Gilbert Bain Hospital Phase 1 Construction

Report on Condition of External Walls

December 2024

100106891NH03

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Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
A	Dec 24	A Stout	N Pearson	J Moncrieff	First Issue

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Contents

Figures

1 Introduction

NHS Shetland became concerned with defects in the east elevation wall of the 4 storey building at the Gilbert Bain Hospital in February 2024. The 4 storey building is a part of the Phase 1 construction and includes plant rooms, part of the Ward 3 area and part of the maternity department. Following a prolonged period of south easterly gales accompanied by heavy rain in February 2024 there was severe water ingress found in the maternity labour room at the south-east corner of the 4 storey block on first floor level. The water appeared to be entering around a lintel and travelling across the floor of the room. During inspections following the water ingress it was noted that the outer leaf wall appeared to be leaning outward at the wall head on the east elevation of this block. Additionally, there was horizontal cracking at the wall head below the parapet upstand and the sealant in the north elevation movement joint was missing over the top two metres of the joint.

The Phase 1 construction had also had historical issues with water ingress for many years on the south elevation walls. The cause of this water ingress had never been fully solved but was thought to be mainly due to defects around window openings (cills and lintels), the parapet, render beads and movement joints in the wall. Cracking just below the top of the parapet is a common feature of the Phase 1 buildings and a remedial parapet flashing has been installed with successful results at some of the elevations.

Phase 1 is the reference for the extensive extensions to the Gilbert Bain Hospital undertaken between the mid and late 1980s. At the time it was built the Phase 1 buildings included outpatients, accident and emergency, X-ray department, maternity department and acute wards. A location plan of the hospital is included in Figure 1.1 and the extent of the Phase 1 construction is shown in the plans in Appendix A.

Mott MacDonald was instructed to inspect the walls of the Phase 1 construction in March 2024 and to inspect cores taken in the outer leaf blockwork between September and October 2024.

Figure 1.1: Location Plan

2 Inspections

2.1 Visual and theodolite inspection of 4 Storey building walls on 11 March 2024

At this visit the walls were inspected visually and an estimate of the outward movement of the upper two metres of the 4 Storey building east elevation wall was made with a theodolite sited on the adjacent roof to the north. It was estimated that the wall had moved 20mm outward at the head with the outward lean springing from a point 2m below the top of the wall. The north elevation movement joint was void of sealant over this height of the wall. Figure 2.1 includes a view of the east elevation wall from the north.

Figure 2.1: View of the east elevation wall from the north

2.2 Visual inspection of Lift Motor Room north elevation wall on 17 May 2024

A typical 3 to 5mm wide crack below the coping had been chased out to allow inspection of the construction at the coping. This included a precast or insitu concrete coping on 30mm of soft mortar on DPC. The crack at the wall head coincided with the DPC location.

Figure 2.2 shows cracking along the east wall head of the lift motor room and Figure 2.3 includes details of the construction at the coping.

Figure 2.2: Cracking along the east wall head of the lift motor room

Figure 2.3: Construction at the coping

2.3 Intrusive inspections in 4 Storey building outer leaf blockwork on 31 August and 01 September 2024

Initial visual inspections were carried out at roof level and a view of the outward lean of the east elevation wall from roof level is shown in Figure 2.4

Figure 2.4: Outward lean of the east elevation wall from roof level

In addition to the east wall head projecting outward by approx. 20mm as noted in Section 2.1 above the north elevation wall was also seen to be leaning outward by approx. 10mm at the wall head at the north-east corner of the 4 Storey block. Photographs of horizontal cracking at parapet level are included in Figures 2.5 to 2.8, with Figures 2.5 and 2.6 showing cracking at the south elevation and Figures 2.7 and 2.8 showing cracking at the east elevation.

Figure 2.5: Cracking at south elevation

Figure 2.6: Cracking at south elevation

Figure 2.7: Cracking at the east elevation

Figure 2.8: Cracking at the east elevation

100mm diameter cores were removed from the north, east and south elevations of the 4 Storey building. The core locations are included in Figures 2.9 to 2.11 inclusive. Cores extracted included 2 no cores at the 4 Storey north elevation wall, 9 no cores at the 4 Storey east elevation wall and 3 no cores at the 4 Storey south elevation wall.

Figure 2.9: 2 no cores at the 4 Storey north elevation wall

Figure 2.10: 9 no cores at the 4 Storey east elevation wall

Figure 2.11: 3 no cores at the 4 Storey south elevation wall

Sample photographs of extracted cores, the exposed cavity and wall ties located with an endoscope inspection are included in Appendix B. Notes of key findings at each core location are also included in Appendix B. The core inspections confirmed that the outer leaf was of good quality dense concrete blocks with weak to very weak mortar jointing. Wall ties were present in the cavity but were difficult to locate due to the narrow cavity and significant amount of mortar droppings in the cavity. The wall ties were of the vertical twist type and where they could be inspected closely appeared to be in good condition. Mortar samples were taken at Cores 2, 11 and 12.

2.4 Intrusive inspections in Water Tank Room at top of 4 Storey Building on 6 and 10 September 2024

The water tank room is located on the east side of the upper level of the 4 storey building. The room occupies the full length of the east elevation. Four inner leaf blocks were removed near the top of the wall to allow inspection of the cavity and wall ties. The blocks removed are shown in Figures 2.12 and 2.13.

Figure 2.12: Blocks removed at NE corner of Water Tank Room

Figure 2.13: Blocks removed at SE corner of Water Tank Room

Photographs and notes of key findings are included in Appendix C. The block inspections confirmed that the inner leaf was of good quality dense concrete blocks with weak to very weak mortar jointing. Wall ties were present in the cavity but where closely inspected were found to be slightly loose to loose and some ties had inadequate embedment in the outer leaf blockwork. The wall ties were of the vertical twist type and where they could be inspected closely appeared to be in good condition. The cavity was wider than expected varying from 75mm at the north elevation to 90 to 105mm at the east elevation and 95mm at the south elevation. The width of the cavity would suggest that the outer leaf blockwork has displaced over time increasing the cavity width from 50mm noted on the original drawings to the recoded values. Mortar samples were taken at Blocks 3 and 4.

2.5 Intrusive inspections at Ward 3/Renal south elevation outer leaf blockwork on 01 and 02 October 2024

100mm diameter cores were removed from the south elevation of the 3 Storey building including Ward 3 at the top floor and Renal on the first floor. The core locations are included in Figures 2.14 and 2.15.

Figure 2.14: Cores at the south elevation of Ward 3 and Renal 1 of 2

Figure 2.15: Cores at the south elevation of Ward 3 and Renal 2 of 2

Sample photographs of extracted cores, the exposed cavity and wall ties located with an endoscope inspection are included in Appendix D. Notes of key findings at each core location are also included in Appendix D. The core inspections confirmed that the outer leaf was of good quality dense concrete blocks with some weak and some reasonable mortar jointing. Wall ties were present in the cavity but were difficult to locate due to the narrow cavity and significant amount of mortar droppings in the cavity. The wall ties were of the vertical twist type and where they could be inspected closely appeared to be in good condition.

2.6 Intrusive inspections in 4 Storey building outer leaf blockwork on 02 and 03 October 2024

100mm diameter cores were removed from the south and west elevations of the 4 Storey building. The core locations are included in Figures 2.16 and 2.17 Sample photographs of extracted cores, the exposed cavity and wall ties located with an endoscope inspection are included in Appendix E. Notes of key findings at each core location are also included in Appendix E. The core inspections confirmed that the outer leaf was of good quality dense concrete blocks with weak mortar jointing. Wall ties were present in the cavity but were difficult to locate due to the narrow cavity and significant amount of mortar droppings in the cavity. The wall ties were of the vertical twist type and where they could be inspected closely appeared to be in good condition.

Figure 2.16: 4 Storey south wall cores – 6 no cores at the 4 Storey south elevation wall

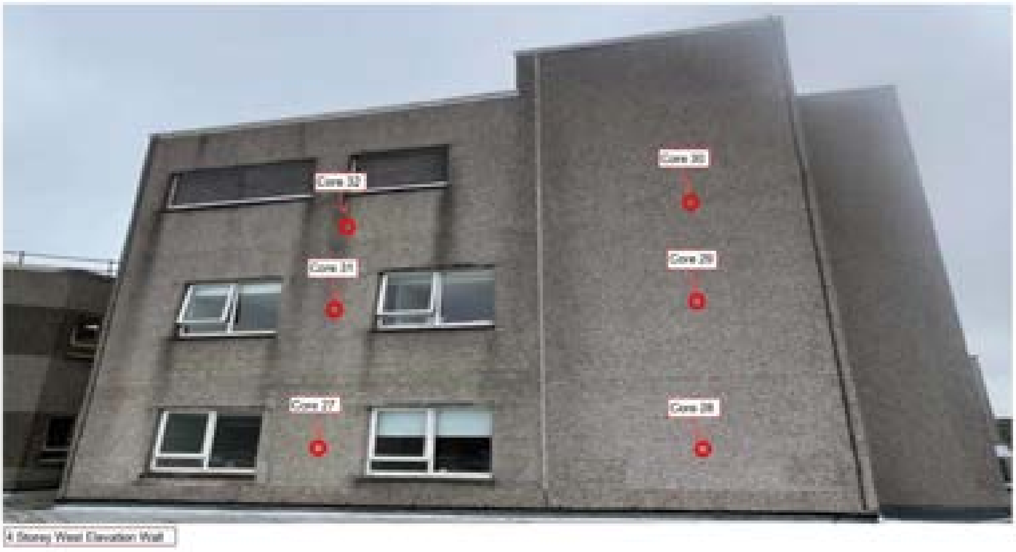


Figure 2.17: 4 Storey west wall cores – 6 no cores at the 4 Storey west elevation wall

2.7 Intrusive inspections at Ward 3/Maternity link and south elevation outer leaf blockwork on 03 and 04 October 2024

100mm diameter cores were removed from the link between the 3 and 4 Storey buildings and from the south elevation of the 3 Storey building including Ward 3 at the top floor and Maternity on the first floor. The core locations are included in Figures 2.18 and 2.19. Sample photographs of extracted cores, the exposed cavity and wall ties located with an endoscope inspection are included in Appendix F. Notes of key findings at each core location are also included in Appendix F. The core inspections confirmed that the outer leaf was of good quality dense concrete blocks with some weak and some reasonable mortar jointing. Wall ties were present in the cavity but were difficult to locate due to the narrow cavity and significant amount of mortar droppings in the cavity. The wall ties were of the vertical twist type and where they could be inspected closely appeared to be in good condition.

Figure 2.18: Cores at the Link west elevation of Ward 3 and Maternity

Figure 2.19: 3 Storey south wall cores" – Cores at the south elevation of Ward 3 and Maternity

2.8 Intrusive inspections at Ward 3/Maternity west elevation outer leaf blockwork on 07 October 2024

100mm diameter cores were removed from the west elevation of the 3 Storey building including Ward 3 at the top floor and Maternity on the first floor. The core locations are included in Figure 2.20. Sample photographs of extracted cores, the exposed cavity and wall ties located with an endoscope inspection are included in Appendix G. Notes of key findings at each core location are also included in Appendix G. The core inspections confirmed that the outer leaf was of good quality dense concrete blocks with some poor and generally more reasonable mortar jointing. Wall ties were present in the cavity but were difficult to locate due to the narrow cavity and significant amount of mortar droppings in the cavity. The wall ties were of the vertical twist type and where they could be inspected closely appeared to be in good condition.

