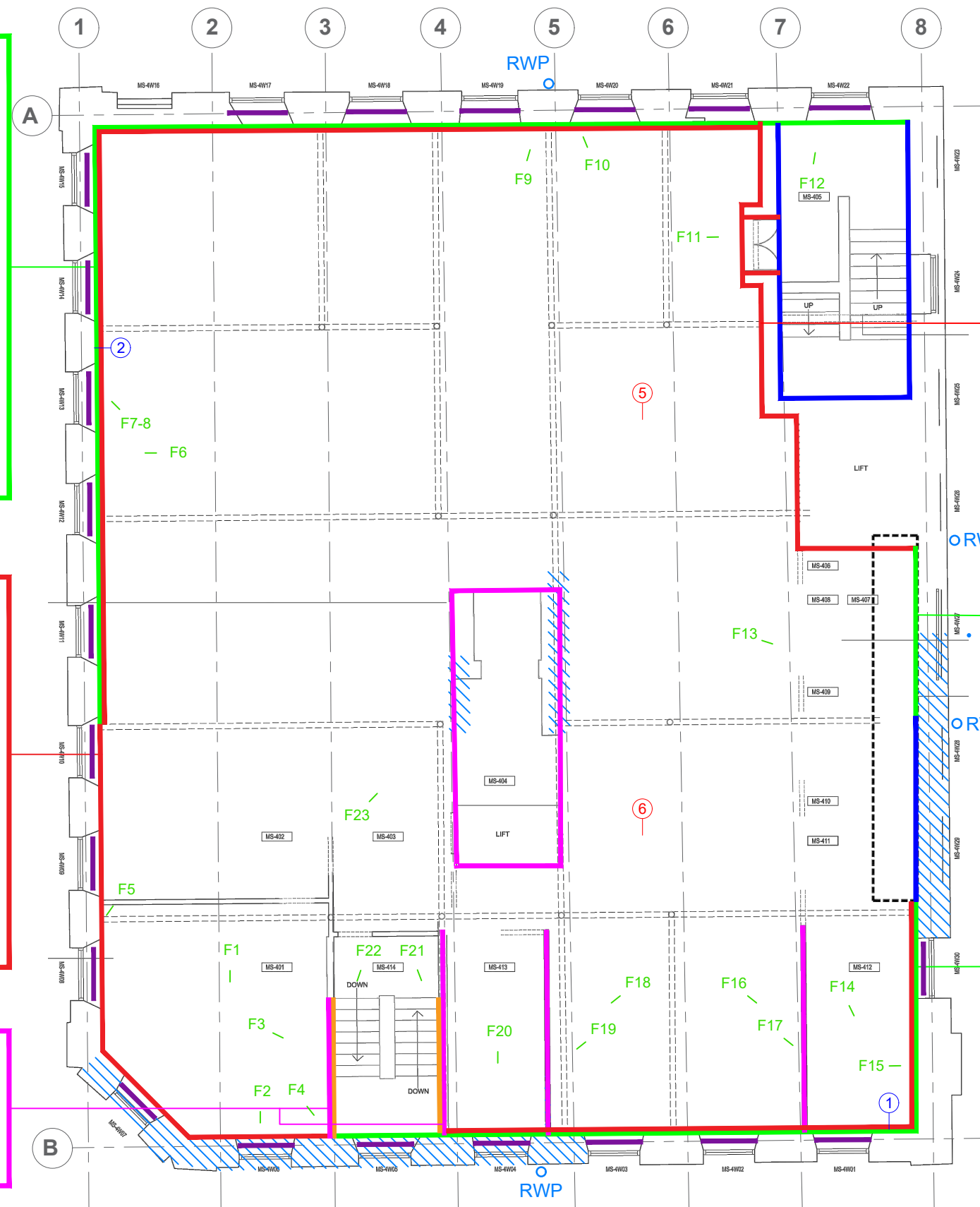
Notes: No previous decorative finishes to brickwork behind the lime plaster

Lower wall

Wall finish: Non-original gypsum plaster to the lower 1m with non-original softwood skirting board

Plaster condition: Good 'key' prepared to brick substrate and plaster generally well bonded but wet in areas of water penetration

Notes: No previous decorative finishes to brickwork behind the gypsum plaster



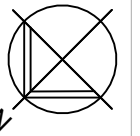
Mindel House, Manchester - Fourth Floor

Plaster condition survey
8 April 2021

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Key:

- | | | | |
|--|-----------------------------------|--|----------------------------------|
| | Area subject to water penetration | | Non-original lime/gypsum plaster |
| | Photograph location | | Timber panelling |
| | Original/early lime plaster | | Painted brick |
| | Lath and plaster | | Modern plasterboard |
| | Wall plaster sample location | | Ceiling plaster sample location |



MS-301 - MS-309

Wall finish: Original/early lime plaster with softwood skirting board
Window soffit: Original/early lath and lime plaster

Plaster condition: Lime plaster generally in fair condition with localised areas of debonding particularly at low level. Lath and plaster generally in fair condition. Plaster damp and laths heavily decayed in areas of water penetration

Skirting board condition: Generally in fair condition but partially decayed in areas of water penetration

Notes: No previous decorative finishes to brickwork behind the lime plaster

Goods lift

Wall finish: Largely original/early lime plaster as well as non-original gypsum plaster. Softwood skirting board

Plaster condition: Wet and largely debonded

Skirting board condition: Generally in fair condition but partially decayed in areas of water penetration

MS-302

Timber stud partition: Original/early lath and plaster with some use of hessian 'scrim' fibrous lime plaster. Softwood skirting board

Condition: Generally in fair condition but damp and partially decayed by wet rot against external wall

Internal wall

Wall finish: Gypsum plaster

Plaster condition: Generally in fair condition

Notes: This internal wall is non-original

MS-312 - MS-320

Upper wall

Wall finish: Original/early lime plaster
Window soffit: Original/early lath and lime plaster

Plaster condition: Generally in fair condition but wet and largely debonded in areas of water penetration. Lath and plaster heavily decayed by wet rot

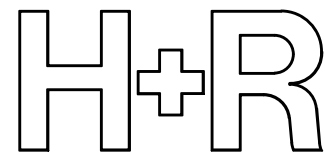
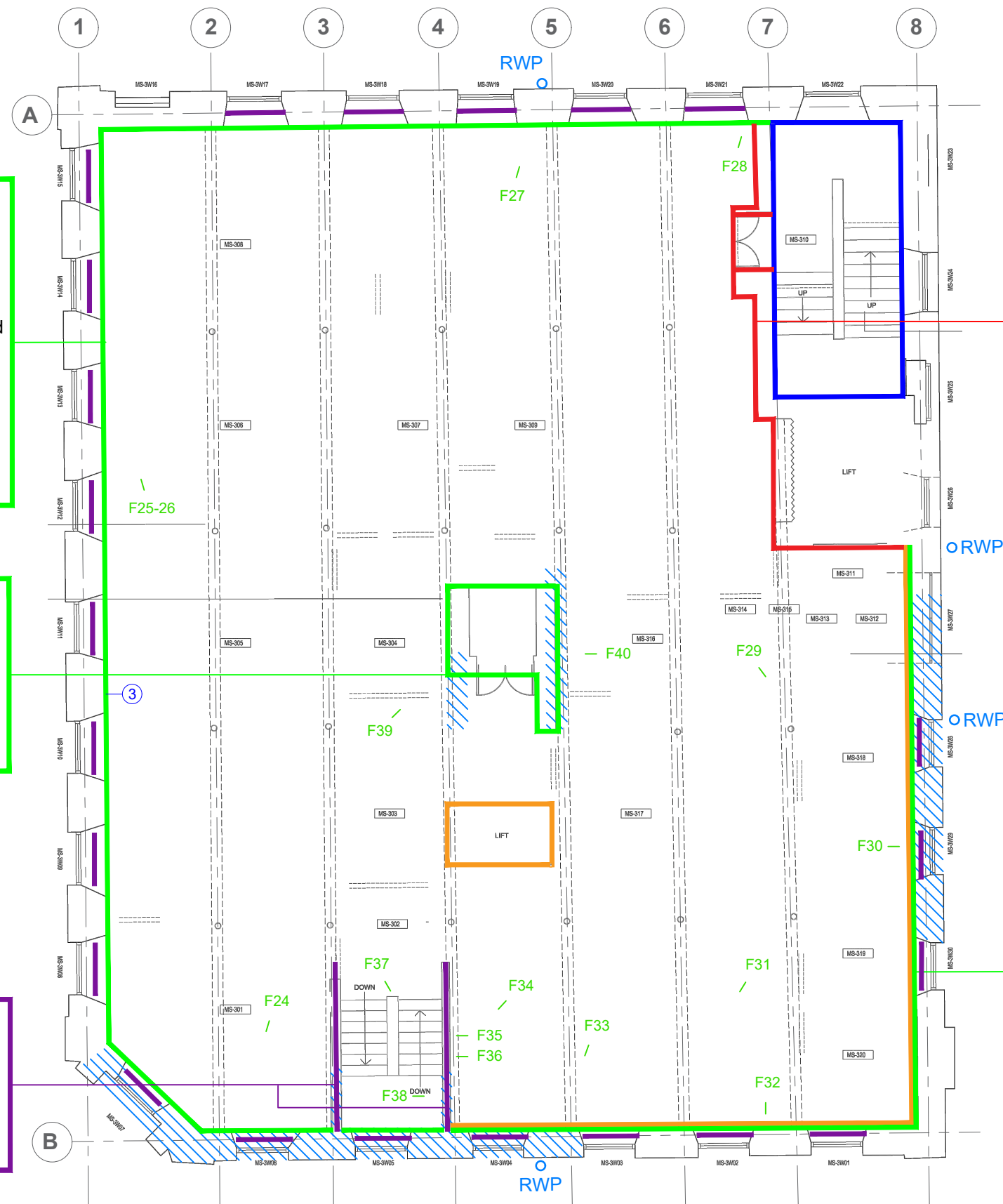
Notes: No previous decorative finishes to brickwork behind the lime plaster

Lower wall

Wall finish: Non-original vertical softwood t&g panelling. Original/early lime plaster with softwood skirting board behind

Panelling and skirting condition: Timbers generally damp and heavily decayed in areas of water penetration

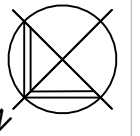
Notes: No previous decorative finishes to brickwork behind the lime plaster



Mindel House, Manchester - Third Floor
Plaster condition survey
8 April 2021

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Key:		Area subject to water penetration		Non-original lime/gypsum plaster
		Photograph location		Timber panelling
		Original/early lime plaster		Painted brick
		Lath and plaster		Modern plasterboard
		Wall plaster sample location		



MS-201 - MS-207

Wall finish: Numerous layers of wallpaper and paint on original/ early lime plaster with softwood skirting board

Plaster condition: Lime plaster generally in fair condition with localised areas of debonding

Skirting board condition: Generally in fair condition but partially decayed in areas of water penetration

Notes: No previous decorative finishes to brickwork behind the lime plaster

Goods lift

Wall finish: Largely original/early lime plaster as well as non-original gypsum plaster. Softwood skirting board

Plaster condition: Wet and largely debonded

Skirting board condition: Generally in fair condition but partially decayed in areas of water penetration

MS-205

Lower wall finish: Non-original reproduction softwood panelling with plasterboard. Original/early lime plaster behind

MS-202

Timber stud partition: Original/early lath and plaster with softwood skirting board

Condition: Generally in fair condition but damp and partially decayed by wet rot against external wall

Internal wall

Wall finish: Numerous layers of wallpaper and paint over gypsum plaster. Softwood skirting board

Plaster and skirting condition: Generally in fair condition

Notes: This internal wall is non-original

MS-216

Timber stud partition: Original/early lath and plaster

Condition: Generally in fair condition but damp and partially decayed by wet rot against external wall

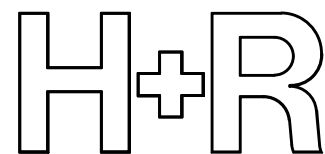
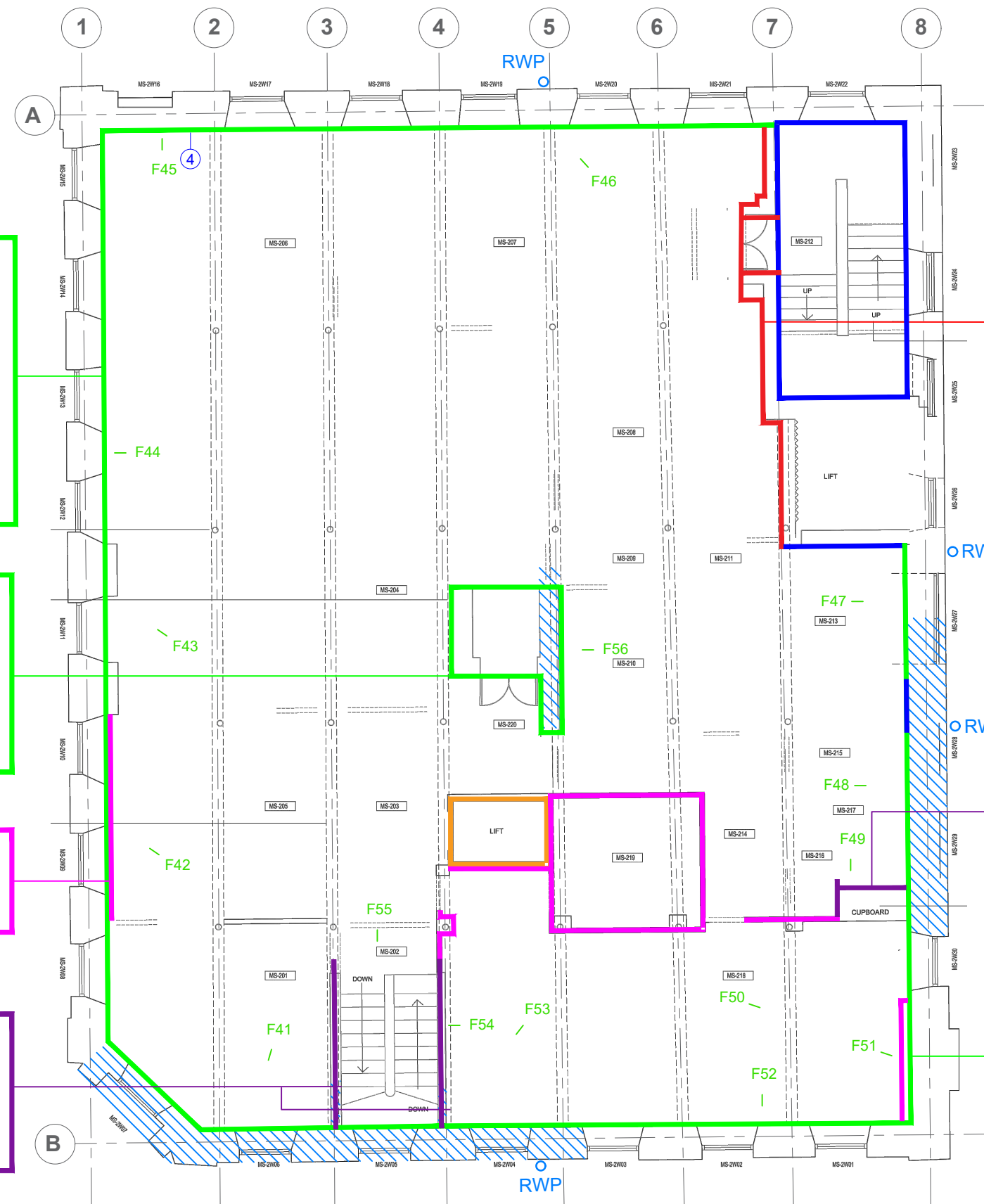
MS-213 - MS-218

Wall finish: Numerous layers of wallpaper and paint over original/early lime plaster with softwood skirting board

Plaster condition: Generally in fair condition but wet and largely debonded in areas of water penetration

Skirting board condition: Generally in fair condition but heavily decayed in areas of water penetration

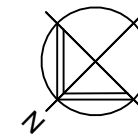
Notes: No previous decorative finishes to brickwork behind lime plaster

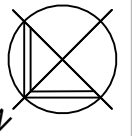


Mindel House, Manchester - Second Floor
Plaster condition survey
8 April 2021

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Key:		Area subject to water penetration		Non-original lime/gypsum plaster
		Photograph location		Timber panelling
		Original/early lime plaster		Painted brick
		Lath and plaster		Modern plasterboard
		Wall plaster sample location		





MS-UG02 - MS-UG11

Upper wall

Wall finish: Numerous layers of wallpaper and paint on original/ early lime plaster
Window reveals: Original/early lath and lime plaster or timber panelling

Plaster condition: Lime plaster generally in fair condition with localised areas of debonding. Lath and plaster partially decayed in localised areas

Lower wall

Wall finish: Modern plasterboard over non-original fibreboard dado panelling. Modern softwood skirting board

Goods lift

Wall finish: Largely original/early lime plaster as well as non-original gypsum plaster. Softwood skirting board

Plaster condition: Wet and largely debonded

Lath and plaster condition: Concealed by modern plasterboard. Probably damp and partially decayed in area of water penetration

Entrance lobby

Timber stud partition: Modern plasterboard, non-original timber paneling and terrazzo effect finish applied over original/early lath and plaster

Condition: Inaccessible. Probably in fair condition but damp and partially decayed by wet rot against external wall

Internal wall

Wall finish: Numerous layers of wallpaper and paint over lime plaster. Softwood skirting board

Plaster condition: Generally in fair condition

Notes: This internal wall is non-original

MS-UG14 - MS-UG20

Wall finish: No decorative finishes. Remnants of lime plaster and paint

Notes: Areas of non-original brickwork and blockwork

MS-UG20 - MS-UG21

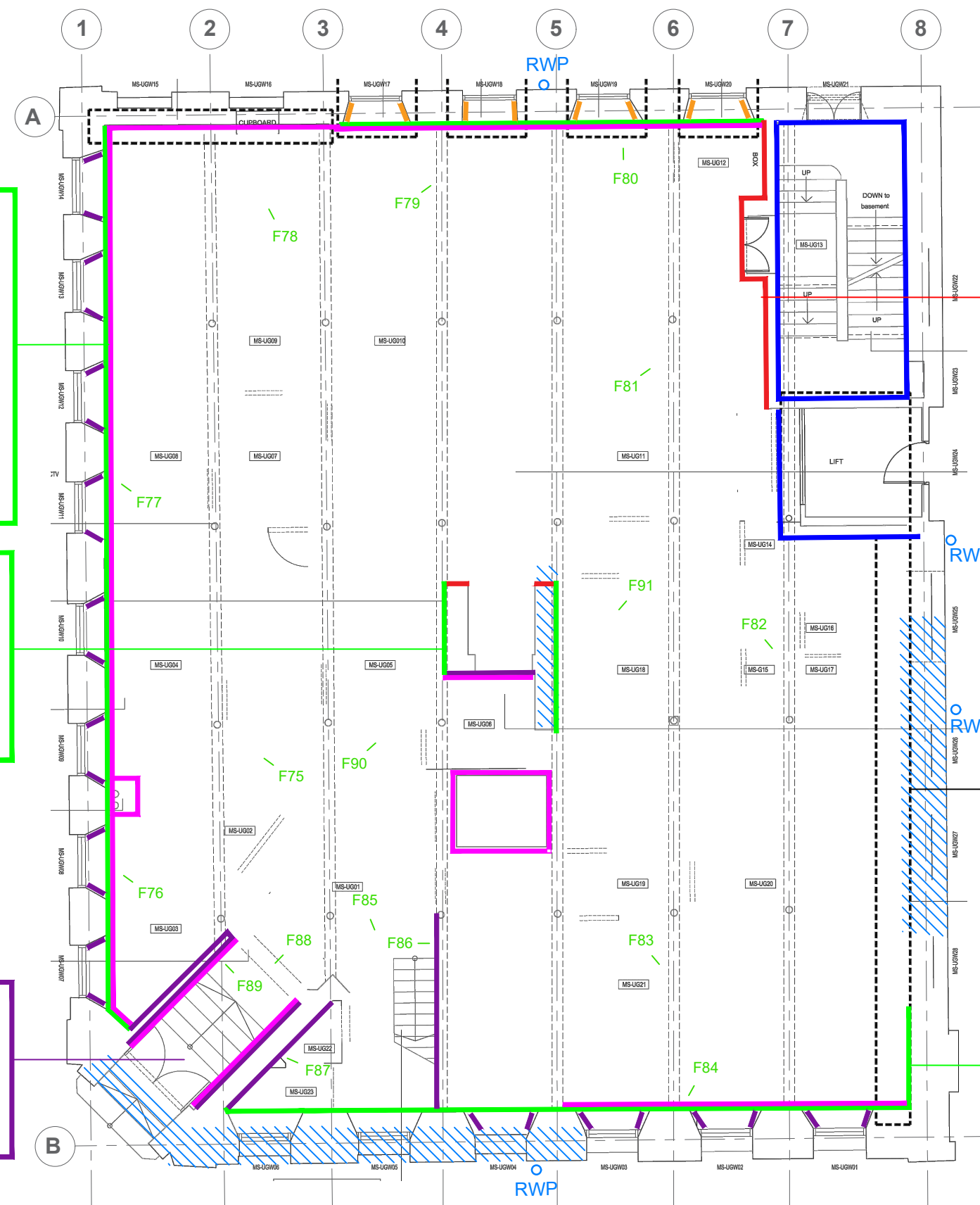
Upper wall

Wall finish: Numerous layers of wallpaper and paint on original/ early lime plaster
Window reveals: Original/early lath and lime plaster

Lime plaster condition: Generally in fair condition but wet and largely debonded in areas of water penetration

Lower wall

Wall finish: Modern plasterboard panelling with non-original softwood skirting board. Original/early lime plaster behind



Key:



Area subject to water penetration



Photograph location



Original/early lime plaster



Lath and plaster



Non-original lime/gypsum plaster



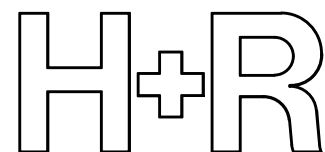
Timber panelling



Painted brick

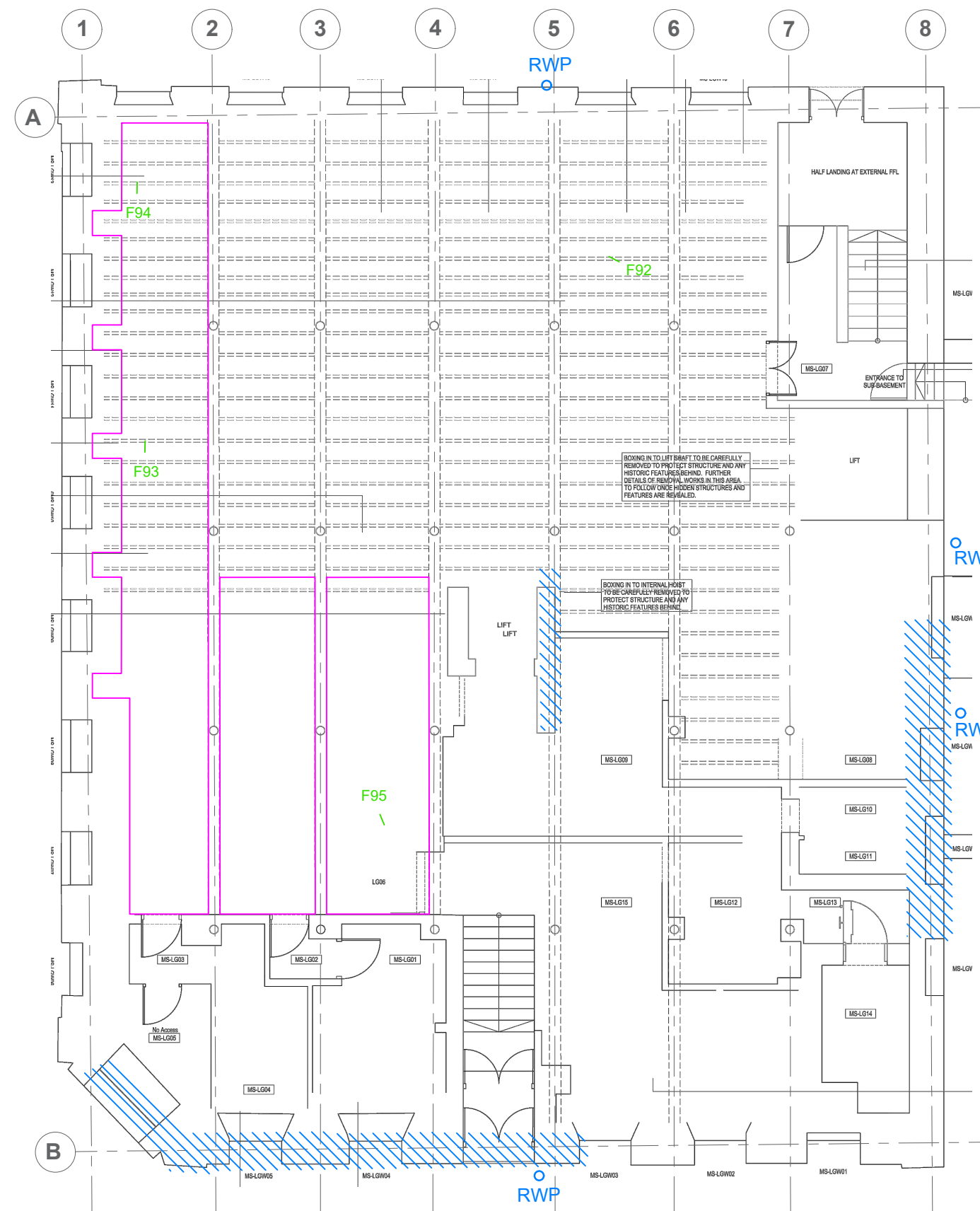


Modern plasterboard



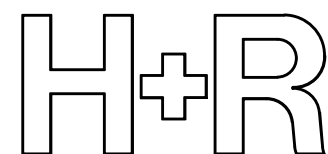
Mindel House, Manchester - Upper Ground Floor

Plaster condition survey
27 July 2021



Key:

- //// Area subject to water penetration
- F1 Photograph location
- Lath and plaster ceiling



Mindel House, Manchester - Lower Ground Floor
 Plaster condition survey
 27 July 2021

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Attachment C



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Report - 70096/K

REPORT ON THE PETROGRAPHIC EXAMINATION OF SIX PLASTER SAMPLES (Site: Mindel House, Manchester)



Hutton & Rostron Environmental Investigation
The Manor House
Mottram in Longdendale
Greater Manchester
SK14 6JD

This report comprises
7 pages of text
Appendix A – 7 pages
Appendix B – 24 pages / photographs
Appendix C – 18 pages / photomicrographs
Appendix D – 5 pages

For the attention of Mr Chris Whitfield

9 August 2021

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Report - 70096/K

REPORT ON THE PETROGRAPHIC EXAMINATION OF SIX PLASTER SAMPLES (Site: Mindel House, Manchester)

1 INTRODUCTION

Six plaster samples were provided on the 4 June 2021. It was requested that samples be examined petrographically. The samples were advised to be from a later 19th Century warehouse building in Central Manchester known as Mindel House. Written instructions to proceed with the analysis were provided with the samples in a letter from Mr Chris Whitfield of Hutton & Rostron Environmental Investigation.

2 SAMPLES

The following samples were provided for analysis:

Laboratory reference	Client / site reference	Approximate dimensions, mm
K16595/1	Sample 1	82-90 / 33-47 / 14-17
K16595/2	Sample 2	60-92 / 45-55 / 15-20
K16595/3	Sample 3	35-52 / 55-65 / 14-21
K16595/4	Sample 4	44-58 / 55-60 / 15-18
K16595/5	Sample 5	18-35 / 5-30 / 30-77
K16595/6	Sample 6	39-60 / 34-61 / 16-25

3 TEST METHODS

The petrographic testing was carried out in accordance with BS 1881-211¹. A summary of the procedures followed and a glossary of terms used in the description of the samples are given in Appendix D. In brief, the following work was carried out:

- (i) The samples were examined as received and photographed.
- (ii) Two fluorescent resin impregnated thin sections were prepared from each sample, each representing the full depth of the plaster layers. Each thin section measured about 40x30mm.
- (iii) The thin sections were examined with a Zeiss petrological photomicroscope and the distribution of porosity and microcracking was assessed from an examination of the thin section in fluorescent light using the petrological microscope.
- (iv) The volume proportions of aggregate matrix and void in the base coat plaster in each sample were determined by point counting of the thin sections using the petrological microscope and the measured volume proportions were used to make estimates of the compositions of the base coat plaster using the method given in BS 1881-211.

4 PETROGRAPHIC EXAMINATION RESULTS

4.1 Visual description of the samples

The samples as received are illustrated in Appendix B. Visual descriptions of the samples as received are given in Tables A1 and A2 in Appendix A.

4.2 Petrographic description of the aggregate in the base coat plaster

A full petrographic description of the aggregate in the base coat plaster in each sample is given in Tables A3 and A4 in Appendix A.

4.3 Petrographic description of the matrix of the base coat plaster

A full petrographic description of the matrix of the base coat plaster in each sample is given in Tables A5 and A6 in Appendix A and photomicrographs illustrating the mortar in the thin sections are given in Appendix C.

4.4 Volume proportions of sand and matrix in the mortar

The measured volume proportions of aggregate, matrix and void in the base coat plaster of each sample are given in Table A7 in Appendix A.

¹ BS 1881-211:2016 Testing concrete. Procedure and terminology for the petrographic examination of hardened concrete

5 SUMMARY AND DISCUSSION

5.1 Surface gypsum-based plaster layers

All samples include surface layers of gypsum plaster and there appears to be two types of gypsum plaster. The majority of the gypsum-based plaster is very light pinkish grey and consists of an abundant gypsum matrix that contains small amounts of lime. The outer of the two gypsum-based plaster layers in Sample 1 differs from that in the other samples in that it is pink in colour and lacks lime.

The following table summarises the principal petrographic characteristics of the surface gypsum-based plaster layers in each sample.

Client / site reference	Surface plaster layer / Thickness	Plaster type / colour
Sample 1	Outermost surface plaster layer / 0.8-0.7mm	Gypsum based / medium pink
Sample 1	Innermost surface plaster layer / 1.1-1.4mm	Gypsum-based with minor lime / Very light grey
Sample 2	1.6-2.9mm	Gypsum-based with minor lime / Very light grey
Sample 3	2.3-3.6mm	Gypsum-based with minor lime / Very light grey
Sample 4	0.6-0.9mm	Gypsum-based with minor lime / Very light grey
Sample 5	3.2-5.2mm	Gypsum-based with minor lime / Very light grey
Sample 6	2.7-4.7mm	Gypsum-based with minor lime / Very light grey

In all samples, the plaster remains attached to the base-coat plaster.

5.2 Base-coat plaster

(i) Principal characteristics of the base coat plaster

All samples include a lime-based base coat plaster layer that accounts for the majority of the thickness of the samples. The base coat plaster is reinforced with animal hairs and contains an aggregate that consists of a blend of abundant fine quartz sand with lesser amounts of ash, slag and coal fragments.

The base coat plaster in Samples 5 and 6 differs from that in the other samples in the following respects:

- The amounts of ash are much smaller than in the other samples
- Undispersed lime fragments are more abundant in the base coat in Samples 5 and 6 compared to the other samples
- The binder contents of the base coat in Samples 5 and 6 are higher than in the other samples
- The inner surfaces of Samples 5 and 6 have the impressions of wooden laths

(ii) Aggregate characteristics in the base coat plaster

The aggregate in all samples is dominated by siliceous polymictic sand that is blended with smaller amounts of ash / slag and coal. The aggregate compositions are as follows:

Client / site reference	Aggregate composition, vol. %		
	<i>Sand</i>	<i>Ash / Slag</i>	<i>Coal</i>
Sample 1	84.4	11.0	4.6
Sample 2	85.5	11.8	2.7
Sample 3	84.0	12.8	3.1
Sample 4	82.3	11.9	5.8
Sample 5	95.6	0.9	3.5
Sample 6	93.2	1.5	5.3

(iii) Binder type in the base coat plaster

The binder throughout the base coat plaster layers in all samples contains lime. The occasional presence of traces of hydrated and carbonated calcium silicate particles in the matrix of the base coat plaster indicates that it may be a feebly hydraulic lime.

(iv) General matrix characteristics in the base coat plaster

The lime matrix in the base coat of all samples is fully carbonated and has the typical high microporosity that is characteristic of lime-based plasters and mortars. The lime binder in all samples is incompletely dispersed and the measured quantities of undispersed lime are as follows:

Client / site reference	Undispersed lime fragments, volume % of matrix
Sample 1	7.7
Sample 2	5.5
Sample 3	1.9
Sample 4	2.8
Sample 5	11.4
Sample 6	8.1

The quantities of undispersed lime in Samples 5 and 6 is high and is possibly indicative of the lime being hot-mixed² with the aggregate.

In Sample 3, the matrix contains moderate quantities of very fine gypsum fragments indicating that it is probable that the binder included calcium sulfate / hemi-hydrate. In Sample 2, the possible presence of minor amounts of calcium sulfate / hemi-hydrate in the binder is indicated by the rare occurrence of gypsum in voids.

Calcium sulfate / gypsum is sometimes added to lime plaster to accelerate setting times. Chemical analysis for acid-soluble sulfate and calcium would be required in order to quantify the proportions of lime and calcium sulfate in the base coat plaster.

² Hot mixing refers to mixing un-slaked lime with damp aggregate, an exothermic process that evolves heat as the lime hydrates (slakes).

(v) Hair reinforcement in the base coat plaster

Hair reinforcement is present in the base coat plaster in all samples. Much of the hair resembles horse hair with distinctive hollow brown fibres that are of the order of 30-50µm in diameter. There are also some transparent / colourless hollow fibres that could not be identified. The fibres are unevenly distributed and frequently concentrated in irregular bundles of fibres.

(vi) Composition of the base coat plaster

The compositions of the base coat plaster have been determined petrographically using a method based on that given in BS 1881-211, 2016 and the results are as follows:

Client / site reference	Estimated volume ratio of binder to aggregate in the base coat plaster ^{Note 1}	Evidence for the presence of gypsum in the base coat plaster
Sample 1	1 : 1.5	None seen
Sample 2	1 : 1.9	Traces of gypsum seen in voids ^{Note 2}
Sample 3	1 : 0.9	Moderate amounts of gypsum fragments seen throughout the matrix. ^{Note 3}
Sample 4	1 : 1.8	None seen
Sample 5	1 : 0.7	None seen
Sample 6	1 : 0.7	None seen

Note 1: The compositions are calculated on the basis that the binder is composed entirely of lime using the assumed densities and water/binder ratios listed in Table A7 in Appendix A. These compositions make no allowance for the possible presence of gypsum in some of the samples. Chemical analysis for acid-soluble sulfate and calcium content would be required in order to quantify the proportions of gypsum and lime.

Note 2: The presence of occasional gypsum crystals in the voids indicates that it is possible that binder may include small amounts of gypsum.

Note 3: The matrix contains moderate amounts of gypsum fragments indicating the presence of gypsum.