Figure 2.20: Cores at the west elevation of Ward 3 and Maternity

2.9 Intrusive inspections in Plant Room and Lift Motor Room at top of 4 storey Building on 08 October 2024

The plant room and lift motor room are located on the west side of the upper level of the 4 storey building. The two rooms occupy the full length of the west elevation with the plant room at the north side and the lift motor room at the south side. Four inner leaf blocks were removed near the top of the walls to allow inspection of the cavity and wall ties. The blocks removed are shown in Figures 2.21 to 2.24. Photographs and notes of key findings are included in Appendix H. The block inspections confirmed that the inner leaf was of good quality dense concrete blocks with generally very weak to some reasonable mortar jointing. Wall ties were present in the cavity. The wall ties were of the vertical twist type and where they could be inspected closely appeared to be in good condition. The cavity was wider than expected varying from 80mm at the north and south elevations to 80 to 90mm at the west elevation. The width of the cavity would suggest that the outer leaf blockwork has displaced over time increasing the cavity width from 50mm noted on the original drawings to the recoded values.

Figure 2.21: Block removed at north wall of Plant Room

Plant Room west wall

Figure 2.22: Block removed at west wall of Plant Room

Figure 2.23: Block removed at west wall of Lift Motor Room

Figure 2.24: Block removed at south wall of Lift Motor Room

2.10 Intrusive inspections in 3 storey building north elevation outer leaf blockwork on 09 and 10 October 2024

100mm diameter cores were removed from the north elevations of the 3 Storey building. The north elevation includes Ward 3 at the upper floor, Maternity and Renal at the first floor and A&E and X-Ray at the ground floor. The core locations are included in Figures 2.25 to 2.27 inclusive. Sample photographs of extracted cores, the exposed cavity and wall ties located with an endoscope inspection are included in Appendix I. Notes of key findings at each core location are also included in Appendix I. The core inspections confirmed that the outer leaf was of good quality dense concrete blocks with reasonable mortar jointing. Wall ties were present in the cavity but were difficult to locate due to the narrow cavity and significant amount of mortar droppings in the cavity. The wall ties were of the vertical twist type and where they could be inspected closely appeared to be in good condition. Dry dash render was noted to boss at the west side of the north elevation wall and boss in patches towards the east side of the wall.

Figure 2.25: Cores at the 3 Storey north elevation wall 1 of 3

Figure 2.26: Cores at the 3 Storey north elevation wall 2 of 3

Figure 2.27: Cores at the 3 Storey north elevation wall 3 of 3

2.11 Intrusive inspections at 4 Storey Building South and East Walls between 11 and 15 October 2024

Cores were extracted from various areas at ground floor and solum levels around the south and east perimeter wall of the 4 Storey building corresponding to the positions of the external walls above the Outpatients roof. The locations of the inspections are shown in Figure 2.28 and Figure 2.29. Sample photographs of extracted cores, the exposed cavity and wall ties located with an endoscope inspection are included in Appendix J. Photographs and notes of key findings are also included in Appendix J. The core inspections confirmed that the outer leaf was of good quality dense concrete blocks with reasonable mortar jointing. The inner leaf at locations around the stair and lift appeared to be of insitu concrete construction. Wall ties were present in the cavity but were difficult to locate due to the narrow cavity and significant amount of mortar droppings in the cavity. The wall ties were of the vertical twist type and where they could be inspected closely appeared to be in good condition. The cavity widths varied from 50 to 55mm at the east wall and 60 to 65mm at the south wall. This would confirm earlier observations that the cavity increases in width towards the top of these walls.

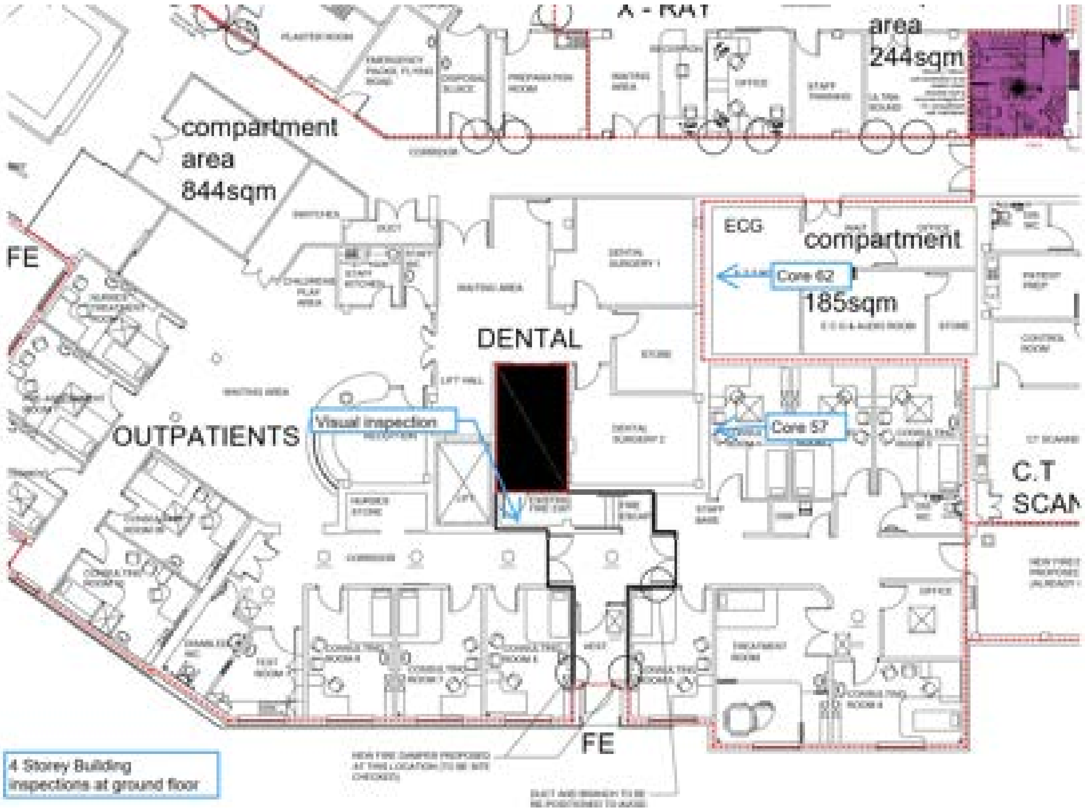


Figure 2.28: 4 Storey South and East Walls (ground floor)

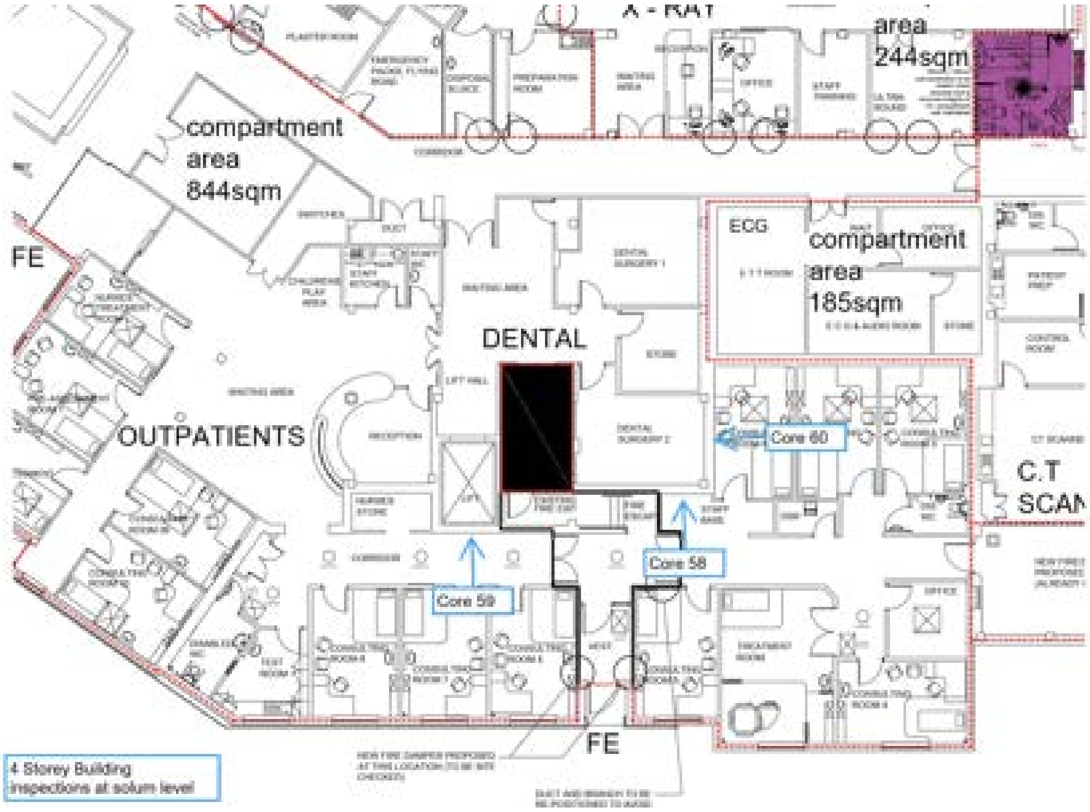


Figure 2.29: 4 Storey South and East Walls (solum)

2.12 Intrusive inspections at Entrance Area and 3 Storey Building North Wall on 14 October 2024

A core was extracted from the west wall of the single storey Outpatients building adjacent to the main entrance to the hospital and an inner leaf block was removed at half landing level of the A & E stair at the north elevation of the 3 Storey building. The locations of the inspections are shown in Figure 2.30. Sample photographs of extracted cores, the exposed cavity and wall ties located with an endoscope inspection are included in Appendix K. Photographs and notes of key findings are also included in Appendix K. The core inspection at the Outpatients confirmed that the outer leaf was of good quality dense concrete blocks with poor mortar jointing. Boss render had been removed previously at this location for safety. The inner leaf block inspection at the 3 Storey building confirmed that the inner and outer leaf was of good quality dense concrete blocks with poor to reasonable mortar jointing. The cavity width was measured as 60mm at this location.

Figure 2.30: Entrance Area and 3 Storey North Wall

2.13 Monitoring of movement in Water Tank Room, Plant Room and Lift Motor Room on 18 October and 21 October 2024

90 degree tell tales were fixed in position at 4no blockwork inspection locations in the Water Tank Room and Plant Room. The blockwork inspection locations which are referenced in Appendices C and H are shown in Figure 2.31. Initial readings on the tell tales were taken on 18 October and following high winds from the south with 70 mph gusts on 20 October and from the west changing to west south west with 55 mph gusts on 21 October. The monitoring results are included in Appendix L. No movement of the outer leaf relative to the inner leaf was recorded in this period. The 0.15mm difference in readings at Block 2 is thought to be due to a slight variance in the position of the camera. There was no water ingress noted at the cavity resulting from the heavy rain which accompanied the winds part of the time.

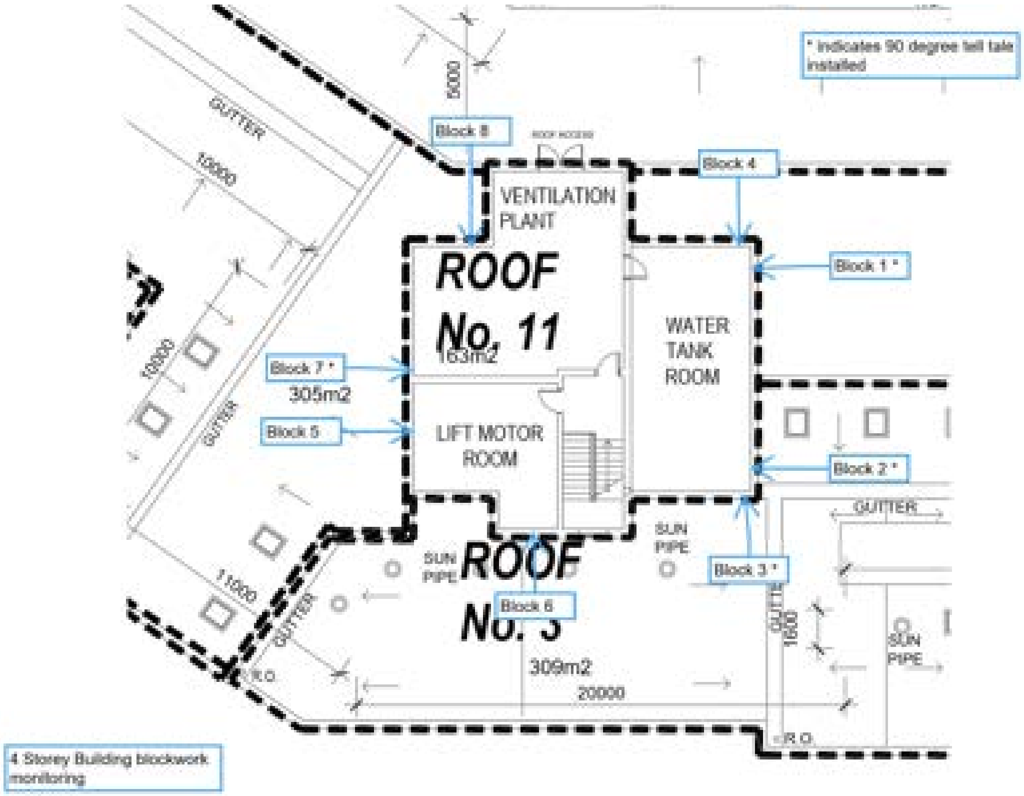


Figure 2.31: Block movement monitoring

3 Mortar Test Report

The mortar samples taken at the 4 storey building were tested by Sandberg and their report is included in Appendix M. Sandberg's report confirms that the mortar is very weak and friable due to low cement content and excess voids. Constituent materials include ordinary portland cement and a marine sand with the possibility of lime in the mix. The report also notes that post construction deterioration of the mortar was not in evidence and that although higher than expected sulfate content was found in two samples there was no evidence of sulfate attack. Referring to Appendix B for core locations, the Cores at 2 and 12 have mortar mix proportions closest to mortar designation (iv) and Core 11 has mix mortar proportions closest to mortar designation (iii). Referring to Appendix C for block locations, Block 3 mortar has mix proportions closest to mortar designation (iii) and Block 4 mortar has mix proportions closest to mortar designation (iv).

4 Discussion

The Phase 1 buildings were constructed between 1985 and 1989 and included reinforced concrete framed structure with inner leaf blockwork infill panels built off the floor slab edge beams and tied to the columns. Outer leaf blockwork was constructed with a constant 50mm cavity throughout the height of the walls. The walls were specified to include 100mm rendered outer leaf blockwork, 25mm air gap plus 25mm rigid board insulation in the cavity and 100mm blockwork inner leaf with plaster finish.

Water ingress has been apparent at the south elevation of Ward 3 and Renal for a long period of time and the condition of the window lintels and cills, movement joints and stop beads on this elevation is poor. A significant horizontal crack at the head of the wall has also been in evidence for a long period. A recent bespoke aluminium flashing which covers the crack has helped reduce but not stop the water ingress. The aluminium flashing has been applied around the south elevations of Ward 3 and Maternity 3 storey block and the west elevation of the 4 storey block. Where the flashing has not been introduced on the north, south and east elevations of the 4 storey block and inset lift motor room the cracking is exposed to view. The crack location coincides with the DPC below the parapet upstand. It is thought that this horizontal crack was the main pathway for water entering the cavity and travelling to the Maternity Labour room at first floor level in the south east corner of the 4 Storey block under severe weather conditions in February 2024. At that time there was a period of up to 5 days of south easterly gales with driving rain. Following the water ingress initial investigations were carried out and when water was sprayed at the top of the 4 Storey east elevation wall by the term contractor similar water ingress was seen in the Labour room. During these inspections it was seen that the east elevation wall appeared to be leaning outward towards the top of the wall and that the sealant in the upper length of the expansion joint on the north elevation, close to the east elevation return, was missing. With concerns over the stability of the blockwork raised the more extensive investigations included in this report were then instructed by NHS.

Our inspections have confirmed that there is an outward displacement of the upper part of the 4 Storey east elevation wall by up to 20mm over a 2metre height. Cavity widths at the lower levels of the east elevation wall were measured as 50 to 55mm. At the top of the wall cavity widths were measured as 90 to 105mm. It is unlikely that the outer leaf has displaced by 55mm in the 35 years since the building was constructed and a displacement of this magnitude is not evident from our inspections. The increase in cavity width with height is likely to be due to some displacement of the outer leaf wall and construction of the inner and outer leafs not being within tolerance originally. The south elevation cavity widths at the lower levels of the wall were measured as 60 to 65mm. At the top of the wall cavity widths were measured as 80 to 95mm. It is unlikely that the outer leaf has displaced by 35mm in the 35 years since the building was constructed and a displacement of this magnitude is not evident from our inspections. The increase in cavity width with height is likely to be due to some displacement of the outer leaf wall and construction of the inner and outer leafs not being within tolerance originally. The cavity width at the north and west elevation walls was measured as 75 to 80mm and 80 to 90mm respectively at the top of the walls. Measurements could not be taken at the lower levels of these walls.

Wall ties were seen to be loose at the south-east corner of the water tank room and it is possible that under high wind suction loading the outer leaf could have displaced relative to the inner leaf with the wall ties sliding in the mortar beds. The mortar test report confirms that the original mix of the mortar included designation (iv), which is equivalent to 2N/mm2 compressive strength at 28 days. This is an unusually weak mix and it is compounded by the high amount of voids found lin the samples giving a very weak and friable mortar over most of the 4 Storey outer leaf walls above ground storey level. On the evidence of inspections in the Water Tank Room, the Plant Room and the Lift Motor Room at the top of the 4 Storey building the inner leaf mortar at the higher levels is also likely to be in poor condition. At the lower levels of the 4 Storey building east and south elevation walls the mortar was found to be of adequate strength. It is our opinion that the outer leaf walls of the 4 Storey building above ground storey should be remediated structurally at the earliest opportunity to eliminate the risk of progressive displacement and instability of the outer leaf relative to the inner leaf.

The other walls including the 3 Storey building walls were found to have variable but generally low strength to adequate mortar to the outer leaf above ground storey. These walls do not present a high risk of displacement of the outer leaf relative to the inner leaf and there is no indication of displacement of the outer leaf occurring. It is our opinion that the 3 Storey outer leaf walls with south and west aspects, except for the Ward 3 and Renal south elevation wall, are repaired to address issues with water ingress including providing replacement lintels, cills movement joints and render beads where required. We would recommend that the Ward 3 and Renal south elevation outer leaf wall is structurally remediated as this wall includes a high proportion of poor mortar and historically has had very significant issues with water ingress over a long period of time.

We would not consider that remedial works are required to the north elevation of the 3 Storey building other than identifying and replacing areas of boss render which present a hazard of falling onto the footpath below. At the single storey Outpatients wall adjacent to the entrance area the mortar was found to be poor but from visual inspection we do not consider there to be a high risk of the outer leaf wall displacing relative to the inner leaf wall and no remedial works are recommended for this area.

5 Recommendations

At the inner leaf inspection locations in the plant room, water tank room and lift motor room the mortar was found to be weak. Accordingly, a remedial solution which avoids tying a new outer leaf to the existing inner leaf blockwork should be avoided. Instead, it is recommended that the outer leaf blockwork walls at the 4 storey building and the south wall of the 3 storey building including Ward 3 and Renal are downtaken and replaced with a cladding system spanning between the reinforced concrete columns. A new cladding system could include cladding rails spanning horizontally between the reinforced concrete columns and supporting a lightweight composite cladding system or similar. Architectural input is required in respect of energy performance and aesthetic appearance of any new cladding system. The time frame for this work should be as soon as possible with scaffolding erected and the existing outer leaf walls taken down in the Spring/Summer of 2025.

The other walls of the Phase 1 construction were found to have stronger mortar and adequate wall tie provision. It is recommended that the outer leaf walls of the 3 storey building to the west of the 4 storey block and along the full north elevation are retained. Remedial works to prevent water ingress should be undertaken as required including provision of new lintels, cills, movement joints and render stop beads. It is recommended that at the north elevation boss render should be identified and replaced within a period of one year. No remedial works are recommended to the single storey Outpatients building walls.

To replace the outer leaf blockwork over the 4 storey elevations and 3 storey part south elevation involves provision of scaffolding on the roof of the Outpatients building. It will be necessary to carry the loads from Outpatients down to either ground floor or solum level and propping will be required in the rooms and corridors adjacent to the 4 storey building where the scaffolding loads are the highest. Transfer beams on the external walls may also be required to carry horizontal load from the scaffolding to the concrete floor diaphragms.

Internal propping to the inner leaf blockwork walls will be required for the period when the existing inner leaf alone is exposed to wind loading. It is anticipated that raking shores back to the concrete floor slabs will be required to meet this requirement.

A. Phase 1 Construction Drawings

MMD-100106891NH03-S-DR-00-00-001

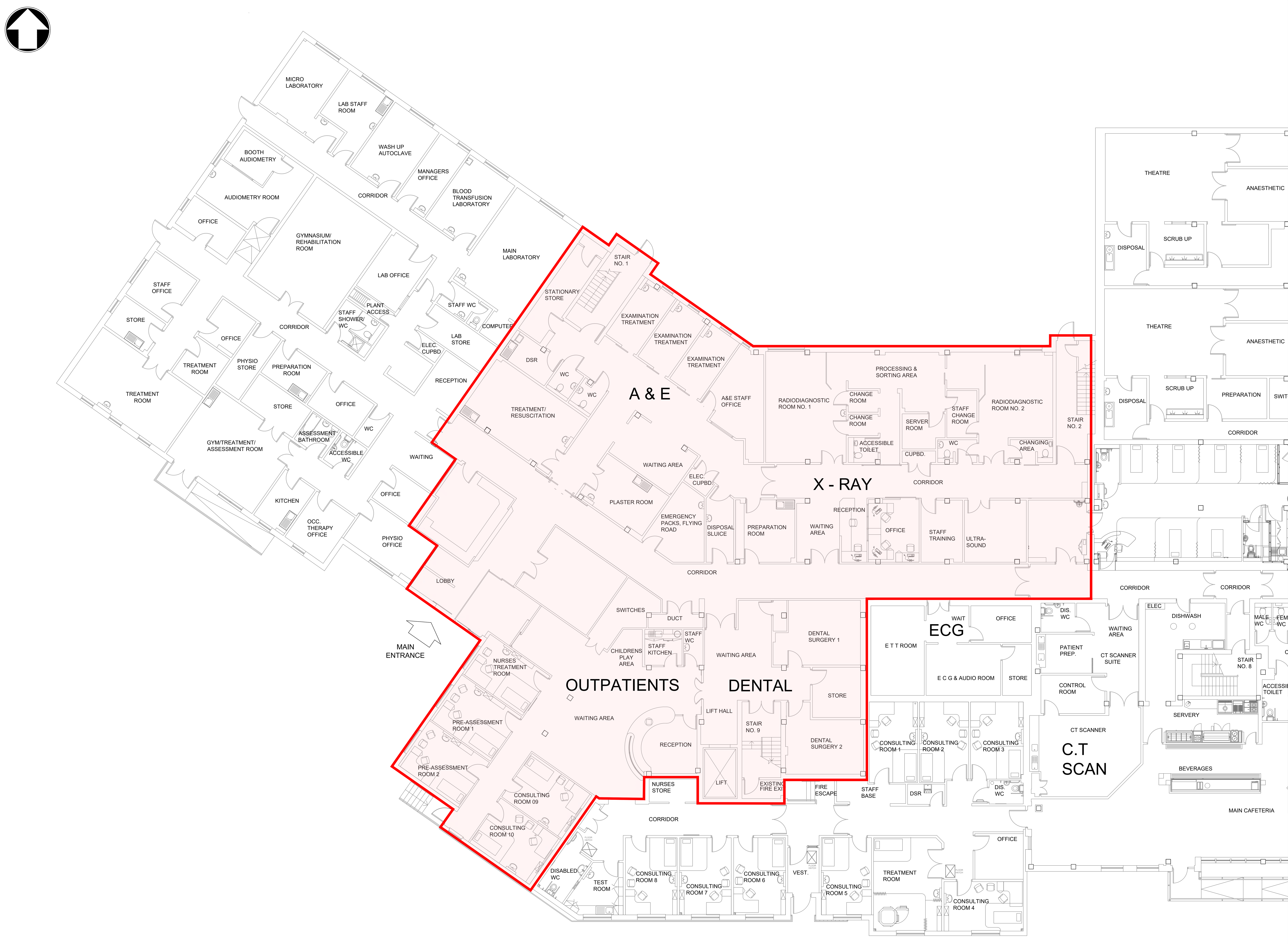
MMD-100106891NH03-S-DR 00-01-001

MMD-100106891NH03-S-DR 00-02-001

MMD-100106891NH03-S-DR 00-03-001

MMD-100106891NH03-S-DR 00-04-001

MMD-100106891NH03-S-DR 00-05-001



GBH GROUND FLOOR
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Notes
1. All dimensions are in metres unless noted otherwise.
2. All levels are in metres unless noted otherwise.