6 SUMMARY

The results of the petrographic examination of the samples are summarised in the following table:

Client / site reference	Surface gypsum plaster layers	Base coat plaster				
		<i>Siliceous sand, vol. %</i>	<i>Ash & slag, vol. %</i>	<i>Coal, vol. %</i>	<i>Binder type</i>	<i>Binder: Aggregate ratio by volume</i> Note 1
Sample 1	2 layers of gypsum plaster	84.4	11.0	4.6	Lime	1 : 1.5
Sample 2	1 layer of gypsum plaster	85.5	11.8	2.7	Lime ^{Note 2}	1 : 1.9
Sample 3	1 layer of gypsum plaster	84.0	12.8	3.1	Lime / gypsum Note 3	1 : 0.9
Sample 4	1 layer of gypsum plaster	82.3	11.9	5.8	Lime	1 : 1.8
Sample 5	1 layer of gypsum plaster	95.6	0.9	3.5	Lime	1 : 0.7
Sample 6	1 layer of gypsum plaster	93.2	1.5	5.3	Lime	1 : 0.7

Note 1: Compositions calculated on the basis that the binder consists entirely of lime. There are some indications of the presence of gypsum in the matrix in Sample 3 and to a lesser extent, Sample 2. Chemical analysis for acid-soluble sulfate and calcium content would be required in order to quantify the proportions of gypsum and lime.

Note 2: The possible presence of minor gypsum in the binder is indicated by the rare occurrence of gypsum in voids.

Note 3: The presence of gypsum in the binder is indicated by the presence of moderate quantities of gypsum fragments in the matrix.



7 REMARKS

The above concludes the requested programme of testing. Please do not hesitate to contact us if we can be of any further assistance in this matter.

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for GEOMATERIALS RESEARCH SERVICES
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Partner

For the attention of Mr Chris Whitfield

9 August 2021

Samples can only be retained for a period of two months from the date of issue of the report unless we are instructed otherwise. Samples can be returned or retained for a further charge.
Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.

APPENDIX A – PETROGRAPHIC DESCRIPTION OF THE SAMPLE

PETROGRAPHIC EXAMINATION OF PLASTER
BS 1881-211, 2016

TABLE A1 OF 7: VISUAL DESCRIPTION OF THE SAMPLES

Laboratory ref.	K16595/1	K16595/2	K16595/3
Sample ref.	Sample 1	Sample 2	Sample 3
Dimensions, mm	82-90 / 33-47 / 14-17	60-92 / 45-55 / 15-20	35-52 / 55-65 / 14-21
Surface layers	Outer gypsum plaster layer 0.8-0.7mm thickness. Inner gypsum plaster with lime inclusions 1.1-1.4mm. The surfaces of both plaster layers are painted.	One layer of gypsum plaster layer 1.6-2.9mm thickness. The surface of the plaster is painted.	One layer of gypsum plaster layer 2.3-3.6mm thickness. The surface of the plaster is painted.
Thickness of base plaster layer	Up to 15mm. There are some indications of a layer boundary within the base coat plaster in some areas.	Up to 20mm. There are some indications of a layer boundary within the base coat plaster in some areas.	Up to 21mm. No indications of internal layer boundaries
Inner surface	Uneven surface	Uneven surface	Uneven surface
Plaster types	The base plaster layer is lime based. The much thinner surface plaster layers are gypsum-based. The inner of the two gypsum-based plaster layers contains lime.	The base plaster layer is lime based. The much thinner surface plaster layer is gypsum-based and contains traces of lime.	The base plaster layer is based on a blend of abundant lime with smaller amounts of gypsum. The much thinner surface plaster layer is gypsum-based and contains traces of lime.
Colour	<u>Gypsum based surface layers:</u> The outer layer is pink and the inner layer is pinkish white. <u>Base plaster layer:</u> Medium greyish brown.	<u>Gypsum based surface layer:</u> Light pink. <u>Base plaster layer:</u> Medium greyish brown.	<u>Gypsum based surface layer:</u> Light pink. <u>Base plaster layer:</u> Medium greyish brown.
Fibre reinforcement	Animal hairs are visible protruding from the broken surfaces of the base plaster layer. The hairs are unevenly distributed and sometimes concentrated in bundles of fibres.	Animal hairs are visible protruding from the broken surfaces of the base plaster layer. The hairs are unevenly distributed and sometimes concentrated in bundles of fibres.	Animal hairs are visible protruding from the broken surfaces of the base plaster layer. The hairs are unevenly distributed and sometimes concentrated in bundles of fibres.
Visible signs of deterioration	None seen	None seen	None seen

APPENDIX A – PETROGRAPHIC DESCRIPTION OF THE SAMPLE

PETROGRAPHIC EXAMINATION OF PLASTER

BS 1881-211, 2016

TABLE A2 OF 7: VISUAL DESCRIPTION OF THE SAMPLES

Laboratory ref.	K16595/4	K16595/5	K16595/6
Sample ref.	Sample 4	Sample 5	Sample 6
Dimensions, mm	44-58 / 55-60 / 15-18	18-35 / 5-30 / 30-77	39-60 / 34-61 / 16-25
Surface layers	One layer of gypsum plaster layer 0.6-0.9mm thickness. The surface of the plaster is painted.	One layer of gypsum plaster layer 3.2-5.2mm thickness. The surface of the plaster is painted.	One layer of gypsum plaster layer 2.7-4.7mm thickness. The surface of the plaster is painted.
Thickness of base plaster layer	Up to 21mm. No indications of internal layer boundaries	Up to 30mm. No indications of internal layer boundaries	Up to 25mm. No indications of internal layer boundaries
Inner surface	Uneven surface	Uneven surface with lath impressions	Uneven surface with lath impressions
Plaster types	The base plaster layer is lime based. The much thinner surface plaster layer is gypsum-based and contains traces of lime.	The base plaster layer is lime based. The much thinner surface plaster layer is gypsum-based and contains traces of lime.	The base plaster layer is lime based. The much thinner surface plaster layer is gypsum-based and contains traces of lime.
Colour	Gypsum based surface layer: Light pink. Base plaster layer: Medium greyish brown.	Gypsum based surface layer: Light pink. Base plaster layer: Light greyish brown.	Gypsum based surface layer: Light pink. Base plaster layer: Light greyish brown.
Fibre reinforcement	Animal hairs are visible protruding from the broken surfaces of the base plaster layer. The hairs are unevenly distributed and sometimes concentrated in bundles of fibres.	Animal hairs are visible protruding from the broken surfaces of the base plaster layer. The hairs are unevenly distributed and sometimes concentrated in bundles of fibres.	Animal hairs are visible protruding from the broken surfaces of the base plaster layer. The hairs are unevenly distributed and sometimes concentrated in bundles of fibres.
Visible signs of deterioration	None seen	None seen	None seen

PETROGRAPHIC EXAMINATION OF PLASTER
BS 1881-211, 2016

TABLE A3 OF 7: PETROGRAPHIC DESCRIPTION OF THE SAND IN THE BASE COAT PLASTER

Laboratory ref.	K16595/1	K16595/2	K16595/3
Sample ref.	Sample 1	Sample 2	Sample 3
Base coat plaster aggregate			
Grading (estimated BS EN 13139 grading classification)	Fine 0/1 (FP)	Fine 0/1 (FP)	Fine 0/1 (FP)
Typical size (mm)	0.05-0.50	0.05-0.50	0.05-0.50
Typical shape	Subangular to subrounded	Subangular to subrounded	Subangular to subrounded
Grain coatings	Traces of brown clay deposits occur on the surfaces of the sand particles.	Traces of brown clay deposits occur on the surfaces of the sand particles.	Traces of brown clay deposits occur on the surfaces of the sand particles.
Major aggregate materials	Quartz, Quartzite	Quartz, Quartzite	Quartz, Quartzite
Minor aggregate materials	Chert, Carbonaceous ash, Glassy ash, Coal, Sandstone and siltstone, Mudstone	Chert, Carbonaceous ash, Glassy ash, Coal, Sandstone and siltstone, Mudstone	Chert, Carbonaceous ash, Glassy ash, Coal, Sandstone and siltstone, Mudstone
Trace aggregate materials	Feldspar, Ironstone	Feldspar, Ironstone	Feldspar, Ironstone
Alteration of the aggregate particles	Many of the coal particles have abundant internal shrinkage cracking	Many of the coal particles have abundant internal shrinkage cracking	Many of the coal particles have abundant internal shrinkage cracking

**PETROGRAPHIC EXAMINATION OF PLASTER
BS 1881-211, 2016**

TABLE A4 OF 7: PETROGRAPHIC DESCRIPTION OF THE SAND IN THE BASE COAT PLASTER

Laboratory ref.	K16595/4	K16595/5	K16595/6
Sample ref.	Sample 4	Sample 5	Sample 6
Base coat plaster aggregate			
Grading (estimated BS EN 13139 grading classification)	Fine 0/1 (FP)	Fine 0/1 (FP)	Fine 0/1 (FP)
Typical size (mm)	0.05-0.50	0.05-0.50	0.05-0.50
Typical shape	Subangular to subrounded	Subangular to subrounded	Subangular to subrounded
Grain coatings	Traces of brown clay deposits occur on the surfaces of the sand particles.	Traces of brown clay deposits occur on the surfaces of the sand particles.	Traces of brown clay deposits occur on the surfaces of the sand particles.
Major aggregate materials	Quartz, Quartzite	Quartz, Quartzite	Quartz, Quartzite
Minor aggregate materials	Chert, Carbonaceous ash, Glassy ash, Coal, Sandstone and siltstone, Mudstone	Chert, Sandstone and siltstone, Mudstone	Chert, Sandstone and siltstone, Mudstone
Trace aggregate materials	Feldspar, Ironstone	Feldspar, Ironstone, Carbonaceous ash, Glassy ash, Coal,	Feldspar, Ironstone, Carbonaceous ash, Glassy ash, Coal,
Alteration of the aggregate particles	Many of the coal particles have abundant internal shrinkage cracking	Many of the coal particles have abundant internal shrinkage cracking	Many of the coal particles have abundant internal shrinkage cracking

PETROGRAPHIC EXAMINATION OF BRICK AND MORTAR MASONRY
BS 1881-211, 2016

TABLE A5 OF 7: PETROGRAPHIC DESCRIPTION OF THE MATRIX IN THE BASE COAT PLASTER

Laboratory ref.	K16595/1	K16595/2	K16595/3
Sample ref.	Sample 1	Sample 2	Sample 3
Binder type	Lime - resembles feebly hydraulic lime or possibly fat lime	Lime - resembles feebly hydraulic lime or possibly fat lime	Lime and gypsum. The lime resembles feebly hydraulic lime or possibly fat lime. The matrix contains moderate amounts of angular gypsum fragments, typically <0.05mm.
Calcium silicates	Rare traces of carbonated calcium silicate particles occasionally seen.	Rare traces of carbonated calcium silicate particles occasionally seen.	Rare traces of carbonated calcium silicate particles occasionally seen.
Undispersed lime lumps, vol. % of matrix	8	6	2
Carbonation	Fully carbonated with a fine-textured carbonation.	Fully carbonated with a fine-textured carbonation.	Fully carbonated with a fine-textured carbonation.
Porosity			
General level	Very high	Very high	High
Porosity distribution	Uniform	Uniform	Uniform
Microcracking level	Moderately high levels of plastic shrinkage cracking	Minor plastic shrinkage cracking	Minor plastic shrinkage cracking
Crack fillings	None seen	None seen	None seen
Void fillings	None seen	Gypsum occasionally lines the voids	None seen
Fibres	Minor amounts of animal hairs seen. Possibly 2 types of hair (brown and white). The hairs are typically <0.05mm in diameter and hollow.	Minor amounts of animal hairs seen. Possibly 2 types of hair (brown and white). The hairs are typically <0.04mm in diameter and hollow.	Traces of brown animal hairs seen. The hairs are typically <0.04mm in diameter and hollow.
Contact with the surface plaster layers	Uneven, sharply defined contact with no evidence for weakening of the contact	Uneven, sharply defined contact with no evidence for weakening of the contact	Uneven, sharply defined contact with no evidence for weakening of the contact
Description of the surface plaster layers	The inner layer is based on a blend of abundant calcium sulfate with smaller amounts of lime. The outer layer is calcium sulfate-based and contains traces of calcareous clay.	The plaster is based on a blend of abundant calcium sulfate with trace amounts of lime and traces of calcareous clay.	The plaster is based on a blend of abundant calcium sulfate with trace amounts of lime and traces of calcareous clay.

PETROGRAPHIC EXAMINATION OF BRICK AND MORTAR MASONRY
BS 1881-211, 2016

TABLE A6 OF 7: PETROGRAPHIC DESCRIPTION OF THE MATRIX IN THE BASE COAT PLASTER

Laboratory ref.	K16595/4	K16595/5	K16595/6
Sample ref.	Sample 4	Sample 5	Sample 6
Binder type	Lime - resembles feebly hydraulic lime or possibly fat lime	Lime - resembles feebly hydraulic lime or possibly fat lime	Lime - resembles feebly hydraulic lime or possibly fat lime
Calcium silicates	Rare traces of carbonated calcium silicate particles occasionally seen.	Rare traces of carbonated calcium silicate particles occasionally seen.	Rare traces of carbonated calcium silicate particles occasionally seen.
Undispersed lime lumps, vol. % of matrix	3	11	8
Carbonation	Fully carbonated with a fine-textured carbonation.	Fully carbonated with a fine-textured carbonation.	Fully carbonated with a fine-textured carbonation.
Porosity			
General level	Very high	High	High
Porosity distribution	Uniform	Uniform	Uniform
Microcracking level	Moderately high levels of plastic shrinkage cracking	Minor plastic shrinkage cracking	Minor plastic shrinkage cracking
Crack fillings	None seen	None seen	None seen
Void fillings	None seen	None seen	None seen
Fibres	Traces of brown animal hairs seen. The hairs are typically <0.04mm in diameter and hollow.	Traces of brown animal hairs seen. The hairs are typically <0.04mm in diameter and hollow.	Traces of brown animal hairs seen. The hairs are typically <0.04mm in diameter and hollow.
Contact with the surface plaster layers	Uneven, sharply defined contact with no evidence for weakening of the contact	Uneven, sharply defined contact with no evidence for weakening of the contact	Uneven, sharply defined contact with no evidence for weakening of the contact
Description of the surface plaster layers	The plaster is based on a blend of abundant calcium sulfate with trace amounts of lime and traces of calcareous clay.	The plaster is based on a blend of abundant calcium sulfate with trace amounts of lime and traces of calcareous clay.	The plaster is based on a blend of abundant calcium sulfate with trace amounts of lime and traces of calcareous clay.

**PETROGRAPHIC EXAMINATION OF BRICK AND MORTAR MASONRY
BS 1881-211, 2016**

TABLE A7 OF 7: PETROGRAPHIC MEASUREMENT OF THE COMPOSITION OF THE MORTAR

Laboratory reference	K16595/1	K16595/2	K16595/3	K16595/4	K16595/5	K16595/6
Sample reference	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Measured volume proportions:						
Matrix	40.0	29.2	48.2	32.2	52.3	52.1
Sand	50.7	46.8	38.0	48.5	35.2	36.2
Ash / Slag / Coal	9.4	6.5	5.8	7.0	0.3	0.6
Assumed w/b ratio ³	0.7	0.7	0.7	0.7	0.7	0.7
Estimated weight fractions: Note 1						
Sand	1327	1225	996	1269	921	949
Ash / Slag / Coal	112	77	70	84	4	7
Lime binder	340	249	410	274	444	443
Estimated volume ratio of binder: aggregate	1: 1.5	1: 1.9	1: 0.9	1: 1.8	1: 0.7	1: 0.7

Note 1: The composition is calculated on the basis of the following assumptions:

- Sand particle density – 2620 kg/m³
- Combined ash/slag/coal particle density – 1200 kg/m³
- Hydrated lime particle density – 2100 kg/m³
- Lime bulk density 575 kg/m³
- Sand bulk density 1675 kg/m³
- Combined ash/slag/coal bulk density – 1000 kg/m³

³ Value taken from the publication, “Hydraulic Lime Mortar for Stone, Brick and Block Masonry: A Best Practice Guide”, by Geoffrey Allen, 2003. Published by Donhead Publishing Ltd.