Key to symbols
Phase 1 Construction

Reference drawings
MMD-100106891-S-DR-00-01-001 - First Floor Plan
MMD-100106891-S-DR-00-02-001 - Second Floor Plan
MMD-100106891-S-DR-00-03-001 - Third Floor Plan
MMD-100106891-S-DR-00-RF-001 - Roof Plan
MMD-100106891-S-DR-00-XX-001 - Phase 1 Construction Elevations

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	11:24	EW	Preliminary Issue	NP	JM

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Title
Gilbert Bain Hospital Phase 1 Construction

Condition of External Walls

Ground Floor Plan

Designed	N Pearson	NP	Eng check	A Stout	AS
Drawn	E Wishart	EW	Coordination	N Pearson	NP
Dwg check	N Pearson	NP	Approved	J Moncrieff	JM

Scale at A1	Status	Rev	Security
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Drawing Number
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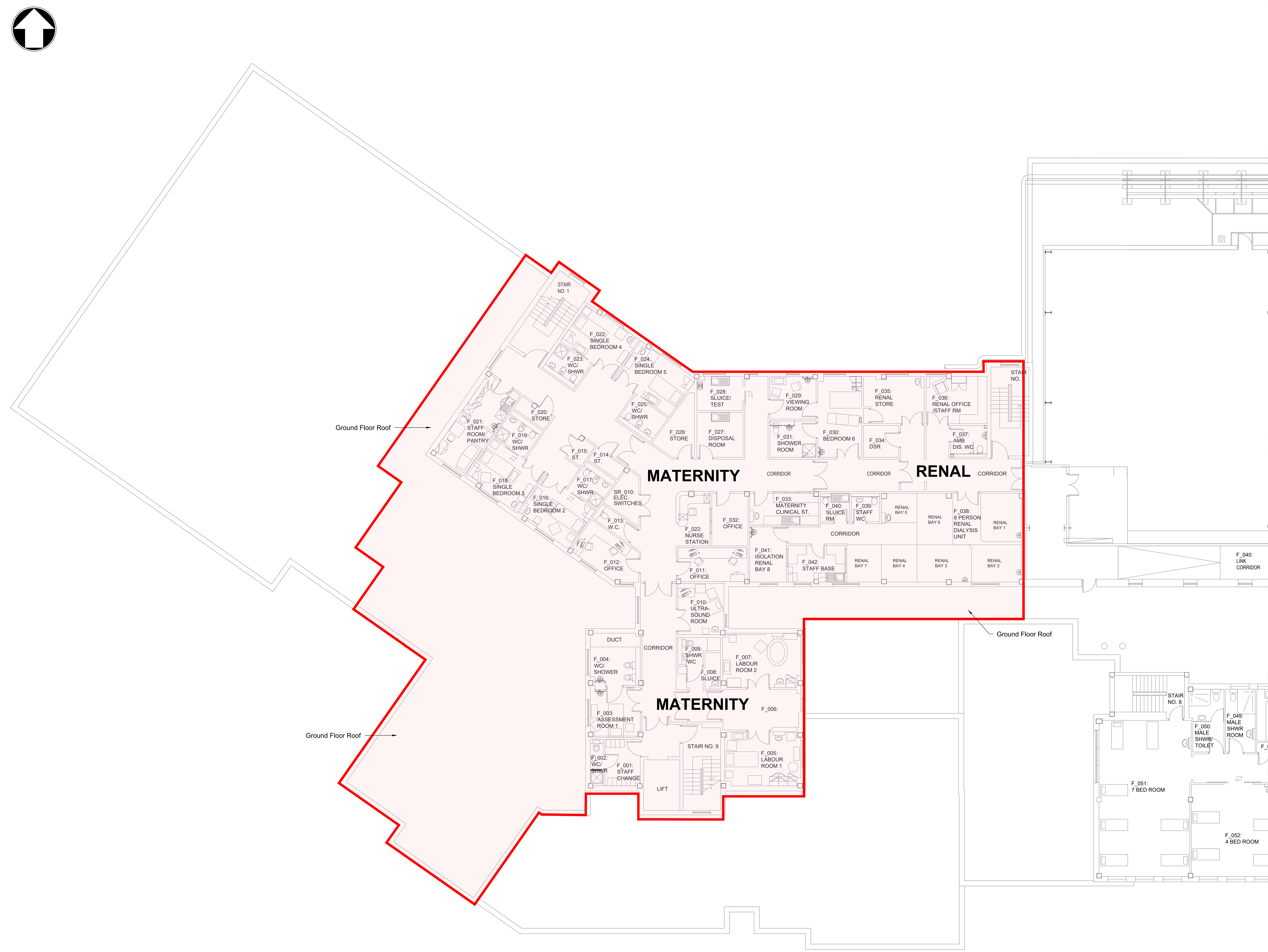

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Key to symbols

Phase 1 Construction

Reference drawings

MMD-100106891-S-DR-00-00-001 - Ground Floor Plan
MMD-100106891-S-DR-00-02-001 - Second Floor Plan
MMD-100106891-S-DR-00-03-001 - Third Floor Plan
MMD-100106891-S-DR-00-RF-001 - Roof Plan
MMD-100106891-S-DR-00-XX-001 - Phase 1 Construction Elevations

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Title
Gilbert Bain Hospital Phase 1 Construction

Condition of External Walls

First Floor Plan

Designed	N Pearson	NP	Eng check	A Stout	AS
Drawn	E Wishart	EW	Coordination	N Pearson	NP
Dwg check	N Pearson	NP	Approved	J Moncrieff	JM

Scale at A1	Status	Rev	Security
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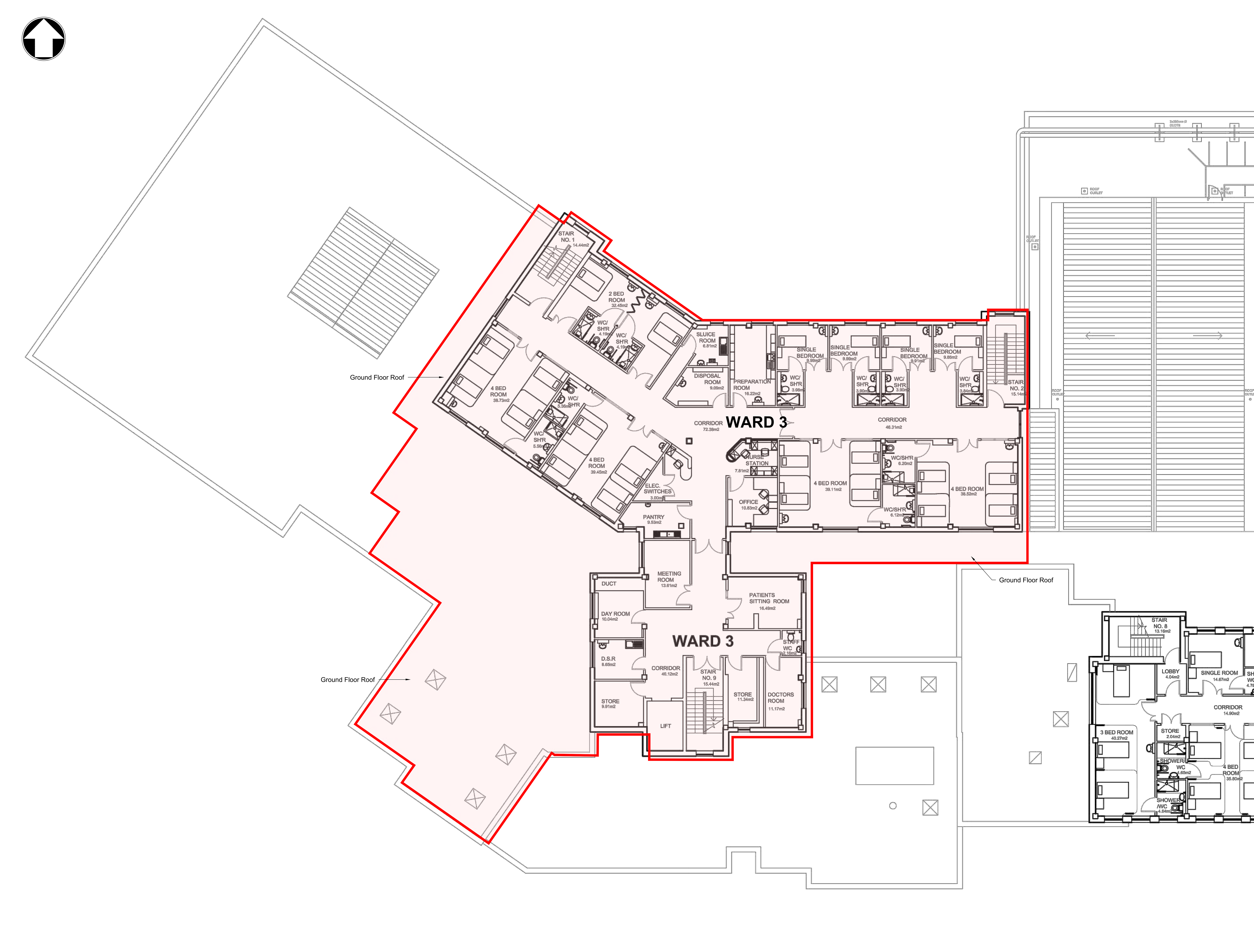

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Client
NHS Shetland
Gilbert Bain Hospital
South Road
Lerwick
ZE1 0TB

Title
Gilbert Bain Hospital Phase 1 Construction

Condition of External Walls

Second Floor Plan

Designed	N Pearson	NP	Eng check	A Stout	AS
Drawn	E Wishart	EW	Coordination	N Pearson	NP
Dwg check	N Pearson	NP	Approved	J Moncrieff	JM