APPENDIX B –PHOTOGRAPHS ILLUSTRATING THE SAMPLE AS RECEIVED

Figure B1

Sample K16595/1

The sample as received, side view A:



Figure B2

Sample K16595/1

The sample as received, side view B:



Figure B3

Sample K16595/1

The sample as received, outer surface:



Figure B4

Sample K16595/1

The sample as received, inner surface:



Figure B5

Sample K16595/2

The sample as received, side view A:



Figure B6

Sample K16595/2

The sample as received, side view B:



Figure B7

Sample K16595/2

The sample as received, outer surface:



Figure B8

Sample K16595/2

The sample as received, inner surface:



Figure B9

Sample K16595/3

The sample as received, side view A:



Figure B10

Sample K16595/3

The sample as received, side view B:



Figure B11

Sample K16595/3

The sample as received, outer surface:

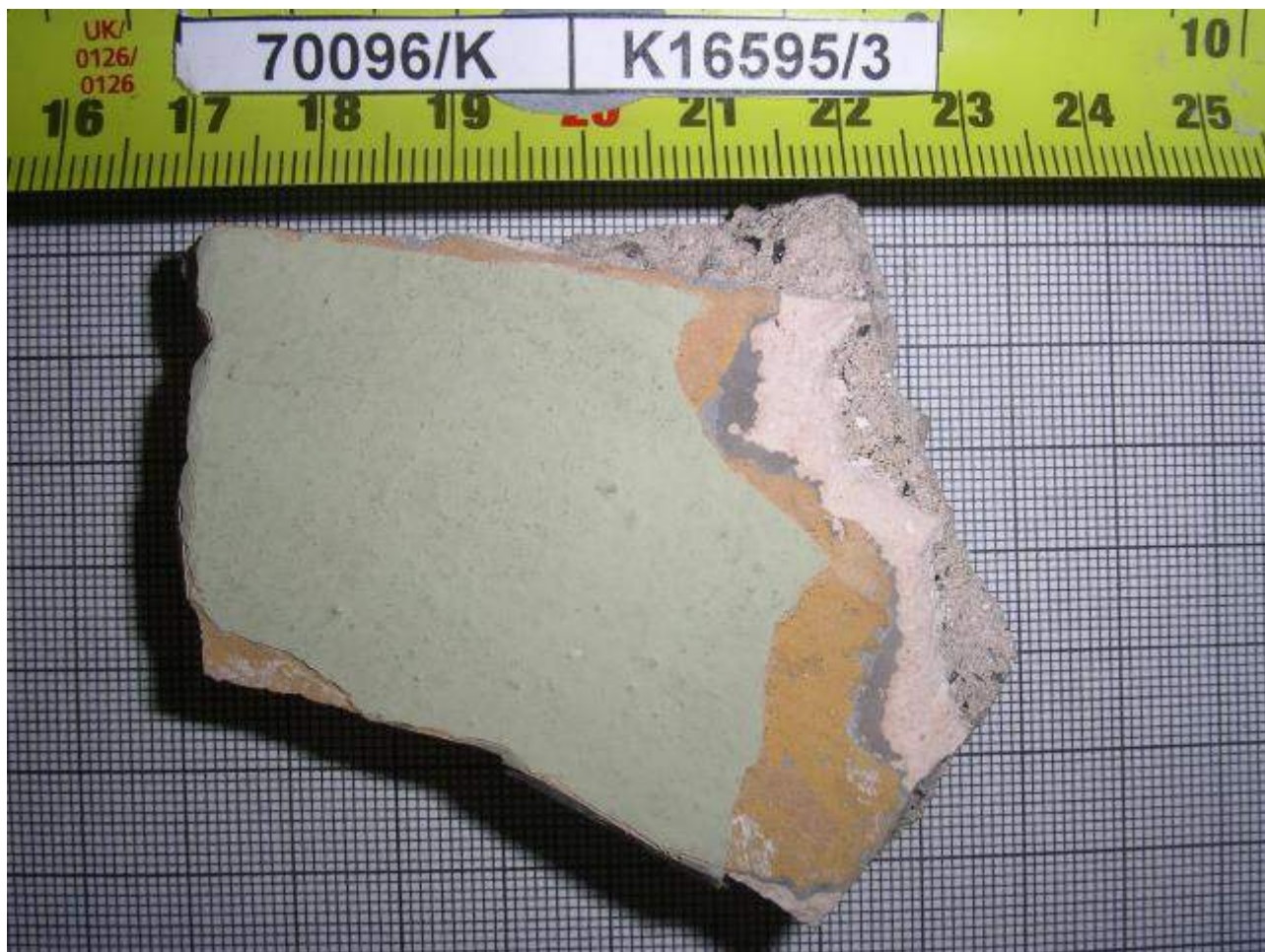


Figure B12

Sample K16595/3

The sample as received, inner surface:



Figure B13

Sample K16595/4

The sample as received, side view A:



Figure B14

Sample K16595/4

The sample as received, side view B:



Figure B15

Sample K16595/4

The sample as received, outer surface:



Figure B16

Sample K16595/4

The sample as received, inner surface:



Figure B17

Sample K16595/5

The sample as received, side view A:



Figure B18

Sample K16595/5

The sample as received, side view B:



Figure B19

Sample K16595/5

The sample as received, outer surface:



Figure B20

Sample K16595/5

The sample as received, inner surface:



Figure B21

Sample K16595/6

The sample as received, side view A:



Figure B22

Sample K16595/6

The sample as received, side view B:



Figure B23

Sample K16595/6

The sample as received, outer surface:



Figure B24

Sample K16595/6

The sample as received, inner surface:



APPENDIX C – PHOTOMICROGRAPHS ILLUSTRATING THE THIN SECTION

Figure C1

Sample K16494/1

Thin section, oblique polars: Low magnification view showing the large-scale structure of the sample. A coal fragment with abundant internal shrinkage cracking occurs in E/F4. A fragment of carbonaceous ash occurs in D2/3. Much of the field of view is occupied by quartz sand particles that appear various shades of grey surrounded by small amounts of carbonated lime matrix. Abundant voids infilled with the green fluorescent resin used during the preparation of the thin section are visible throughout the field of view for example around H5 and B/C5.

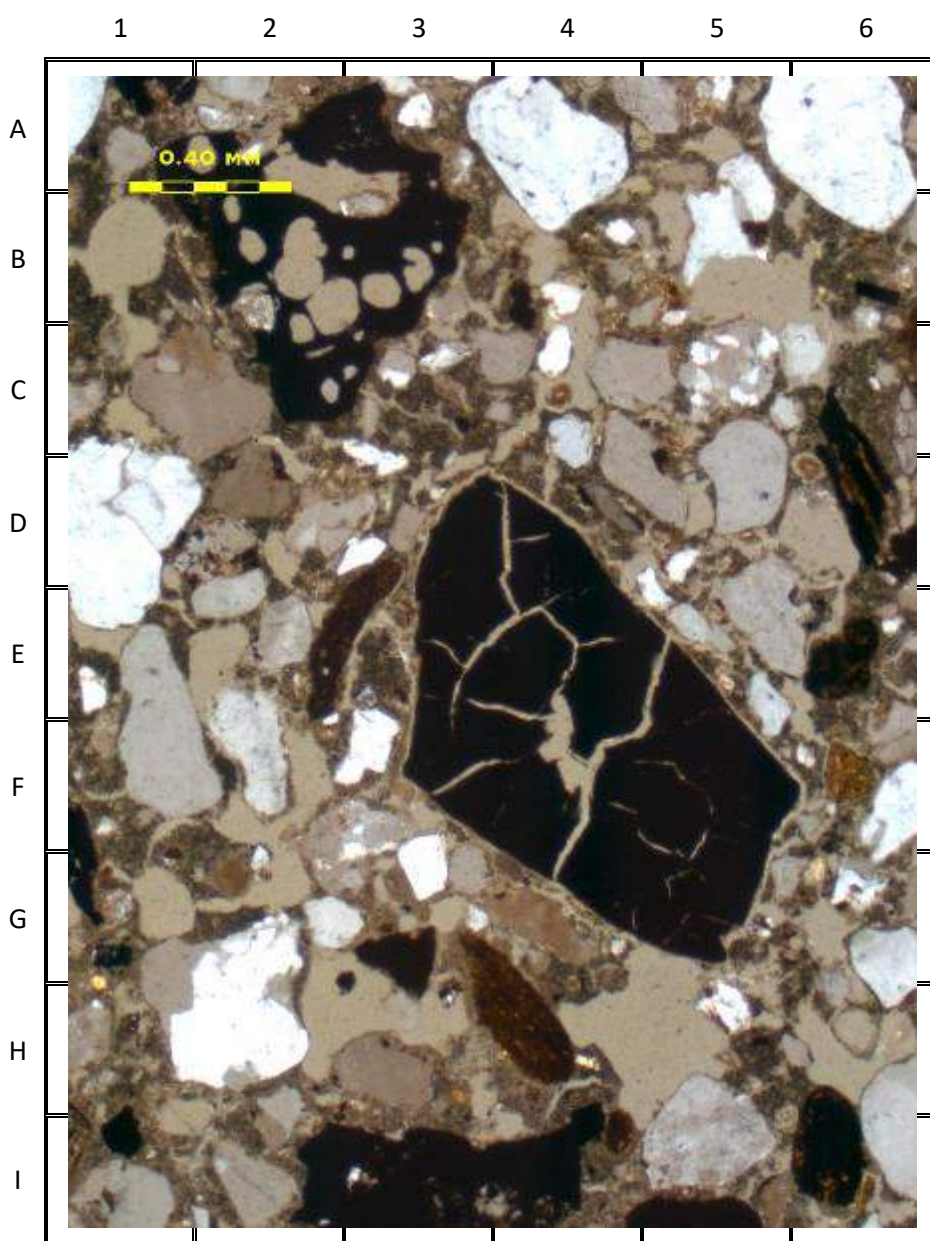


Figure C2

Sample K16494/1

Thin section, oblique polars: A fragment of undispersed lime is centred around C/D1. Particles of ash occur in A3 and A6. Areas of carbonated lime matrix are visible for example in I3 and E/F4 and a quartz sand particle can be seen in G/H4.

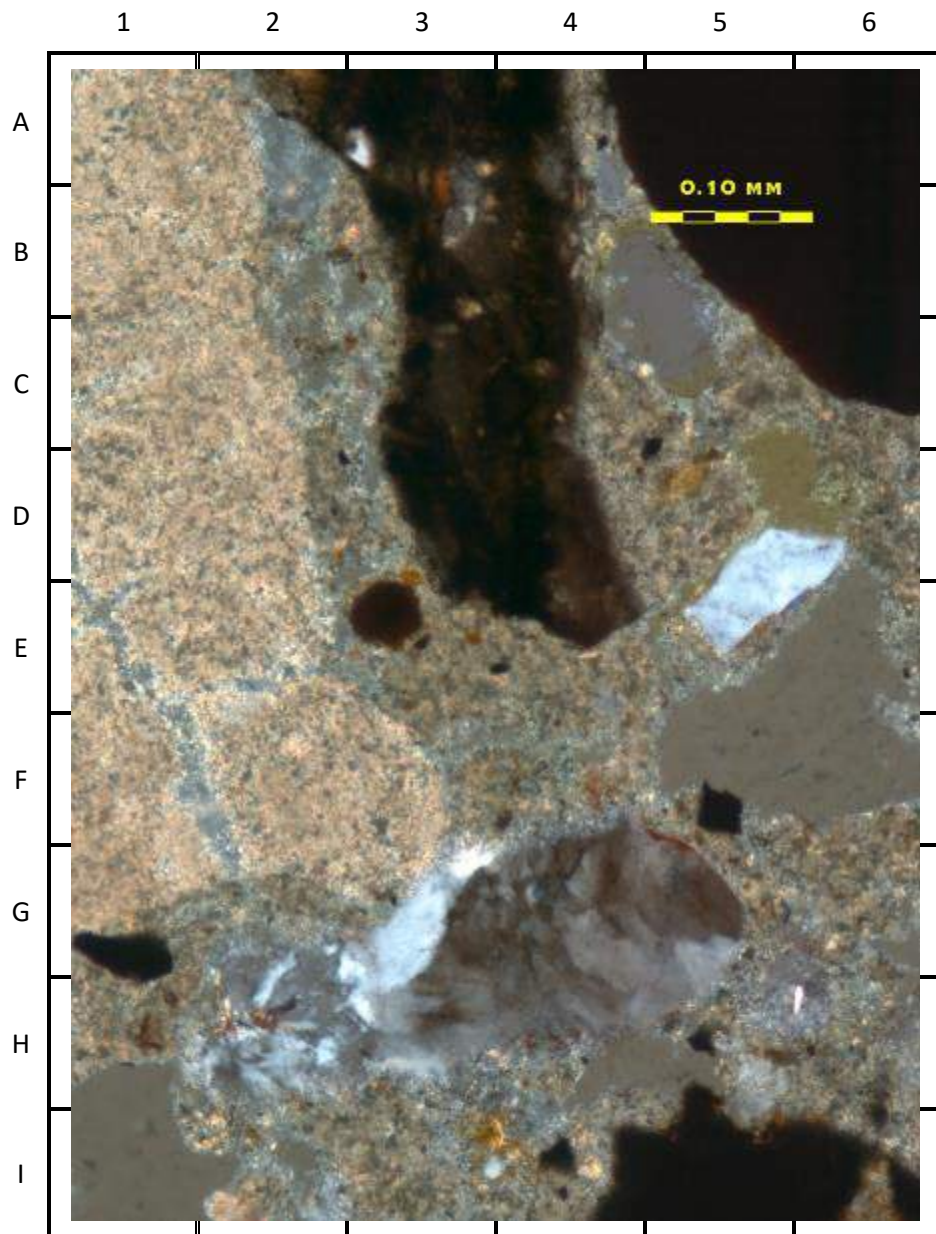


Figure C3

Sample K16494/1

Thin section, crossed polars: View showing a cross section through the contact between the surface gypsum plaster layers in the upper half of the field of view and the base coat plaster in the bottom half of the field of view. The gypsum plaster layer is composed mainly of microcrystalline gypsum crystals visible for example around B/C1. The base coat plaster contains particles of carbonaceous ash visible for example in H3/4 and quartz particles visible for example in F6 that are surrounded by a carbonated lime matrix that can be seen for example in G1.

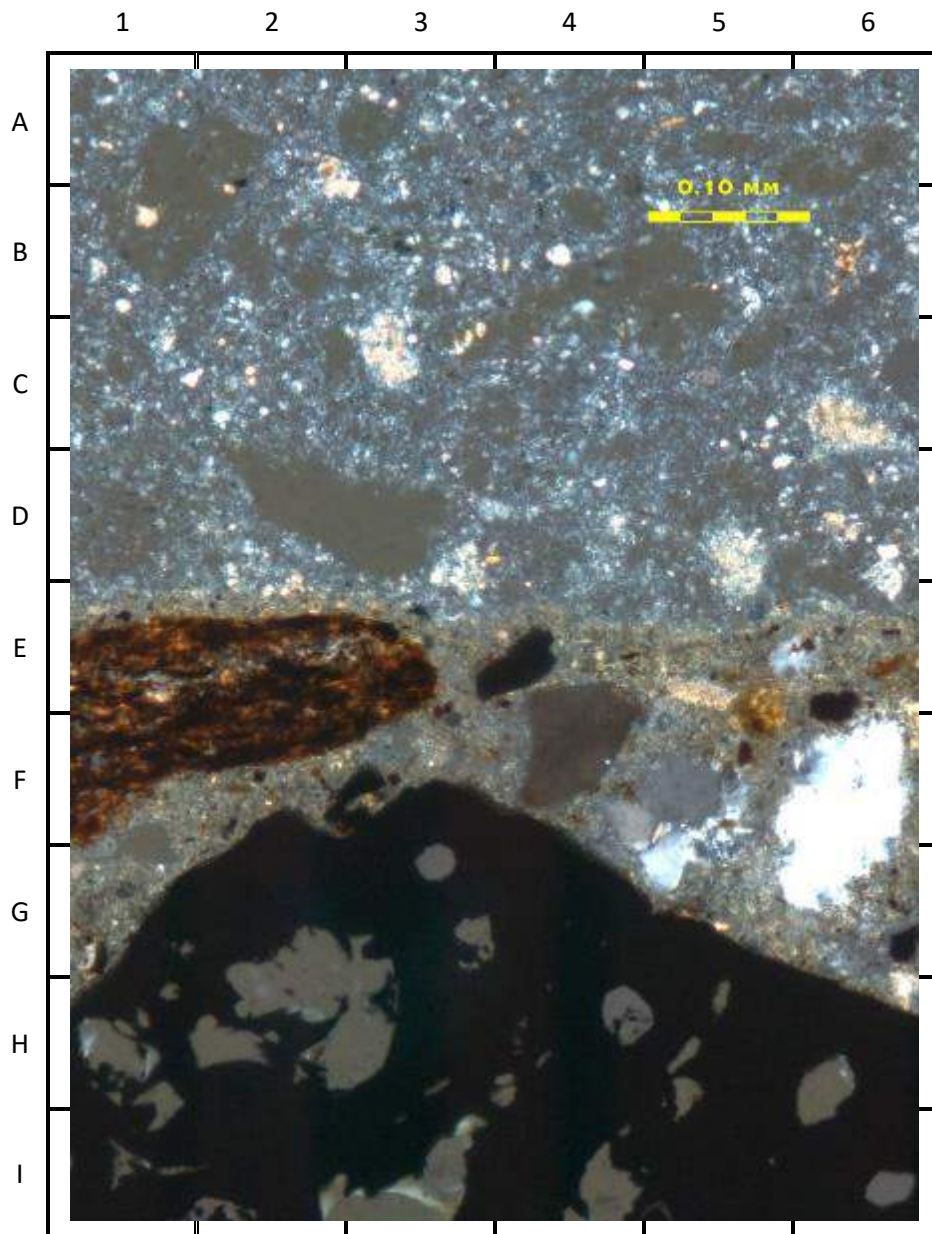


Figure C4

Sample K16494/2

Thin section, oblique polars: A fragment of carbonaceous ash occurs in F/G2. A particle of undispersed lime occurs in E5. Quartz sand particles appear various shades of grey and can be seen throughout the field of view for example in B/C3. The aggregate particles are surrounded by carbonated lime matrix.

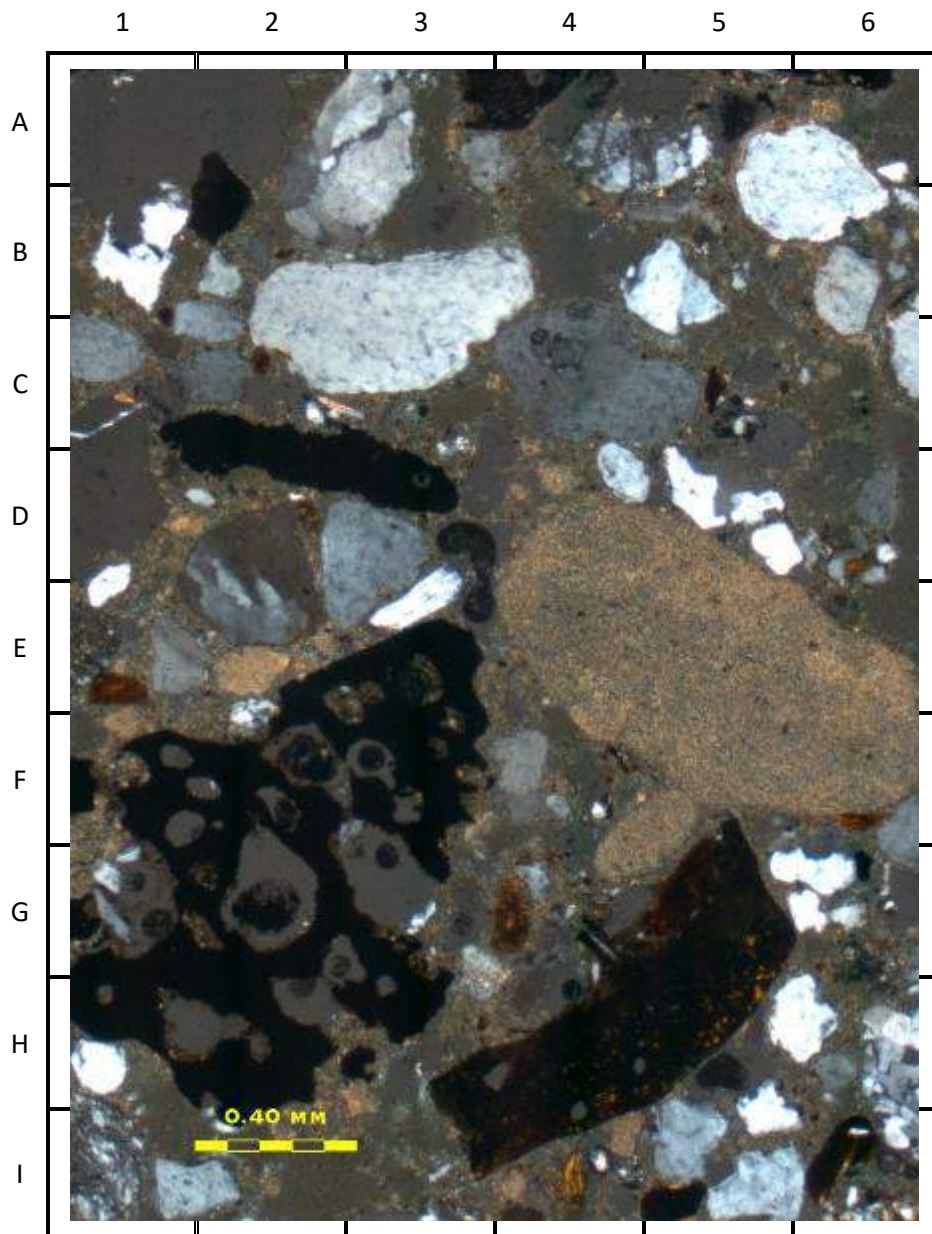


Figure C5

Sample K16494/2

Thin section, oblique polars: Quartz particles with small amounts of reddish brown clay around their surfaces are centred on B/C3 and D5/6. Areas of carbonated lime matrix occur for example in F2. A fragment of undispersed lime occurs in H/I6.

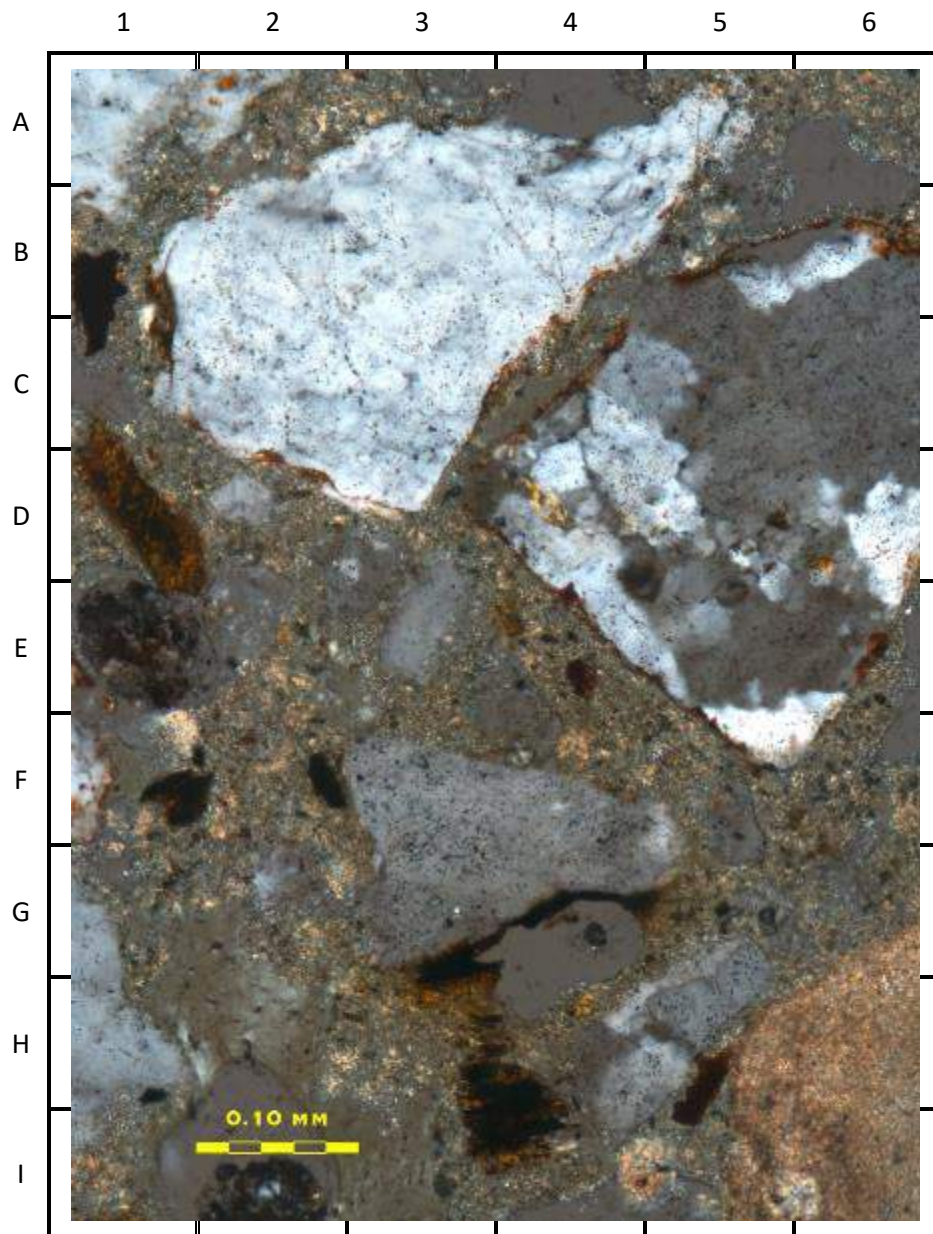


Figure C6

Sample K16494/2

Thin section, crossed polars: View showing a cross section through the contact between the gypsum plaster layer in the upper half of the field of view and the lime based base coat plaster in the lower half of the field of view. The base coat plaster contains quartz sand particles visible for example in F1 and H3 that are surrounded by carbonated lime matrix visible for example in E/F5. The gypsum plaster layer is composed almost entirely of microcrystalline gypsum, visible for example around C3/4.

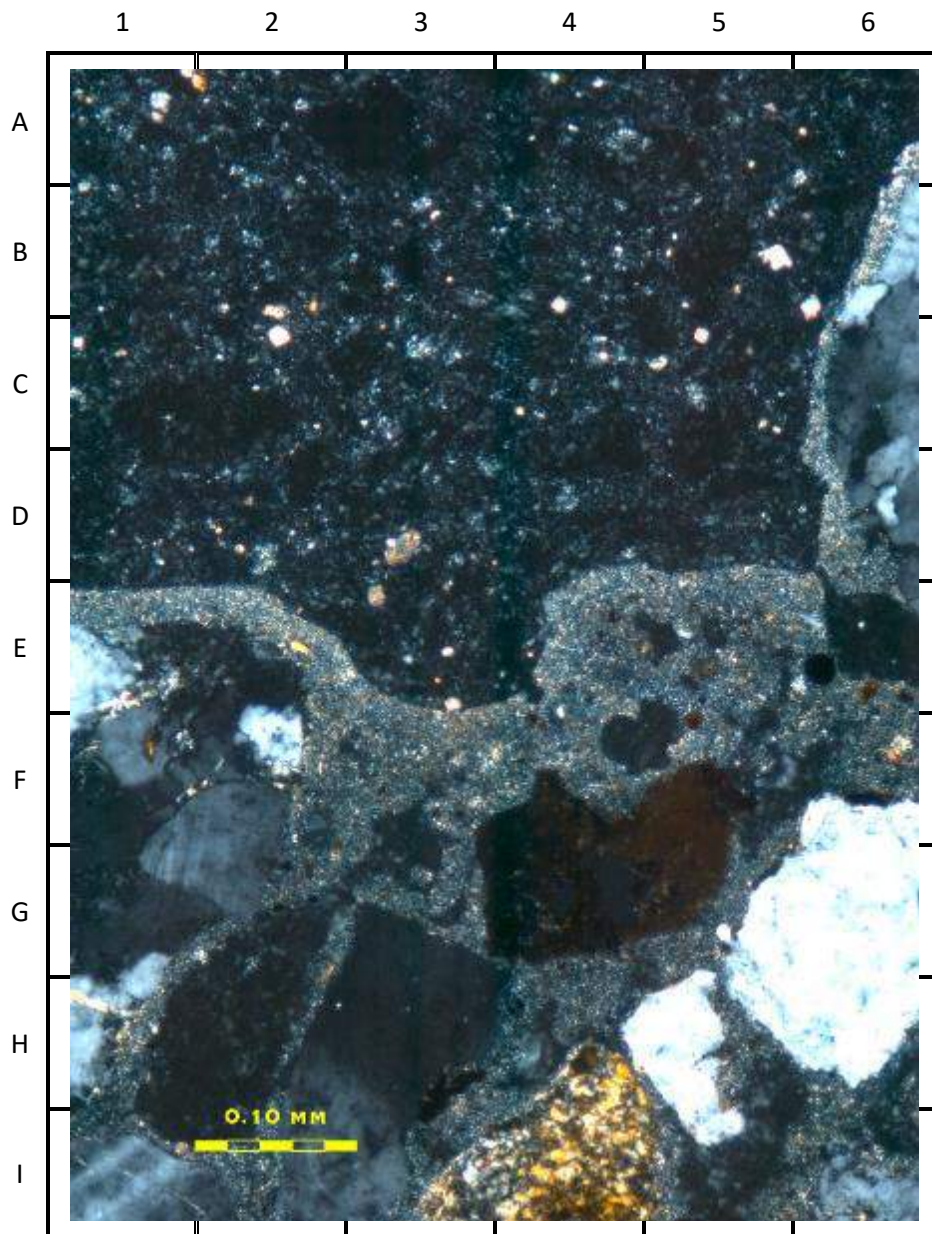


Figure C7

Sample K16494/3

Thin section, crossed polars: Low magnification view showing the large-scale structure of the sample. A fragment of coal with abundant internal shrinkage cracking occurs in F3. Quartz sand particles appear various shades of grey and occur throughout the field of view. The aggregate particles are surrounded by porous, carbonated lime matrix. A fragment of undispersed lime occurs in C/D1.

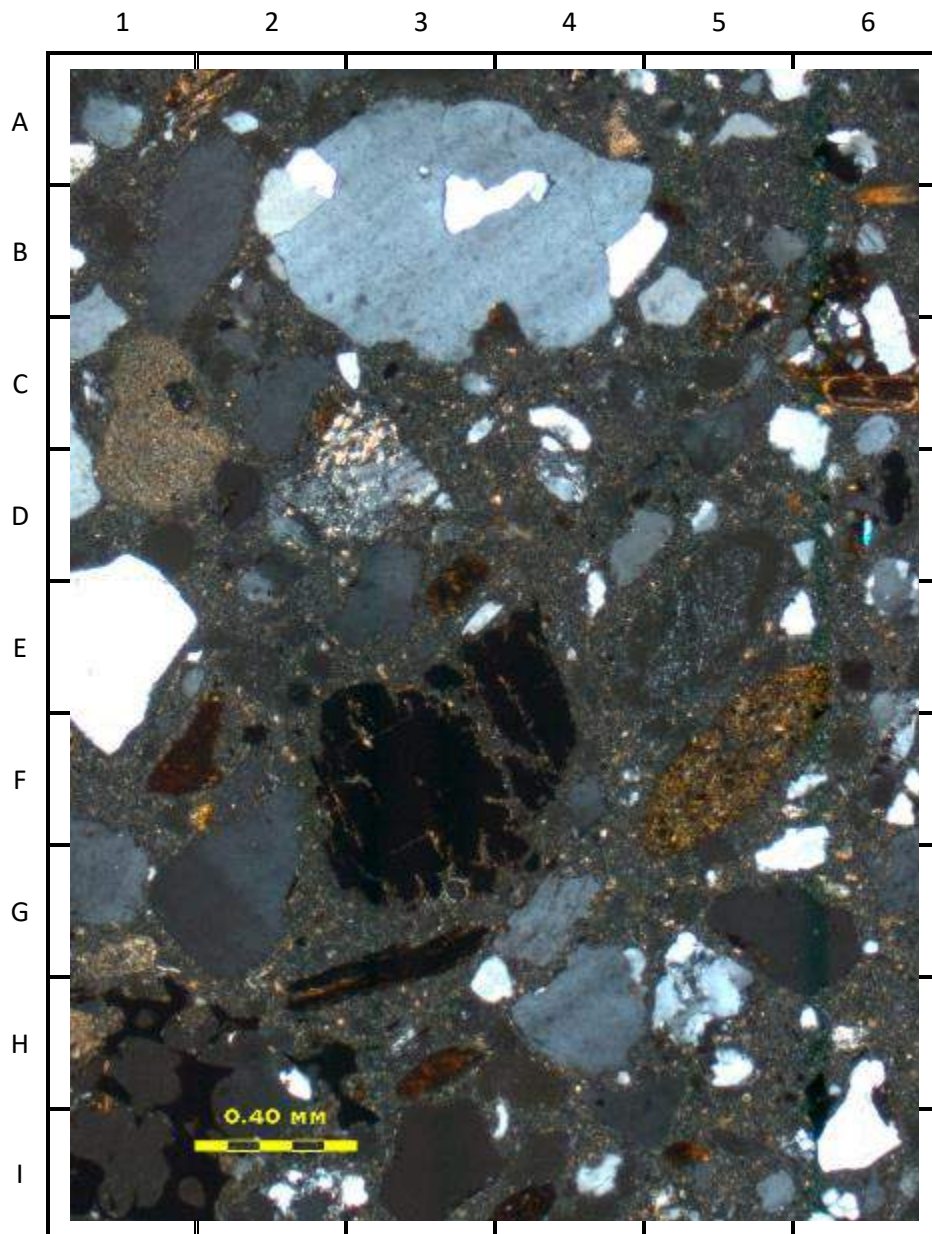


Figure C8

Sample K16494/3

Thin section, oblique polars: View showing the typical appearance of the fragments of gypsum that occur in the lime matrix in the base coat plaster. The gypsum fragment is partially dissolved around its margins and is centred on D5. Typical areas of carbonated lime matrix occur for example in B1 and G2/3. A fragment of mudstone occurs in H5/6 and a quartz particle occurs in B3.

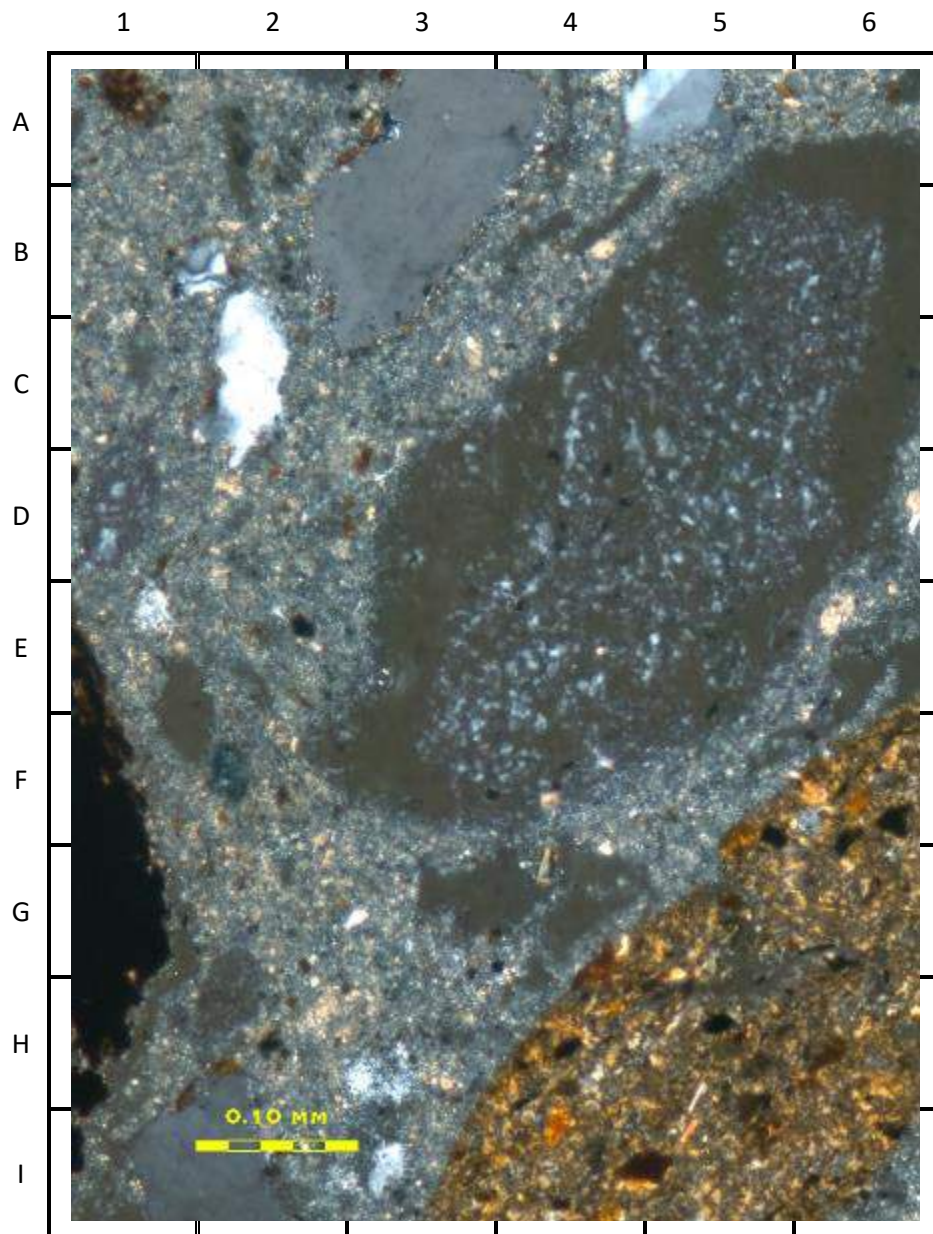


Figure C9

Sample K16494/3

Thin section, crossed polars: View showing a cross section through the contact between the surface gypsum plaster layers and the base coat plaster. The gypsum plaster layer is composed mainly of microcrystalline gypsum visible for example around B1/2. A coal fragment in the surface of the base coat plaster is centred around H1/2. Quartz particles occur for example in F2 and G5.