Scale at A1	Status	Rev	Security
1:125	PRE	P1	STD

Drawing Number
MMD-100106891 NH03-S-DR-00-02-001

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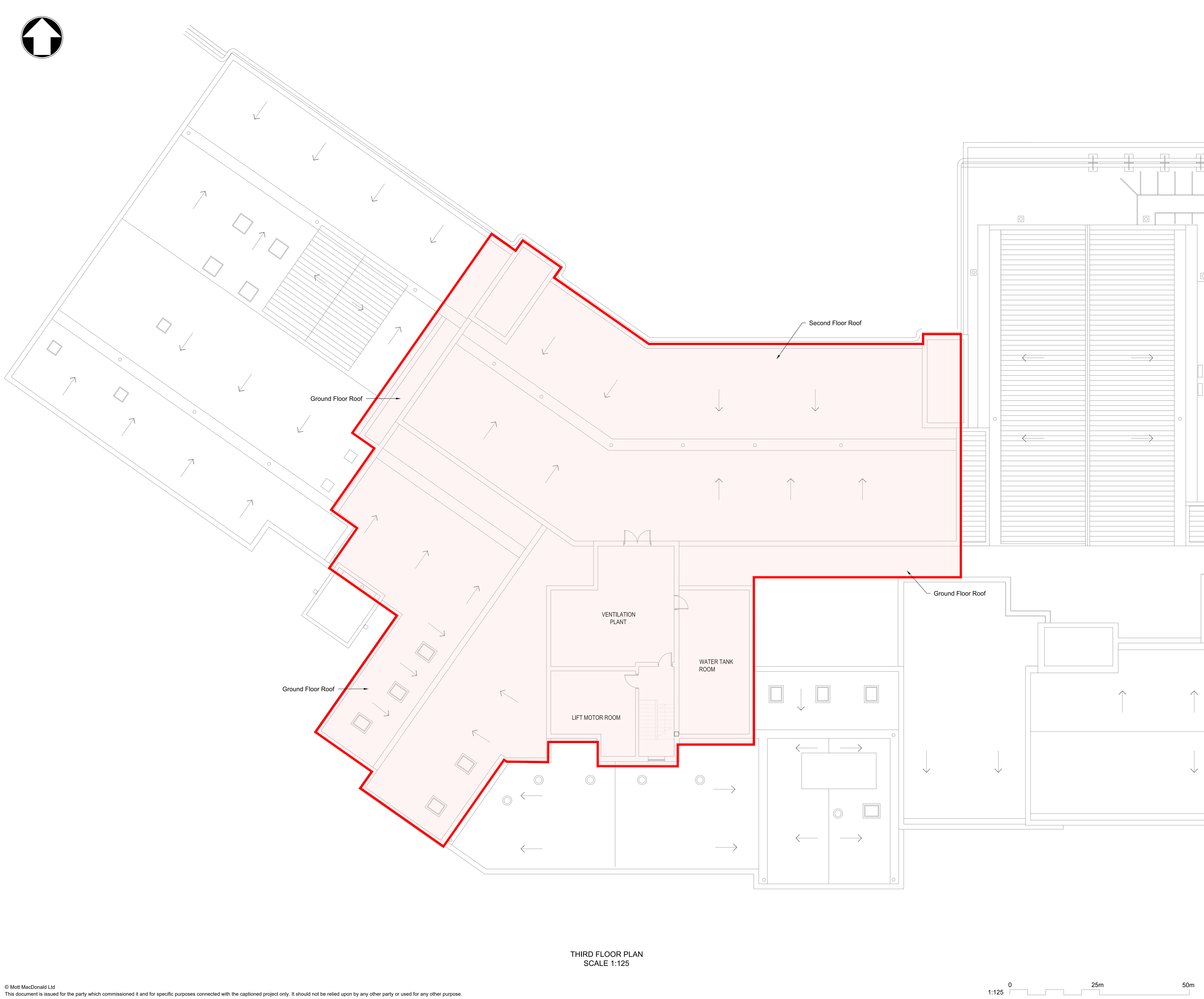

THIRD FLOOR PLAN
SCALE 1:125

Notes

1. All dimensions are in metres unless noted otherwise.
2. All levels are in metres unless noted otherwise.

Key to symbols

Phase 1 Construction

Reference drawings

MMD-100106891-S-DR-00-00-001 - Ground Floor Plan
MMD-100106891-S-DR-00-01-001 - First Floor Plan
MMD-100106891-S-DR-00-02-001 - Second Floor Plan
MMD-100106891-S-DR-00-RF-001 - Roof Plan
MMD-100106891-S-DR-00-XX-001 - Phase 1 Construction Elevations

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	11:24	EW	Preliminary Issue	NP	JM

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Client
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Gilbert Bain Hospital
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Lerwick
ZE1 0TB

Title
Gilbert Bain Hospital Phase 1 Construction

Condition of External Walls

Third Floor Plan

Designed	N Pearson	NP	Eng check	A Stout	AS
Drawn	E Wishart	EW	Coordination	N Pearson	NP
Dwg check	N Pearson	NP	Approved	J Moncrieff	JM

Scale at A1	Status	Rev	Security
1:125	PRE	P1	STD

Drawing Number
MMD-100106891 NH03-S-DR-00-03-001

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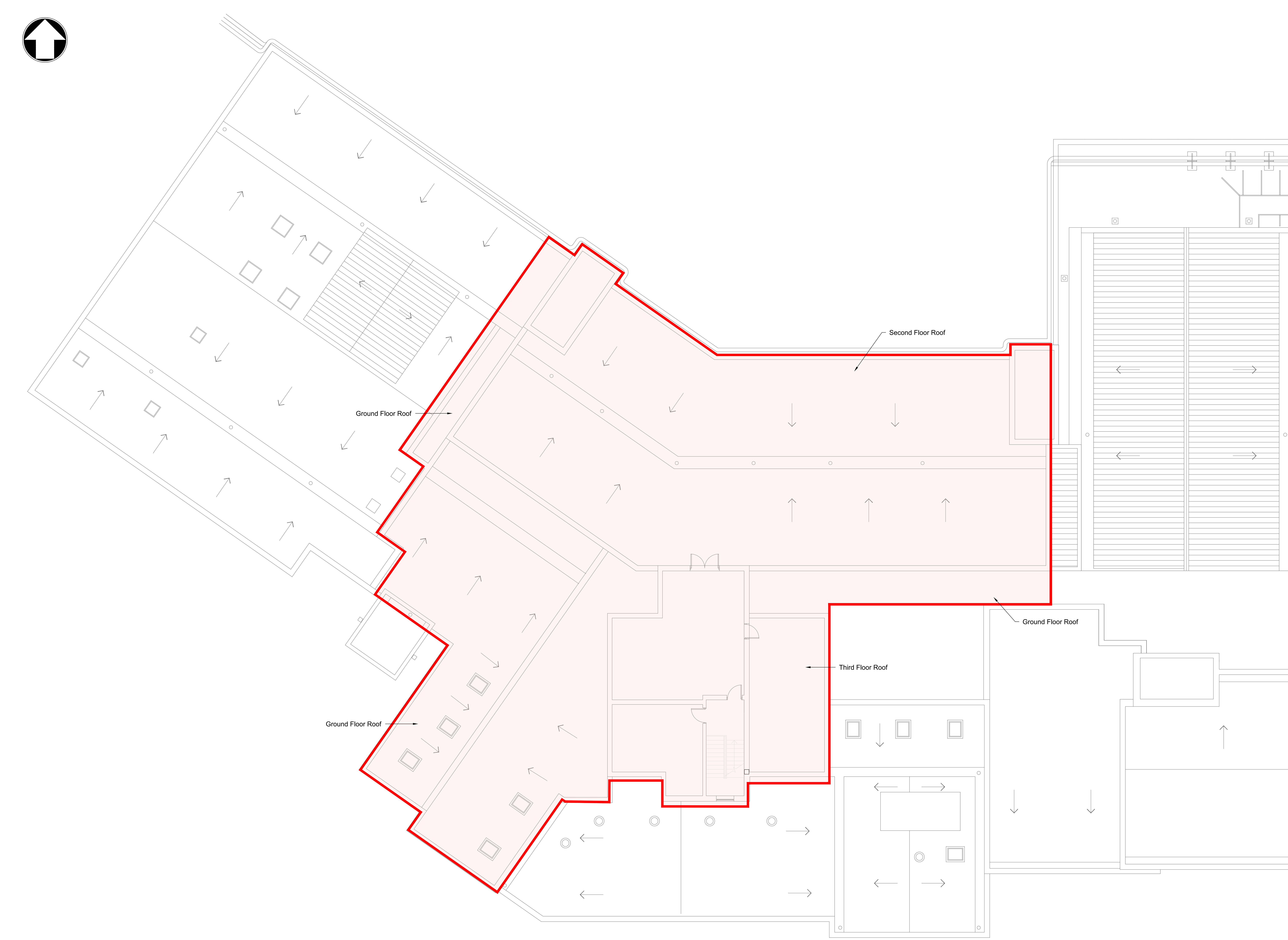

GBH ROOF PLAN
SCALE 1:125

1:125 0 25m 50m

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Notes

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2. All levels are in metres unless noted otherwise.

Key to symbols

Phase 1 Construction

Reference drawings

MMD-100106891-S-DR-00-00-001 - Ground Floor Plan
MMD-100106891-S-DR-00-01-001 - First Floor Plan
MMD-100106891-S-DR-00-02-001 - Second Floor Plan
MMD-100106891-S-DR-00-03-001 - Third Floor Plan
MMD-100106891-S-DR-00-XX-001 - Phase 1 Construction Elevations

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	11:24	EW	Preliminary Issue	NP	JM

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Client

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Gilbert Bain Hospital
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Title

Gilbert Bain Hospital Phase 1 Construction

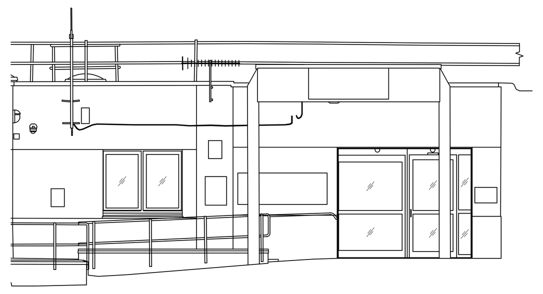
Condition of External Walls

Roof Plan

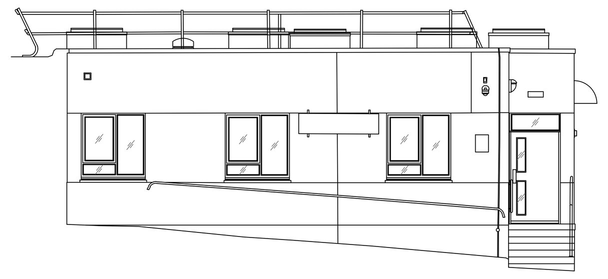
Designed	N Pearson	NP	Eng check	A Stout	AS
Drawn	E Wishart	EW	Coordination	N Pearson	NP
Dwg check	N Pearson	NP	Approved	J Moncrieff	JM

Scale at A1	Status	Rev	Security
1:125	PRE	P1	STD

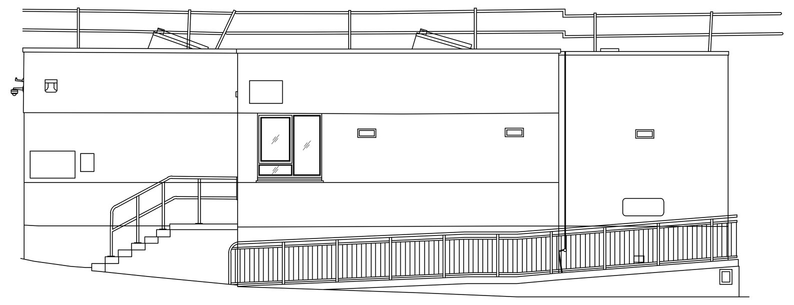
Drawing Number
MMD-100106891 NH03-S-DR-00-RF-001



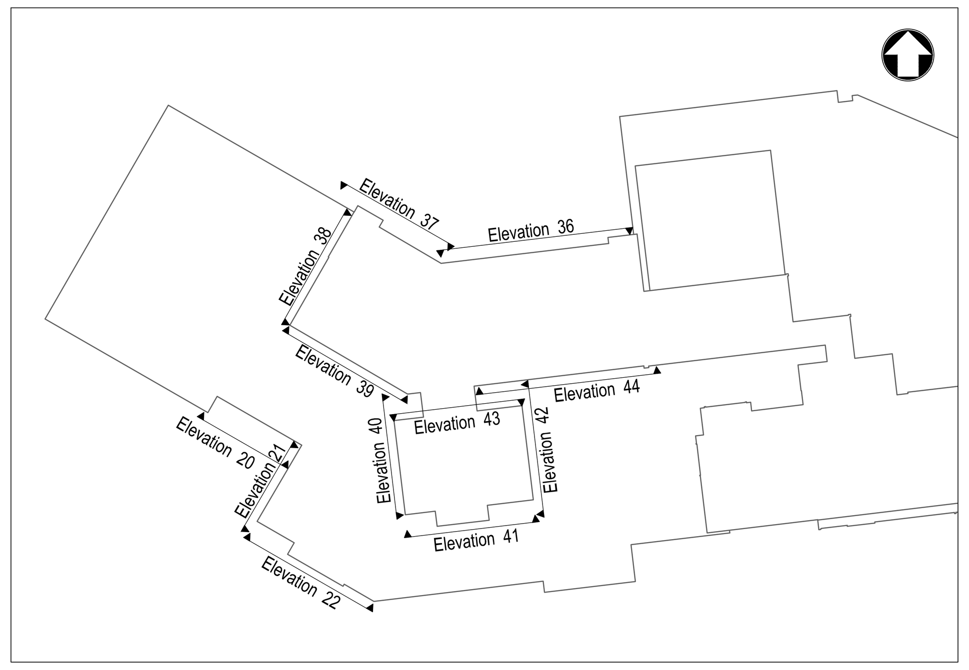
ELEVATION 20
SINGLE STOREY MAIN ENTRANCE SOUTH ELEVATION
SCALE 1:100