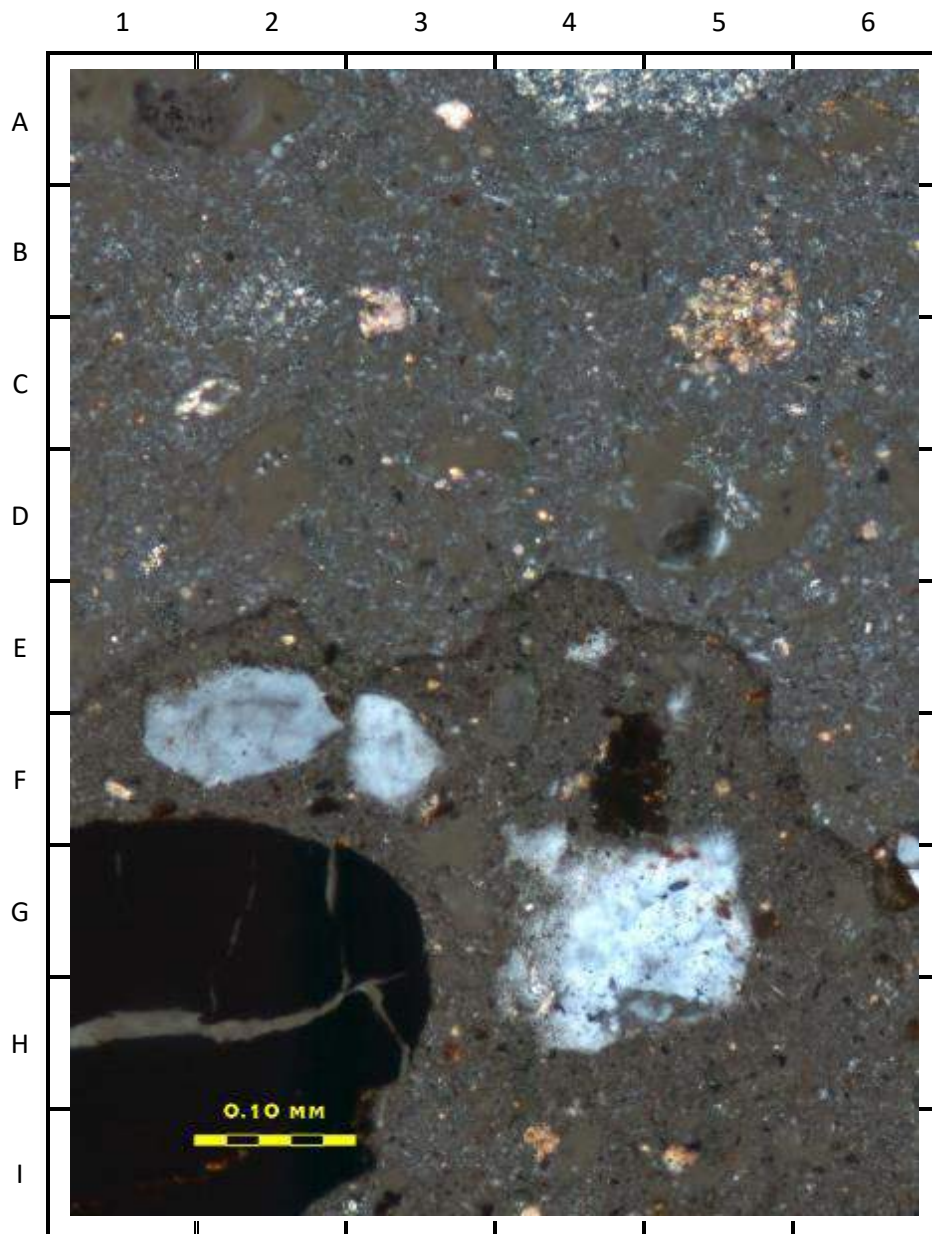


Figure C10

Sample K16494/4

Thin section, crossed polars: A coal fragment with abundant internal shrinkage cracking is centred around H2/3. The majority of the field of view is occupied by carbonated lime matrix surrounding quartz particles appearing various shades of grey. A fragment of undispersed lime can be seen in D3.

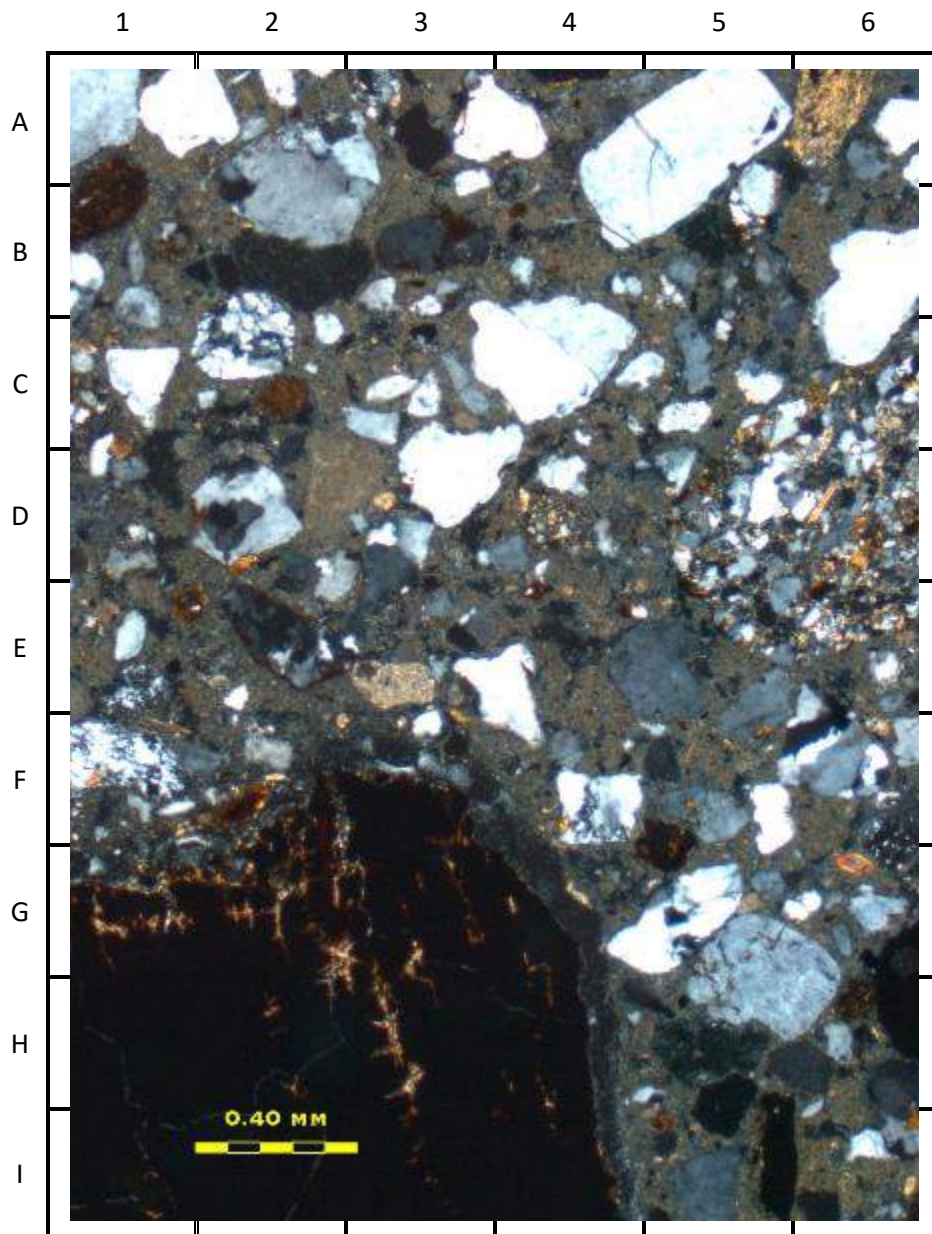


Figure C11

Sample K16494/4

Thin section, crossed polars: View showing the typical appearance of the base coat plaster in thin section. A fragment of undispersed lime is centred on C5. Quartz particles occur in B1, G1 and H5. The aggregate particles are surrounded by carbonated lime matrix visible for example in D1.

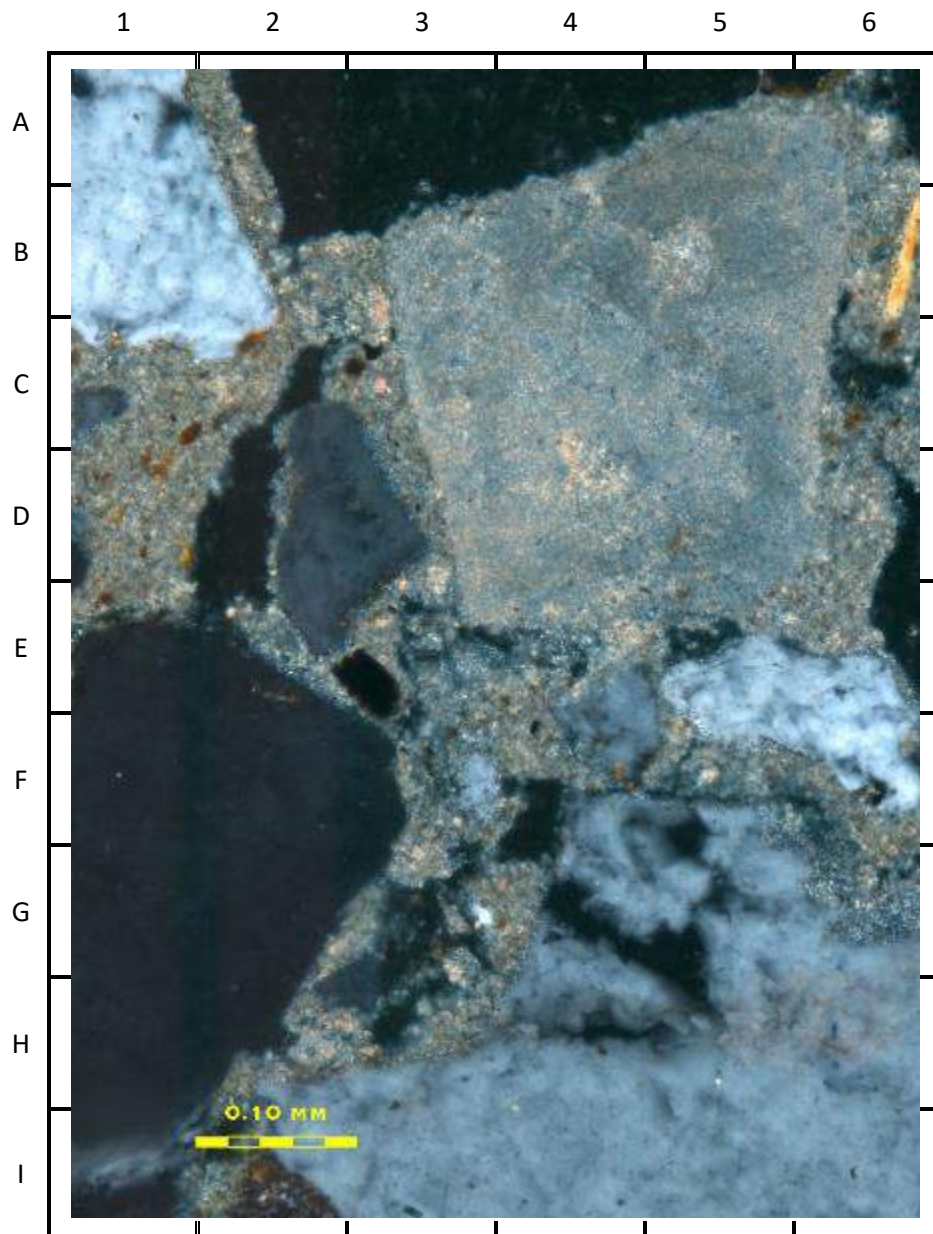


Figure C12

Sample K16494/4

Thin section, crossed polars: A fragment of ash is centred around F2. Carbonated lime matrix can be seen for example in C1 and E6. Quartz particles occur in A2, A5 and G/H5.

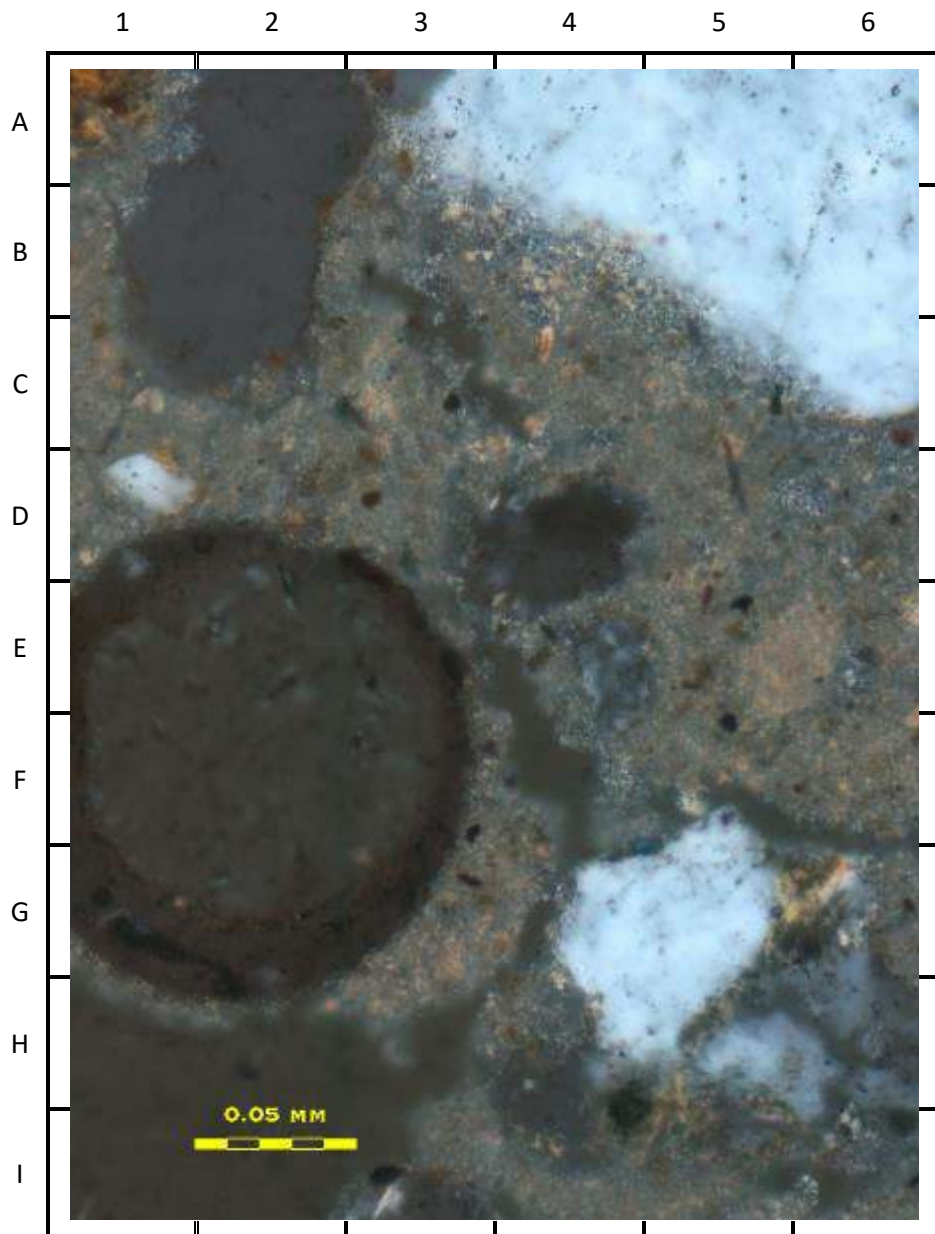


Figure C13

Sample K16494/5

Thin section, crossed polars: A fragment of undispersed lime occurs in C5. Carbonated lime matrix is visible for example in C2 and B6. A quartzite particle occurs in E2 and a quartz particle occurs in A1.

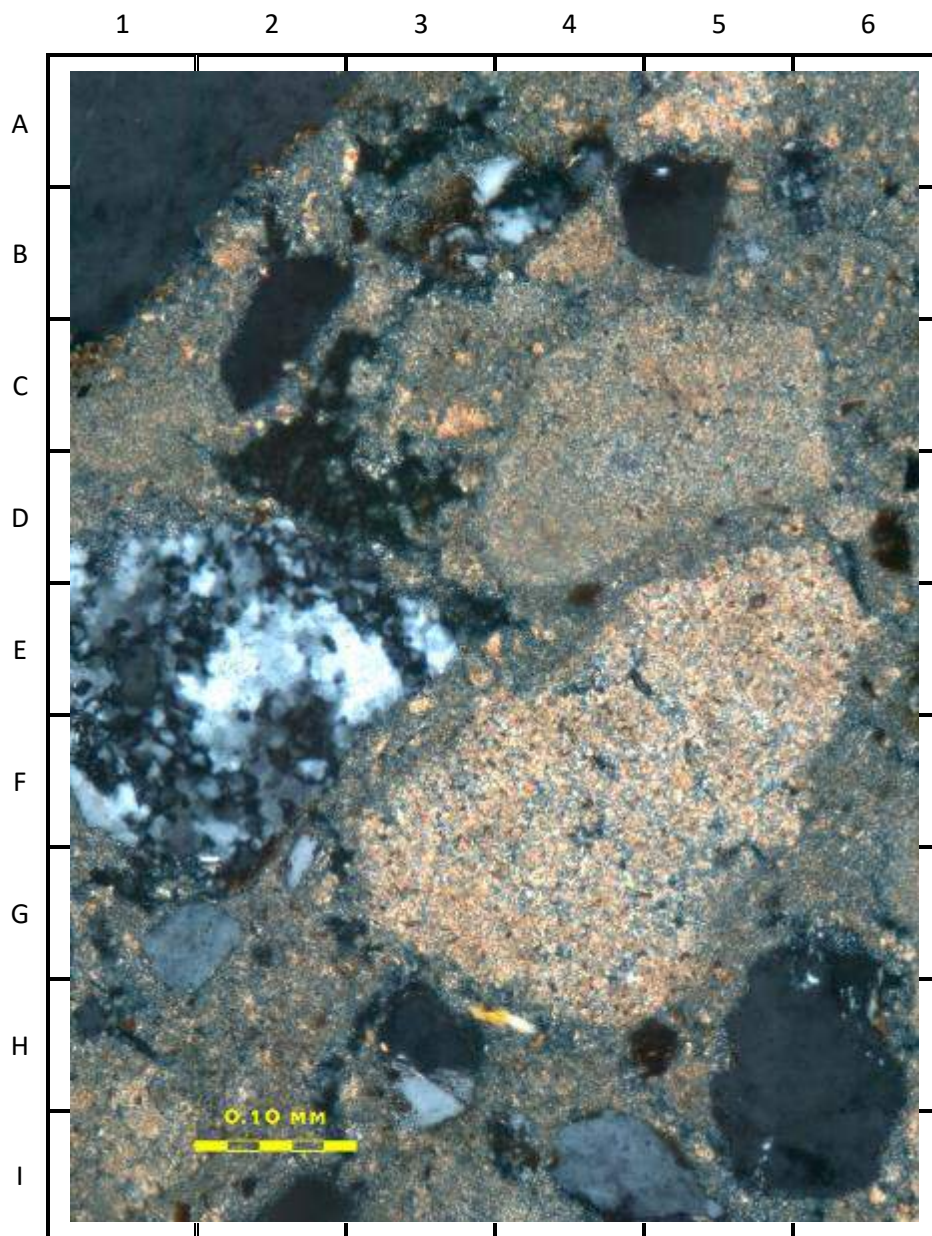


Figure C14

Sample K16494/5

Thin section, oblique polars: A fragment of argillaceous sandstone occurs in B3. A coal fragment occurs in E1. Much of the field of view is occupied by carbonated lime matrix visible for example in G3 and C5/6. Quartz particles occur for example around G/H1 and H4/5.

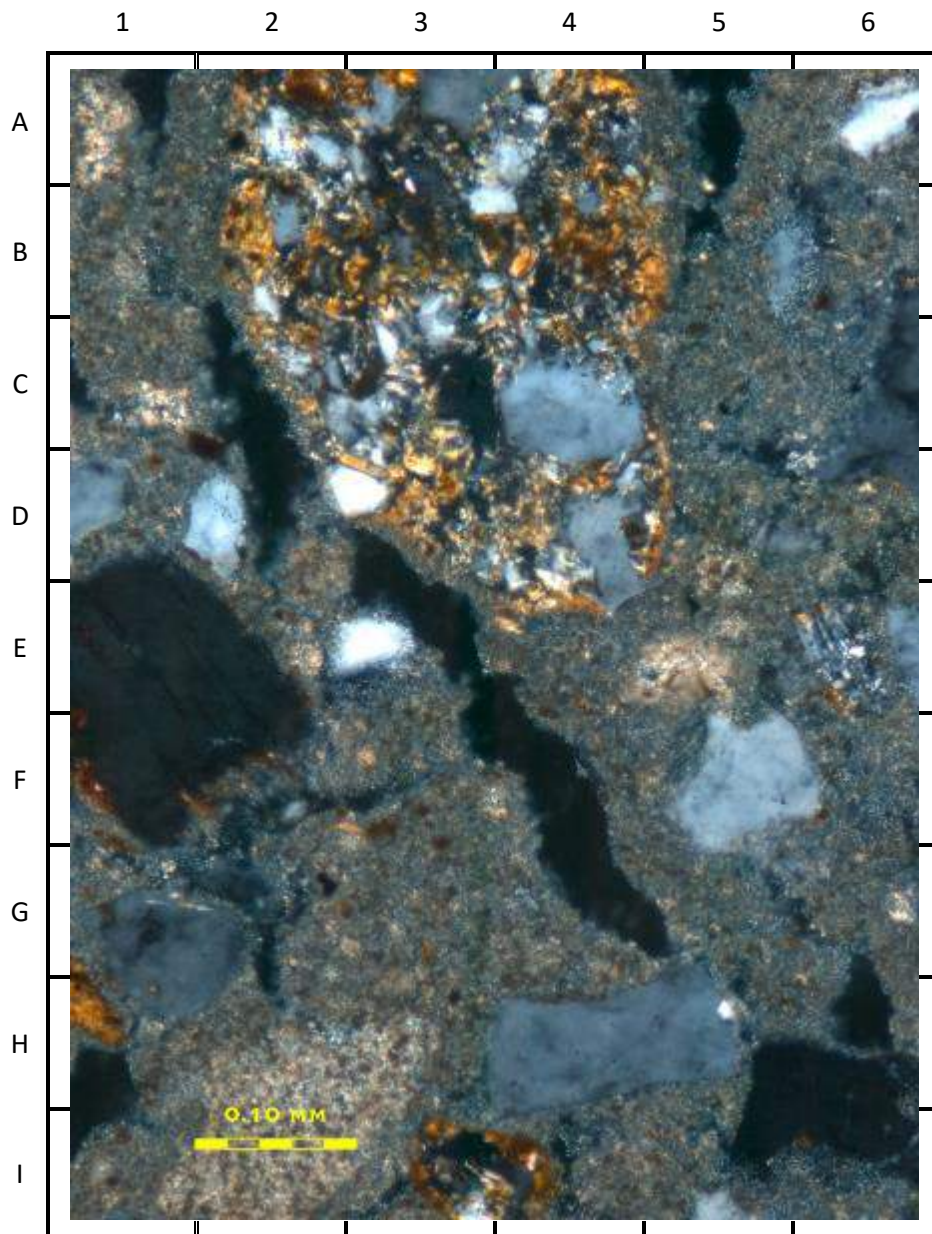


Figure C15

Sample K16494/5

Thin section, oblique polars: View showing the typical appearance of the animal hairs. The hairs are hollow and can be seen from C2 to G5. Carbonated lime matrix can be seen for example around B2 and H1. Quartz particles occur in I3 and C6.

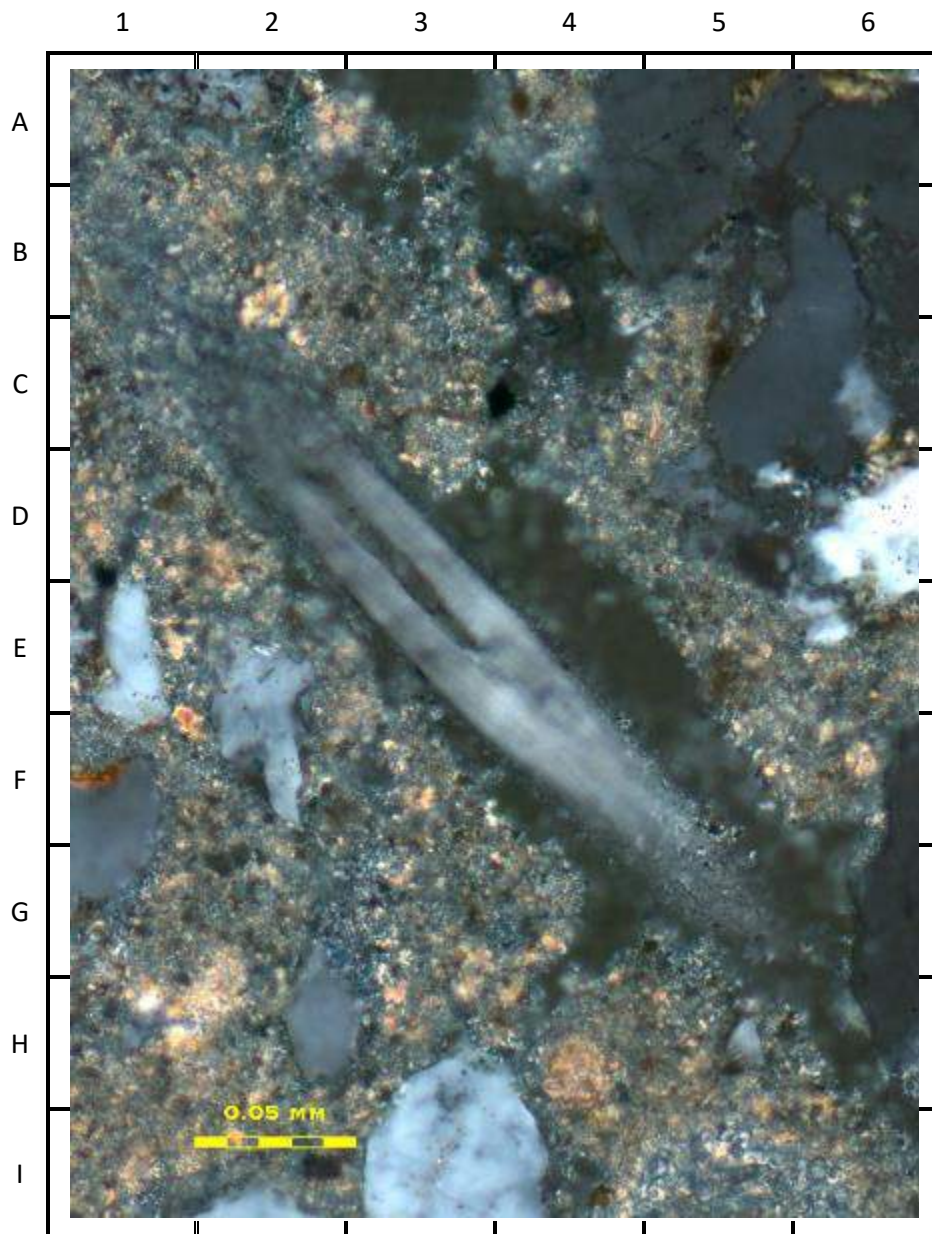


Figure C16

Sample K16494/6

Thin section, oblique polars: The field of view is dominated by a lime lump centred around H1/2. The upper half of the field of view is dominated by porous, carbonated lime matrix surrounding quartz particles that appear various shades of grey.

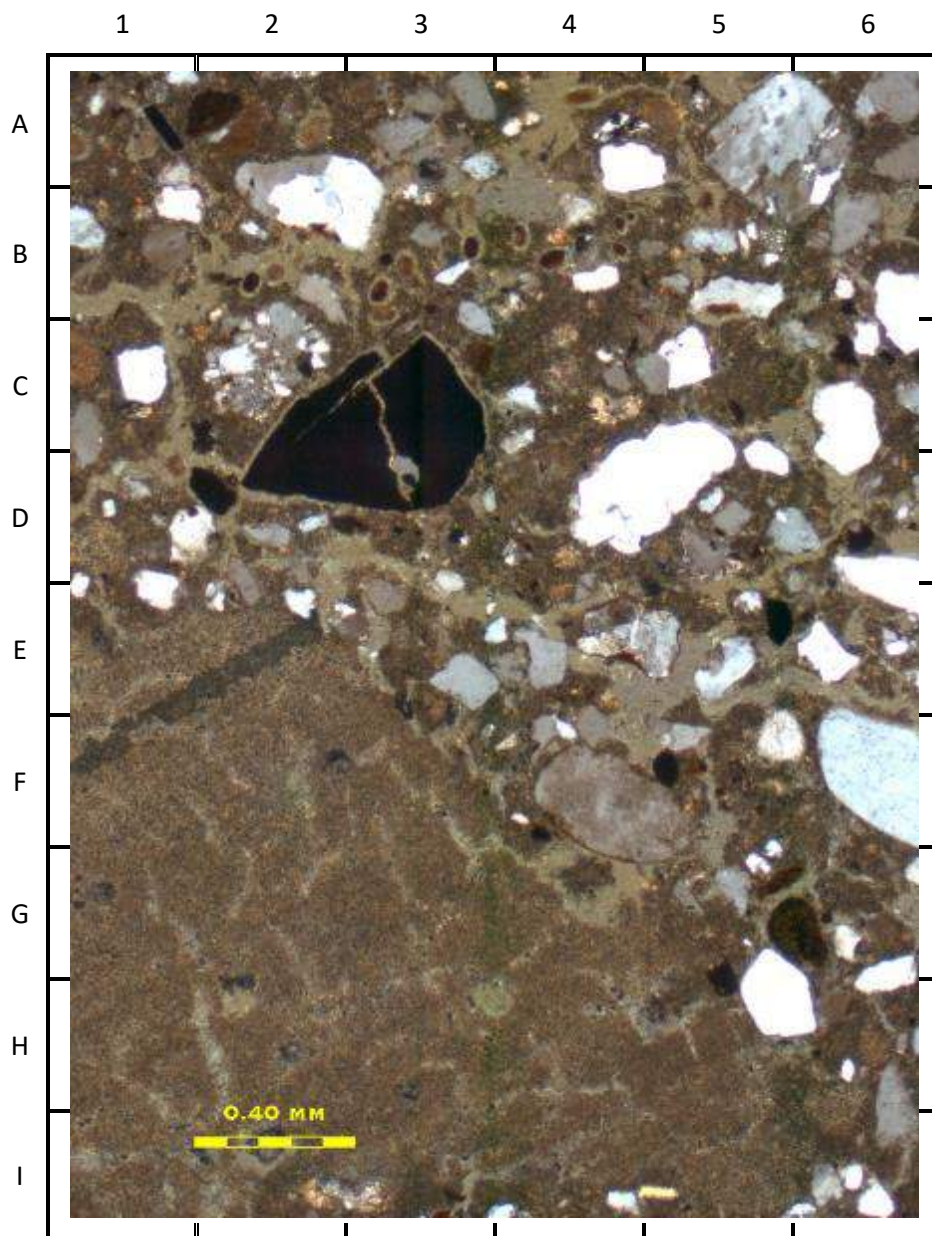


Figure C17

Sample K16494/6

Thin section, oblique polars: View showing the typical appearance of the base coat plaster in thin section. The base coat plaster contains abundant lime lumps visible for example around A3/4 and A6. Typical areas of carbonated lime matrix occur for example around E/F5. A camel hair resembling horse hair occurs in E3/4. Quartz particles can be seen for example in G5 and C5.