ELEVATION 21
SINGLE STOREY OUTPATIENTS EAST ELEVATION
SCALE 1:100

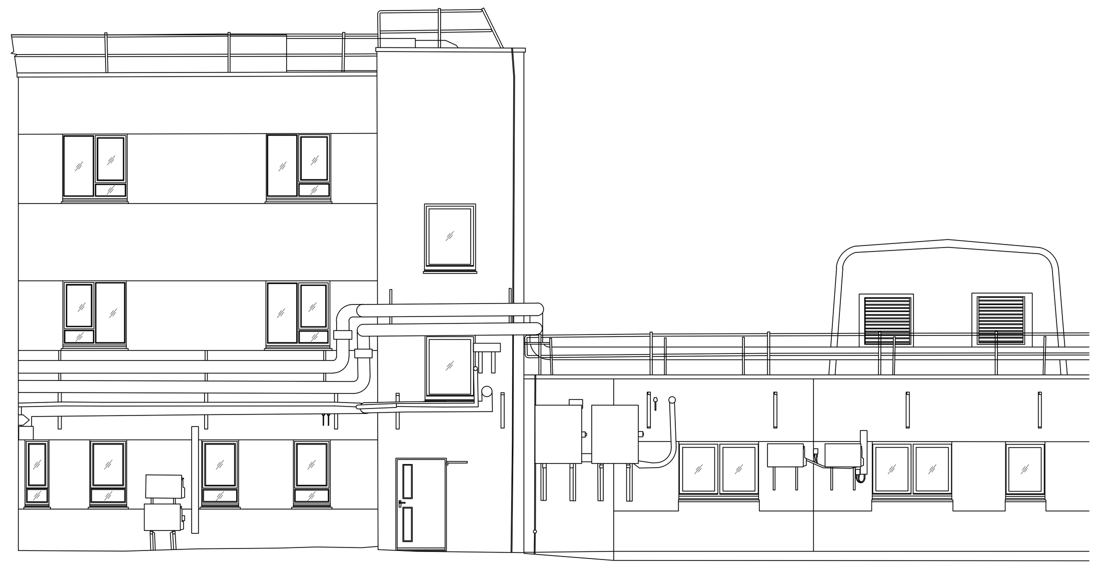


ELEVATION 22
SINGLE STOREY OUTPATIENTS SOUTH ELEVATION
SCALE 1:100

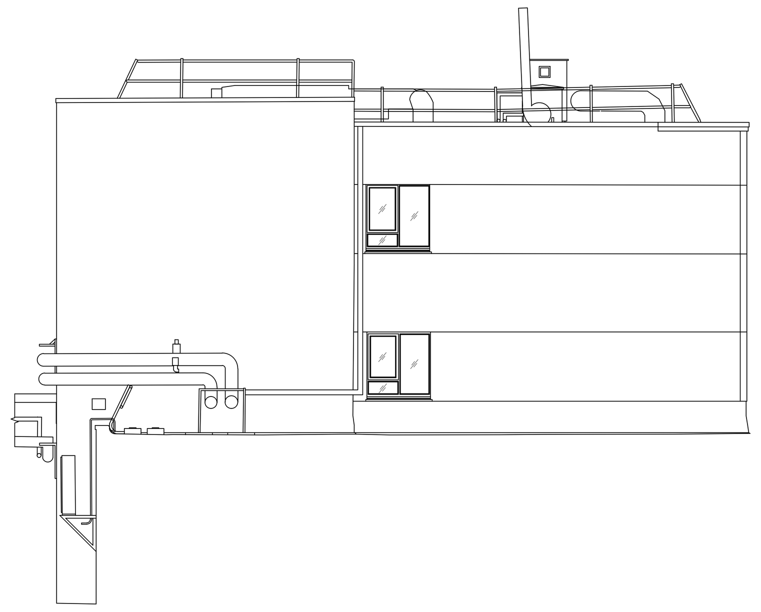


GILBERT BAIN HOSPITAL
ELEVATION LOCATION PLAN
SCALE 1:500

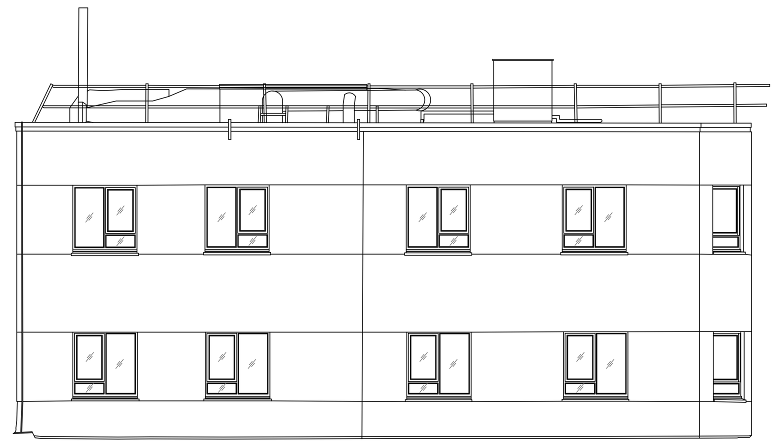
ELEVATION 36
THREE STOREY NORTH ELEVATION
SCALE 1:100



ELEVATION 37
THREE STOREY NORTH ELEVATION
SCALE 1:100

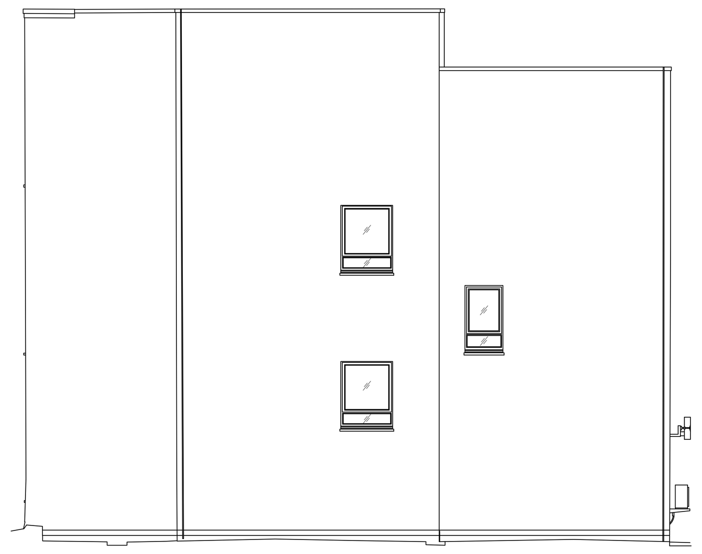


ELEVATION 38
THREE STOREY WEST ELEVATION
SCALE 1:100

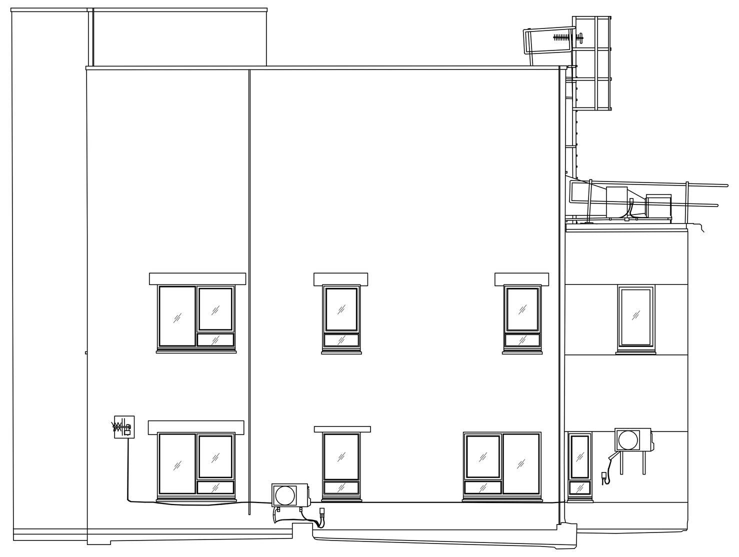


ELEVATION 39
THREE STOREY SOUTH ELEVATION
SCALE 1:100

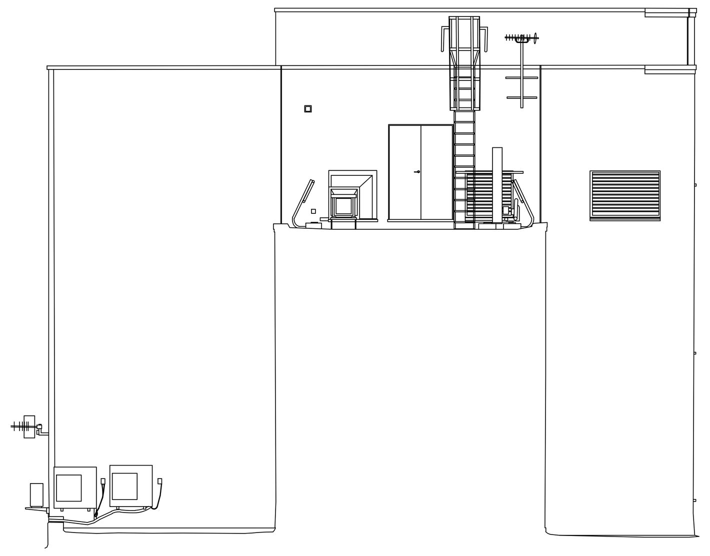
ELEVATION 40
FOUR STOREY WEST ELEVATION
SCALE 1:100



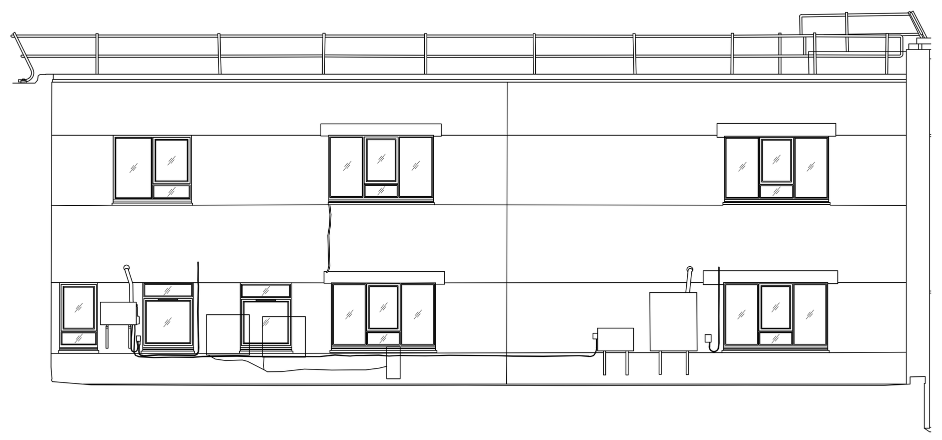
ELEVATION 41
FOUR STOREY SOUTH ELEVATION
SCALE 1:100