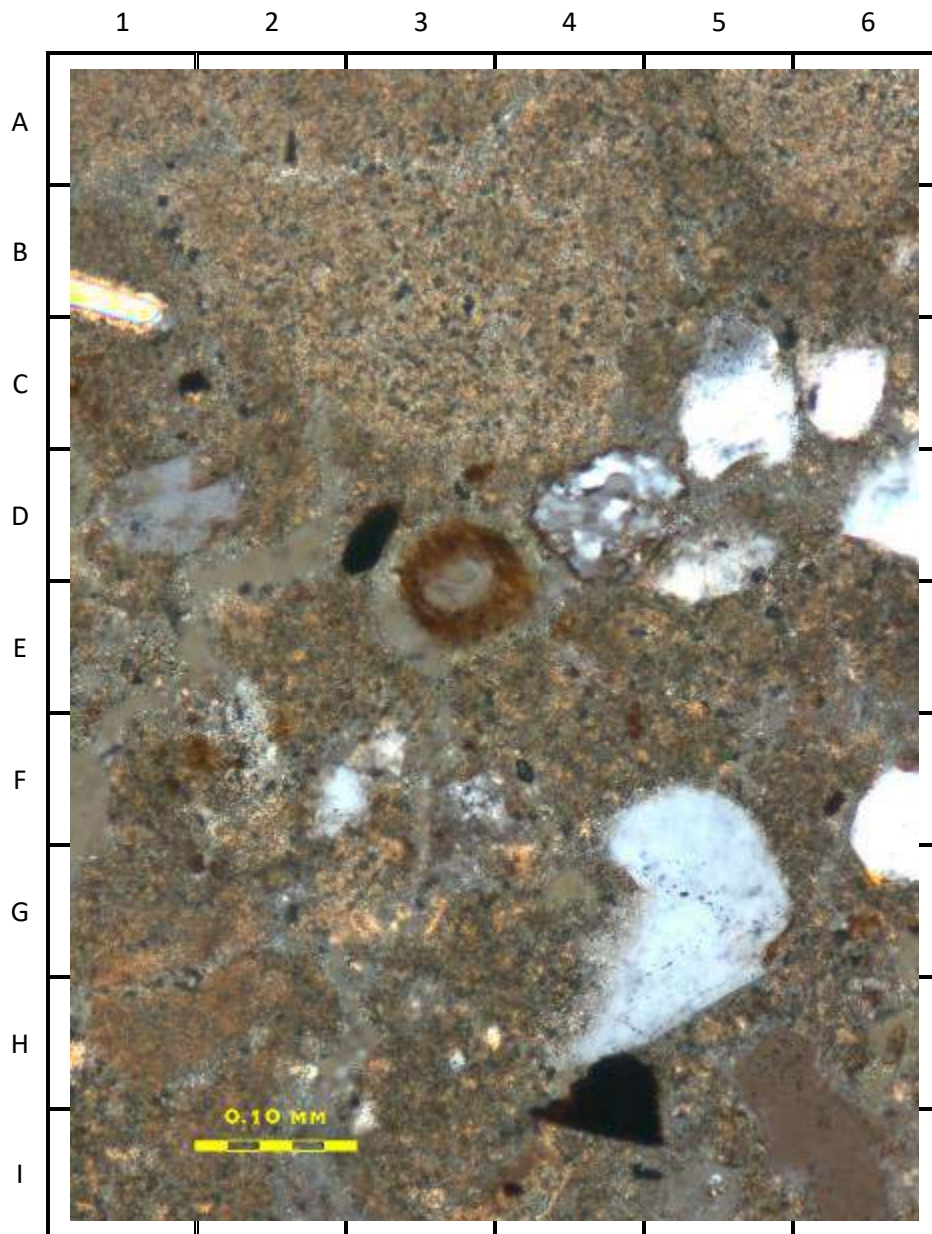
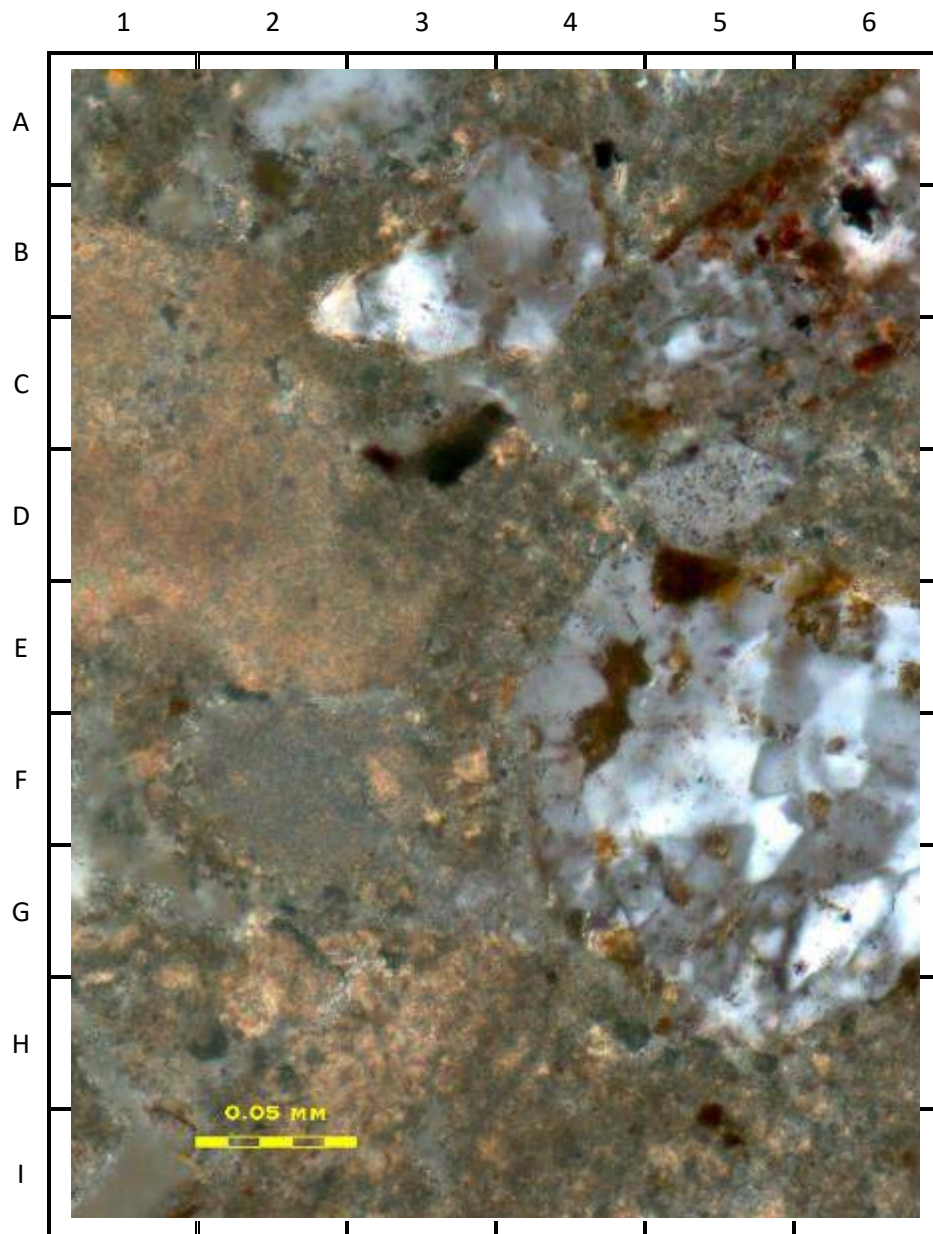


Figure C18

Sample K16494/6

Thin section, oblique polars: View showing an area of the base coat plaster in thin section. Fragments of undispersed lime occur in C/D1 and H2/3. A quartzite particle can be seen in F/G5. Areas of porous, carbonated lime matrix occur for example in I4 and E4.



APPENDIX D – PETROGRAPHIC PROCEDURES AND GLOSSARY

1. Preliminary examination:

The samples are examined with the binocular microscope as received and their dimensions and main features are recorded. The features observed include the following.

- (a) The presence and position of reinforcement.
- (b) The extent to which reinforcement is corroded.
- (c) The nature of the external surfaces of the concrete.
- (d) The features and distribution of macro and fine cracks.
- (e) The distribution and size range and type of the aggregate.
- (f) The type and condition of the cement paste.
- (g) Any superficial evidence of deleterious processes affecting the concrete.

2. Polished surfaces:

A plate is cut, where possible, from each sample. This is typically about 20 mm thick and usually provides as large a section of the sample as is possible and typically has a polished surface area of $>100\text{cm}^2$. The plate is polished to give a high quality surface that can be examined with a high quality binocular microscope or even with the petrological microscope if necessary. The polished plate is used to assess the following.

- (a) The size, shape and distribution of coarse and fine aggregate.
- (b) The coherence, colour, and porosity of the cement paste.
- (c) The distribution, size, shape, and content of voids.
- (d) The composition of the concrete in terms of the volume proportions of coarse aggregate, fine aggregate, paste and void.
- (e) The distribution of fine cracks and microcracks. Often the surface is stained with a penetrative dye, so that these cracks can be seen. Microcrack frequency is measured along lines of traverse across the surface.
- (f) The relative abundance of rock types in the coarse aggregate is assessed.

3. Thin sections:

A thin section is prepared for each sample as appropriate. The section is usually made from a plate cut at right angles to the external surface of the concrete, so that the outer 70 mm or so of the concrete are included in the section. Sometimes it is more appropriate to make the section from inner parts of the concrete. This might be appropriate where specific problems are being investigated for example. The section normally measures about 50 x 70 mm.

In manufacturing the thin section a plate some 10 mm thick is cut from the sample. This is impregnated with a penetrative resin containing a yellow fluorescent dye. The resin penetrates into cracks, microcracks, and capillary pores in the sample. One side of the impregnated plate is then polished and the plate is mounted on to a glass slide. The surplus sample is then removed and the plate is ground and polished to give a final thickness of between 20 and 30 micrometres. At all stages the cutting and grinding is carried out using an oil based coolant in order to prevent further hydration of the cement and excessive heating of the section. The thin section is covered and then examined with a high quality Zeiss petrological photomicroscope.

The thin section supplies the following types of information:

- (a) Details of the rock types present in the coarse and fine aggregate and in particular structures seen within those rocks.
- (b) Details of the aggregate properties are measured such as the degree of strain in quartz.
- (c) The size, distribution and abundance of phases in the cement paste are assessed including, for example, the occurrence of calcium hydroxide and the amount of residual unhydrated clinker.
- (d) The presence of cement replacement phases such as slag or PFA can usually be recognised (though the amount of these phases cannot be judged accurately). The presence of high alumina cement can be detected and the type of cement clinker can often be assessed.
- (e) Any products of processes of deterioration of either the cement paste or the aggregate can be recognised.

4. Broken surfaces:

After the specially prepared surfaces and sections are completed, the remainder of the core is examined with the binocular microscope. In particular, the pieces are broken to produce fresh surfaces. These surfaces allow the contents of voids to be studied and the nature of aggregate surfaces or crack surfaces to be investigated.

5. Composition:

Where the size of the sample is appropriate the composition of the sample can be measured using either the polished slice or the thin section, depending on the size of the sample and on details of the aggregate type and paste. The thin section is preferable, for example where large quantities of dust are present. The volume proportions are found by the method of point counting using a mechanical stage. The amount of coarse aggregate can also be assessed by this method if a distinction can be made between coarse and fine aggregate. The results obtained usually represent the sample reasonably, but may not represent the concrete.

6. Water/cement ratio:

The hydration processes of cement paste vary significantly with the original water/cement ratio. Concretes with a low water/cement ratio tend to leave substantial quantities of unhydrated cement clinker and to develop only limited amounts of coarsely crystalline calcium hydroxide. In particular, the extent to which calcium hydroxide is separated into layers on aggregate surfaces and occurs in voids and on void surfaces varies with the original water/cement ratio. The number and proportion of unhydrated cement clinker particles varies inversely with the original water/cement ratio. Comparison with standard concretes made with known water/cement ratios visually, and by measurement allows the water/cement ratio of the cement paste to be assessed directly. The standard error attached to the estimation of water/cement ratio by this means is considered to be approximately ± 0.1 for unaltered concrete of similar type that in the Sandberg Reference Concrete Collection. It should be noted that aggregate dust, the presence of admixtures and additives all contribute to uncertainty in the petrographic measurement of the water/cement ratio of the concrete.

7. Glossary:

The following is a short list of technical terms in common use in the petrographic examination of concrete⁴.

Alkali-aggregate reaction (AAR): This is a broad term encompassing both alkali carbonate reaction (ACR) and alkali silicate reaction and alkali-silica reaction (ASR). It refers to reactions between alkalis in usually derived from the cement in the cement paste and aggregate particles. Some forms of alkali-aggregate reaction such as ASR result in the formation of an alkali-silicate gel that is readily detectable in thin sections. Other forms of alkali-carbonate reaction such as ACR may not result gel formation.

Alkali carbonate reaction (ACR): This form of reaction is very rare in the UK and there is some debate over the precise mechanism of this reaction. Most documented cases of ACR involve argillaceous, dolomitic limestone. The reaction which is expansive is rarely associated with the formation of obvious gel deposits.

Alkali-silicate/silica reaction (ASR): This is by far the most common form of AAR and generally results from reactions between either microcrystalline, cryptocrystalline, or substantially strained quartz and associated microcrystalline quartz at grain margins and alkalis in cement paste. On rare occasions, ASR may result from the presence of highly reactive opaline silica in aggregate. Petrographic examination is the definitive method for the detection of this form of concrete deterioration. The reaction commonly results in the development of cracking that originates within reactive aggregate particles and continues into the surrounding paste and gel deposits are commonly associated with the occurrence of ASR.

Calcium aluminate cement (CAC): This is a general term that encompasses high alumina cement (HAC) as well as some of the more modern aluminate cements used in rapid setting concrete repair materials or some types of sprayed concretes and grouts.

Carbonation: Carbonation most commonly results from the exposure of concrete to atmospheric carbon dioxide and results in the conversion of portlandite to calcium carbonate and also affects some of the cement hydrate phases forming complex calcium silicate hydrate carbonate compounds. In damp conditions or in concrete exposed to moisture containing dissolved carbon dioxide, coarse-textured carbonation may develop and coarse crystals of calcium carbonate may develop within the cement paste. "Popcorn" calcite deposition (PCD) is one form of this type of carbonation.

Cracking: Cracks are classified using the following terms:

- **Macroscopic cracks:** These cracks are visible in the hand specimen or with the aid of a stereo binocular microscope and are typically >0.01mm wide.
- **Macrocrack:** These are cracks that are readily visible to the naked eye without the aid of a stereo binocular microscope and are typically >0.1mm wide.
- **Fine crack:** These are cracks that are only readily visible with a stereo binocular microscope or in thin section. Cracks of this type are typically between 0.01 and 0.10mm wide.
- **Microcracking:** These cracks cannot be detected with a stereo binocular microscope. They are typically <0.01mm wide and are most easily seen in petrographic thin sections containing fluorescent dye and by using fluorescent illumination.

Delayed ettringite formation (DEF): This term describes deleterious ettringite formation in concrete that has been cured at elevated temperatures, typically >65°C. Ettringite formation resulting from this process can be readily detected using thin sections and the ettringite tends to form in peripheral cracks around aggregate surfaces and sometimes within microcracks in the paste.

⁴ Applied Petrography Group. A code of practice for the petrographic examination of concrete (Author M A Eden), SR2, The Geological Society of London, London, 2010 (Available for download from <http://www.appliedpetrographygroup.com>).

Drying shrinkage cracking: Drying shrinkage microcracks tend to develop radially around the surfaces of fine aggregate particles in concrete. Fine cracks and macrocracks caused by drying shrinkage tend to be parallel-sided cracks and orientated perpendicular to concrete surfaces.

Ettringite: This is a very common calcium-alumino-sulfate mineral. It occurs in most concretes where moisture ingress has occurred. Ettringite formation may be deleterious in the case of DEF or sulfate attack where it can give rise to a deleterious expansion and distinctive forms of cracking but in most cases secondary ettringite formation is non-deleterious.

Fly ash (also known as PFA / pulverised fly ash): This material is a by-product of coal burning power stations and can be readily recognised in thin sections, where it is visible as spherical glass particles, some of which may be hollow. Hollow PFA particles may be referred to as cenospheres. PFA is also commonly associated with small quantities of graphite particles that appear black in thin section.

Fine crack: See section on cracking.

GGBS: Ground, granulated blast furnace slag. This material is commonly employed as a cement replacement material in concrete and can be easily recognised in thin section. The GGBS particles are typically angular and are composed almost entirely of glass.

High alumina cement (HAC): This is a form of cement manufactured from the fusion of limestone and bauxite. It is readily distinguishable in thin section from most other types of cement. Petrographic examination is the definitive method for the detection of carbonation in concrete containing HAC.

Macrocrack: See section on cracking.

Macroscopic: This is a general term referring to features that are visible to the naked eye or with the aid of a stereo microscope.

Microcrack: See section on cracking.

Microsilica: Well dispersed microsilica cannot be directly observed in thin sections. However, distinctive clots of undispersed microsilica are commonly present in concrete containing microsilica – even where most of the microsilica is well dispersed. Microsilica clots are isotropic, and tend to be spherical and are sometimes concentrically layered. They are typically <100µm in diameter.

PFA: See section on fly ash

Plastic shrinkage cracking: This form of cracking occurs in concrete prior to its hardening. It can be distinguished from many other forms of cracking in that it results in cracks that are generally restricted to the cement paste and are non-parallel sided. Cracks of this type typically appear on the concrete surface and commonly diminish in width rapidly with depth and the paste surrounding cracks of this type is commonly of locally high porosity reflecting the migration of moisture towards the cracks during the drying out of the concrete surfaces.

Porosity: This term is distinct from void content. It refers to microscopic pores within cement hydrates. Porosity is directly related to water/cement ratio, but is also strongly influenced by curing and many forms of concrete deterioration. Porosity is sometimes used as an indicator of water/cement ratio in hardened concrete.

Portland cement: Portland cement is the most common form of binder used in concrete and is manufactured from the burning of limestone and an alumino-silicate rock (clay or shale) at temperatures of up to 1500°C. There are many forms of Portland cement and it is commonly possible to distinguish sulfate-resisting and white Portland cement and ordinary Portland cement using petrographic thin sections.

Portlandite: Portlandite is calcium hydroxide and is one of the products formed during cement hydration. Portlandite is readily recognisable in thin sections and has a distinctively high birefringence that contrasts with the much lower birefringence of the hydrated cement phases.

Sulfate attack: This is a general term encompassing both conventional sulfate attack resulting in gypsum and ettringite formation, but also includes sulfate attack associated with thaumasite formation. Sulfate attack can be readily recognised in thin sections and commonly results in the development of surface-parallel cracks infilled with ettringite or thaumasite.

Thaumasite: This is a carbonate-sulfate calcium hydrate mineral with a complex composition. It is a common reaction product in concrete exposed to moisture containing both carbonate and sulfate ions. Thaumasite is most commonly encountered in concrete exposed to temperatures of $<4^{\circ}\text{C}$. Some forms of thaumasite can be readily distinguished from ettringite and have a high birefringence. However, some forms of thaumasite have a much lower birefringence and can be difficult to distinguish from ettringite without recourse to SEM micro-analysis.

Void: This describes empty spaces present in concrete that are typically greater than about 5 micrometres in diameter. It encompasses both entrained air voids (spherical voids typically $<1\text{mm}$ in diameter) as well as much larger entrapped air voids. It should be noted that it is possible for concrete to have a low porosity, but a high void content.

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