ELEVATION 42
FOUR STOREY EAST ELEVATION
SCALE 1:100



ELEVATION 43
FOUR STOREY NORTH ELEVATION
SCALE 1:100



ELEVATION 44
THREE STOREY SOUTH ELEVATION
SCALE 1:100

1:100 0 5m 10m

Notes

1. All dimensions are in metres unless noted otherwise.
2. All levels are in metres unless noted otherwise.

Key to symbols

Reference drawings

MMD-100106891-S-DR-00-00-001 - Ground Floor Plan
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MMD-100106891-S-DR-00-02-001 - Second Floor Plan
MMD-100106891-S-DR-00-03-001 - Third Floor Plan
MMD-100106891-S-DR-00-RF-001 - Roof Plan

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Gilbert Bain Hospital
South Road
Lerwick
ZE1 0TB

Title
Gilbert Bain Hospital Phase 1 Construction

Condition of External Walls

Elevations

Designed	N Pearson	NP	Eng check	A Stout	AS
Drawn	E Wishart	EW	Coordination	N Pearson	NP
Dwg check	N Pearson	NP	Approved	J Moncrieff	JM

Scale at A0	Status	Rev	Security
1:100	PRE	P1	STD

Drawing Number
MMD-100106891 NH03-S-DR-00-XX-001

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B. Core locations at 4 Storey Building (above Outpatients roof)

4 Storey East Elevation Wall

4 Storey South Elevation Wall

4 Storey North Elevation Wall

Summary of Cores at 4 Storey Building (above Outpatients roof)

Core reference	Block condition	Mortar condition	No of Wall Ties found and condition	Comments
Core 1 (east wall)	100mm thick dense concrete in good condition	Poor – weak and friable	1 no 300mm to right lower of core/covered with mortar	25mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 2 (east wall)	100mm thick dense concrete in good condition	Poor – weak and friable	None	35mm cavity to 25mm insulation board. Lot of mortar droppings in cavity. Mortar sample taken
Core 3 (east wall)	100mm thick dense concrete in good condition	Poor – very weak and friable	1 no 250mm to right upper of core/good	35mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 4 (east wall)	100mm thick dense concrete in good condition	Poor – very weak, friable and damp mortar with void joint 30mm to left of core hole	1 no 250mm to right upper of core/good. 1 no 400mm to left lower of core/covered with mortar	30mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 5 (south wall)	100mm thick dense concrete in good condition	Poor – very weak and friable	None	55mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 6 (east wall)	100mm thick dense concrete in good condition	Poor –weak and friable	None	35mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 7 (east wall)	100mm thick dense concrete in good condition	Poor –weak and friable	1 no 600mm to left of core/good. Suspected ties 300mm to right and 900mm below core/covered with mortar	35mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 8 (east wall)	100mm thick dense concrete in good condition	Poor –weak and friable	1 no 150mm to right upper of core/good. Suspected tie 500mm to left lower of core/covered with mortar	20mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 9 (east wall)	100mm thick dense concrete in good condition	Poor –weak and friable	None	70mm cavity with no insulation but insulation board above and below. Lot of mortar droppings in cavity

Core 10 (east wall)	100mm thick dense concrete in good condition	No mortar as core through centre of block	Suspected ties 700mm to right, 200mm to left and 450mm below core/covered with mortar	20mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 11 (south wall)	100mm thick dense concrete in good condition	Poor – very weak and friable	1 no 100mm to right of core/minor corrosion and insufficient embedment. Suspected tie 600mm to left lower of core/covered with mortar	55mm cavity to 25mm insulation board. Lot of mortar droppings in cavity. Mortar samples (x2) taken
Core 12 (south wall)	100mm thick dense concrete in good condition	Poor – very weak and friable. Joint in outer leaf void of mortar.	1 no 500mm to right upper of core/good. 1 no 500mm to left upper of core/good. 1 no 100mm below core/good	40mm cavity to 25mm insulation board. Lot of mortar droppings in cavity. Mortar sample taken
Core 13 (north wall)	100mm thick dense concrete in good condition	Poor –weak and friable.	Suspected ties 500mm to left upper of core, 500mm to left lower of core and 200mm to right of core/covered with mortar	25mm cavity to 25mm insulation board. Lot of mortar droppings in cavity.
Core 14 (north wall)	100mm thick dense concrete in good condition	Poor –weak and friable.	Suspected ties 500mm to left upper of core, 500mm to left lower of core, 200mm to right of core and 1350mm below core/covered with mortar	25mm cavity to 25mm insulation board. Lot of mortar droppings in cavity.

Cores 1 and 2


2024. 8.31 9:48

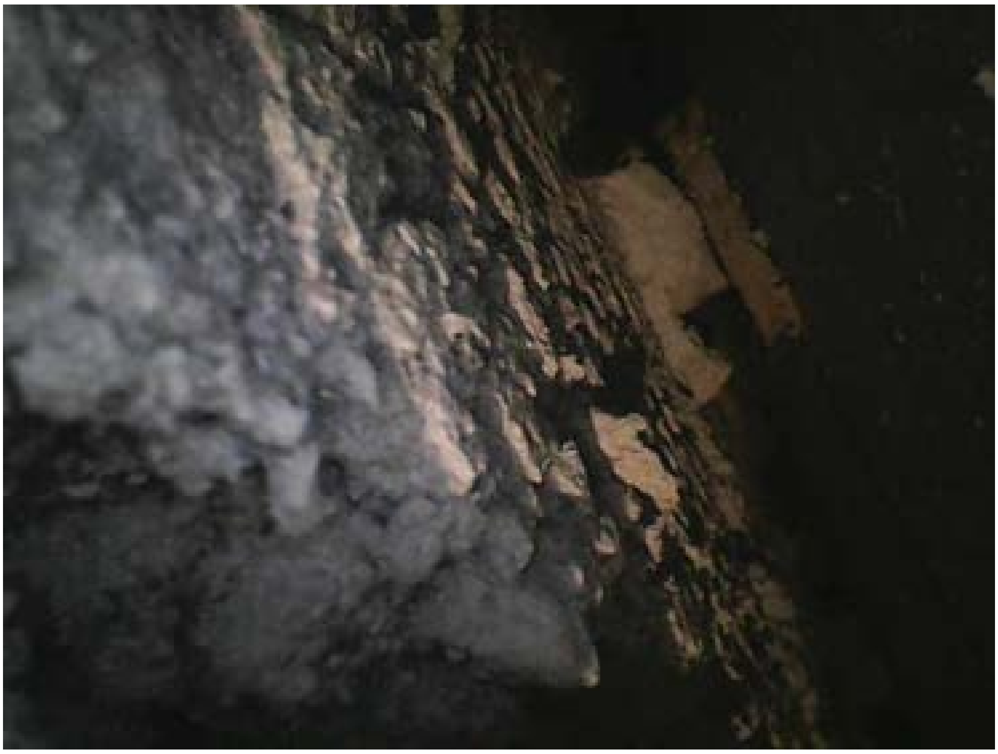
Core 10

Core 11

Core 13

Wall tie at Core 12

Wall tie at Core 14



C. Location of blocks removed at Water Tank Room

Water Tank Room NE corner

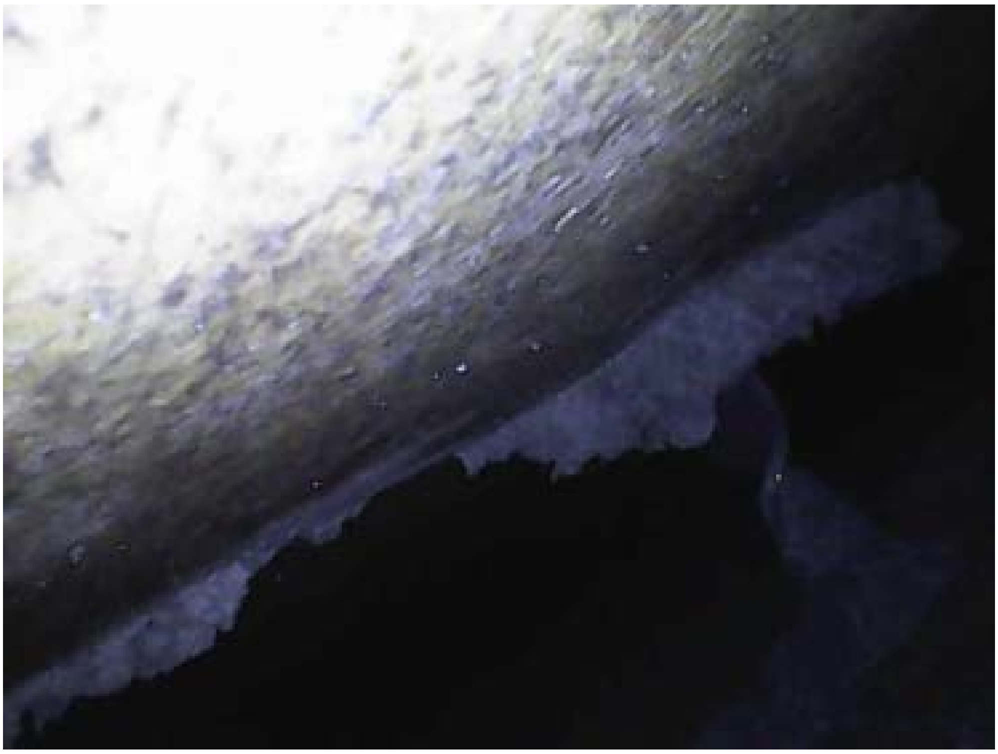
Water Tank Room SE corner

Summary of Inspections at Water Tank Room inner leaf blockwork

Block reference	Block condition	Mortar condition	No of Wall Ties found and condition	Comments
Block 1 (east wall)	100mm thick dense concrete in good condition	Poor – inner leaf weak and friable; outer leaf very weak and friable	3no to upper, lower and right side of block within 450mm and 2 no adjacent to RC column to left of block/good	105mm cavity overall with 25mm insulation board displaced 20mm off inner leaf wall. Insufficient wall tie embedment in outer leaf.
Block 2 (east wall)	100mm thick dense concrete in good condition	Poor – inner leaf weak and friable; outer leaf very weak and friable	4no to top of block, upper right, lower left and lower right side of block within 900mm/good	90mmm cavity overall with 25mm insulation board displaced 20mm off inner leaf wall. Wall tie at top of block slightly loose. Insufficient wall tie embedment in outer leaf.
Block 3 (south wall)	100mm thick dense concrete in good condition	Poor – inner leaf very weak and friable; outer leaf very weak and friable	4no to top of block, upper, upper right and lower right side of block within 450mm and 2 no adjacent to RC column to left of block/good	95mm cavity overall with 25mm insulation board displaced 20mm off inner leaf wall. Wall tie at top of block loose. Insufficient wall tie embedment in outer leaf. Mortar sample taken
Block 4 (north wall)	100mm thick dense concrete in good condition	Poor – inner leaf very weak and friable; outer leaf very weak and friable	3no to upper, lower and left side of block within 450mm and 2 no adjacent to RC column to right of block/covered in mortar	75mm cavity overall with 25mm insulation board displaced 15mm off inner leaf wall. Insufficient wall tie embedment in outer leaf. Mortar sample taken

Block 1

Block 2



Block 3

Block 4

D. Core locations at 3 Storey Building, South Elevation of Ward 3/Renal (above Outpatients roof)

Summary of Cores at 3 Storey Building, South Elevation of Ward 3/Renal (above Outpatients roof)

Core reference	Block condition	Mortar condition	No of Wall Ties found and condition	Comments
Core 15	100mm thick dense concrete in good condition	Poor – satisfactory strength but 50% voided joint at core	Suspected ties 300mm and 1200mm above and 600mm below core/covered with mortar	20mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 16	100mm thick dense concrete in good condition	Poor – weak and friable	1no 1200mm to right of core/good. 2no suspected 450mm below and 900mm to left lower of core/covered with mortar	20mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 17	100mm thick dense concrete in good condition	Reasonable – strength of mortar satisfactory	1 no at core/good. 2no suspected 600mm above and 600mm to left lower of core/covered with mortar	25mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 18	100mm thick dense concrete in good condition	Reasonable – strength of mortar satisfactory	3no suspected 900mm to left, 600mm to left upper and 600mm to left lower of core/covered with mortar	20mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 19	100mm thick dense concrete in good condition	Reasonable – strength of mortar satisfactory	1no at core/good. 2no suspected 900mm above and 600mm to right lower of core/covered with mortar	30mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 20	100mm thick dense concrete in good condition	Poor –weak and friable	2no 350mm to upper left and 250mm to lower right of core/good. 1no suspected tie 800mm to upper right/covered with mortar	30mm cavity to 25mm insulation board. Lot of mortar droppings in cavity

Core 15

Core 17

Core 20

Wall tie at Core 19

E. Core locations at 4 Storey Building (above Outpatients roof)

4 Storey south wall cores and 4 Storey west wall cores

4 Storey South Elevation Wall

4 Storey West Elevation Wall

Summary of Cores at 4 Storey Building (above Outpatients roof)

Core reference	Block condition	Mortar condition	No of Wall Ties found and condition	Comments
Core 21 (south wall)	100mm thick dense concrete in good condition	Reasonable - mortar satisfactory	2no 600mm above core and 450mm to right of core /good. 1no 1200mm below core/covered with mortar	30mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 22 (south wall)	100mm thick dense concrete in good condition	Poor – weak and friable	1no 300mm to right upper of core/good. 1no 900mm below core/covered with mortar	25mm cavity to 25mm insulation board. Lot of mortar droppings in cavity.
Core 23 (south wall)	100mm thick dense concrete in good condition	Poor – weak and friable	3 no 250mm to left upper of core, 1200mm to right lower of core and 900mm below core/covered in mortar	30mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 24 (south wall)	100mm thick dense concrete in good condition	Poor - weak and friable	2 no 600mm to right upper of core and at core/covered with mortar. 1 no 900mm to right of core/good	35mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 25 (south wall)	100mm thick dense concrete in good condition	Poor – weak and friable	2 no 650mm to right upper of core and 450mm to right lower of core/covered with mortar. 1 no 200mm to left upper of core/good	25mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 26 (south wall)	100mm thick dense concrete in good condition	Poor –weak and friable	3 no 600mm to right upper of core, 900mm to right of core and at core/okay	25mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 27 (west wall)	100mm thick dense concrete in good condition	Poor –weak and friable	2 no 600mm to left lower of core and 900mm below core core/covered with mortar	20mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 28 (west wall)	100mm thick dense concrete in good condition	Poor –weak and friable	3 no 450mm to left of core, 450mm to right of core and 1000mm below core/covered in mortar	20mm cavity to 25mm insulation board. Lot of mortar droppings in cavity

Core 29 (west wall)	100mm thick dense concrete in good condition	Poor –weak and friable	2 no suspected ties 600mm to left upper of core and 200mm to right lower of core/covered with mortar	30mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 30 (west wall)	100mm thick dense concrete in good condition	Poor –weak and friable	Not possible to insert endoscope in cavity as cavity full of mortar	15mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 31 (west wall)	100mm thick dense concrete in good condition	Poor – weak and friable	1 no suspected tie 150mm to left of core/covered with mortar. Mortar in cavity prevents further inspections	20mm cavity to 25mm insulation board. Lot of mortar droppings in cavity.
Core 32 (west wall)	100mm thick dense concrete in good condition	Poor - weak and friable.	1 no suspected tie 950mm to right upper of core/covered with mortar. Mortar in cavity prevents further inspections	35mm cavity to 25mm insulation board. Lot of mortar droppings in cavity.

Core 21

Core 26

Core 29

Core 32

Wall tie at Core 28

F. Core locations at Ward 3/Maternity Link West Elevation and Ward 3/Maternity South Elevations (above Outpatients roof)

Ward 3/Maternity Link Wall

3 Storey south wall cores

Ward 3 and Maternity South Elevation Wall

Summary of Cores at Ward 3/Maternity Link West Elevation and Ward 3/Maternity South Elevation (above Outpatients roof)

Core reference	Block condition	Mortar condition	No of Wall Ties found and condition	Comments
Core 33 (link west wall)	100mm thick dense concrete in good condition	Poor to reasonable – low strength	2no 1200mm above core and 450mm to right upper of core /good.	20mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 34 (link west wall)	100mm thick dense concrete in good condition	Poor – weak and friable	1no at core/good. 2no 450mm above core and 450mm below core/covered with mortar	30mm cavity to 25mm insulation board. Lot of mortar droppings in cavity.
Core 35 (south wall)	100mm thick dense concrete in good condition	Poor to reasonable – low strength	2 no 300mm above of core and 500mm to right lower of core/covered in mortar	15mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 36 (south wall)	100mm thick dense concrete in good condition	Poor to reasonable- low strength	No ties found due to mortar in cavity	15mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 37 (south wall)	100mm thick dense concrete in good condition	Reasonable – strength adequate	2 no 950mm to right upper of core and 300mm to right of core/covered with mortar	10mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 38 (south wall)	100mm thick dense concrete in good condition	Reasonable – strength adequate	3 no 900mm above core, 450mm to left of core and 500mm to right lower of core/good	25mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 39 (south wall)	100mm thick dense concrete in good condition	Reasonable – strength adequate	3 no 300mm above core, 450mm to left of core and 600mm to right lower of core/covered with mortar	10mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 40 (south wall)	100mm thick dense concrete in good condition	Poor to reasonable –low strength	2 no 600mm to left lower of core and 850mm to left lower of core/good	40mm cavity to 25mm insulation board. Lot of mortar droppings in cavity

Core 34

Core 38

Core 40

G. Core locations at Ward 3/Maternity West Elevation (above Outpatients roof)

Summary of Cores at Ward 3/Maternity West Elevation (above Outpatients roof)

Core reference	Block condition	Mortar condition	No of Wall Ties found and condition	Comments
Core 41 (west wall)	100mm thick dense concrete in good condition	Reasonable – strength adequate	2 no 150mm to left lower and 1200mm to right upper of core /good. 1 no 1350mm to left upper of core/covered with mortar	40mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 42 (west wall)	100mm thick dense concrete in good condition	Poor – weak and friable	1no 250mm to left of core/good. 1no 650mm to right of core/covered with mortar	25mm cavity to 25mm insulation board. Lot of mortar droppings in cavity.
Core 43 (west wall)	100mm thick dense concrete	Poor – very weak and friable. 50%	1no 750mm to right upper of core/good. 1no	30mm cavity to 25mm insulation

	in good condition	void joint at core	350mm to left upper of core/covered with mortar	board. Lot of mortar droppings in cavity
Core 44 (west wall)	100mm thick dense concrete in good condition	Reasonable – strength adequate	2 no 400mm to left lower and 400mm to right upper of core /covered with mortar	30mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 45 (west wall)	100mm thick dense concrete in good condition	Reasonable – strength adequate	2 no 900mm to left upper of core and 600mm below core/good. 1 no 550mm to right upper of core/covered with mortar	30mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 46 (west wall)	100mm thick dense concrete in good condition	Reasonable – strength adequate	2 no 800mm to left of core and 100mm to right of core/covered with mortar	35mm cavity to 25mm insulation board. Lot of mortar droppings in cavity

Core 41

Core 43

Core 45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Wall tie at Core 42

H. Location of blocks removed at Plant Room and Lift Motor Room

Plant Room north wall

Plant Room west wall

Lift Motor Room west wall

Lift Motor Room south wall

Summary of Inspections at Plant Room and Lift Motor Room inner leaf blockwork

Block reference	Block condition	Mortar condition	No of Wall Ties found and condition	Comments
Block 5 (west wall)	100mm thick dense concrete in good condition	Poor – inner leaf weak and friable; outer leaf weak and friable	1no at bottom of block/good; 2 no 600mm to right lower of block and 900mm below block/covered in mortar	80mm cavity overall with 25mm insulation board displaced 25mm off inner leaf wall.
Block 6 (south wall)	100mm thick dense concrete in good condition	Reasonable – adequate strength mortar to both inner and outer leaf	2no at top left of block and 450mm to right of block/good; 1 no 500mm to left lower of block/covered in mortar	80mm cavity overall with 25mm insulation board displaced 25mm off inner leaf wall.
Block 7 (west wall)	100mm thick dense concrete in good condition	Poor – inner leaf very weak and friable; outer leaf very weak and friable	3no 300mm to upper right of block, 200mm to upper left of block and 225mm below block/good	90mm cavity overall with no insulation board.
Block 8 (north wall)	100mm thick dense concrete in good condition	Poor – inner leaf very weak and friable; outer leaf very weak and friable	2no 450mm to upper right of block and 450mm to lower right of block/good	80mm cavity overall with 25mm insulation board displaced 20mm off inner leaf wall.

Block 5

Block 6

Block 7

Block 8

I. Core locations at 3 Storey Building North Elevation Wall

3 Storey North Elevation Wall

3 Storey North Elevation Wall

3 Storey North Elevation Wall

Summary of Cores at 3 Storey Building North Elevation Wall

Core reference	Block condition	Mortar condition	No of Wall Ties found and condition	Comments
Core 47 (north wall)	100mm thick dense concrete in good condition	Reasonable – mortar strength is adequate	3 no 500mm to right upper of core, 300mm below core and 550mm to left lower of core/covered with mortar	20mm cavity to 25mm insulation board. Lot of mortar droppings in cavity. Dry dash render is boss.
Core 48 (north wall)	100mm thick dense concrete in good condition	Reasonable – mortar strength is adequate	2 no 800mm to right upper of core and 800mm to left upper of core/good. 1 no 1100mm above core/covered with mortar	35mm cavity to 25mm insulation board. Lot of mortar droppings in cavity. Dry dash render is boss.
Core 49 (north wall)	100mm thick dense concrete in good condition	Reasonable – mortar strength is adequate	2 no 1100mm to right upper of core and 1100mm to left upper of core/good. 1 no 300mm below core/covered with mortar	30mm cavity to 25mm insulation board. Lot of mortar droppings in cavity. Dry dash render is slightly boss.

Core 50 (north wall)	100mm thick dense concrete in good condition	Reasonable – mortar strength is adequate	2 no 600mm to left of core and 300mm to right of core /covered with mortar	35mm cavity to 25mm insulation board. Lot of mortar droppings in cavity.
Core 51 (north wall)	100mm thick dense concrete in good condition	Reasonable – mortar strength is adequate	2 no 600mm to left upper of core and 700mm to right upper of core /good	35mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 52 (north wall)	100mm thick dense concrete in good condition	Reasonable – mortar strength is adequate	2 no 600mm to left upper of core and 250mm to left lower of core /good	35mm cavity to 25mm insulation board. Lot of mortar droppings in cavity. Overall cavity width 65mm. Dry dash render is boss.
Core 53 (north wall)	100mm thick dense concrete in good condition	Reasonable – mortar strength is adequate	2 no 150mm below core and 1050mm below core/covered with mortar	50mm cavity to 25mm insulation board. Lot of mortar droppings in cavity. Dry dash render boss in patches.
Core 54 (north wall)	100mm thick dense concrete in good condition	Reasonable – mortar strength is adequate	3 no 450mm to right of core, 250mm below core and 1150mm below core/covered with mortar	40mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 55 (north wall)	100mm thick dense concrete in good condition	Reasonable – mortar strength is adequate	2 no 600mm to left upper of core and 50mm below core/good. 1 no 600mm to right upper of core/covered with mortar	50mm cavity to 25mm insulation board. Lot of mortar droppings in cavity
Core 56 (north wall)	100mm thick dense concrete in good condition	Poor to reasonable – low strength	3 no 400mm to right upper, 600mm to left lower and 600mm to right lower of core/covered with mortar	30mm cavity to 25mm insulation board. Lot of mortar droppings in cavity

Core 48

Core 51

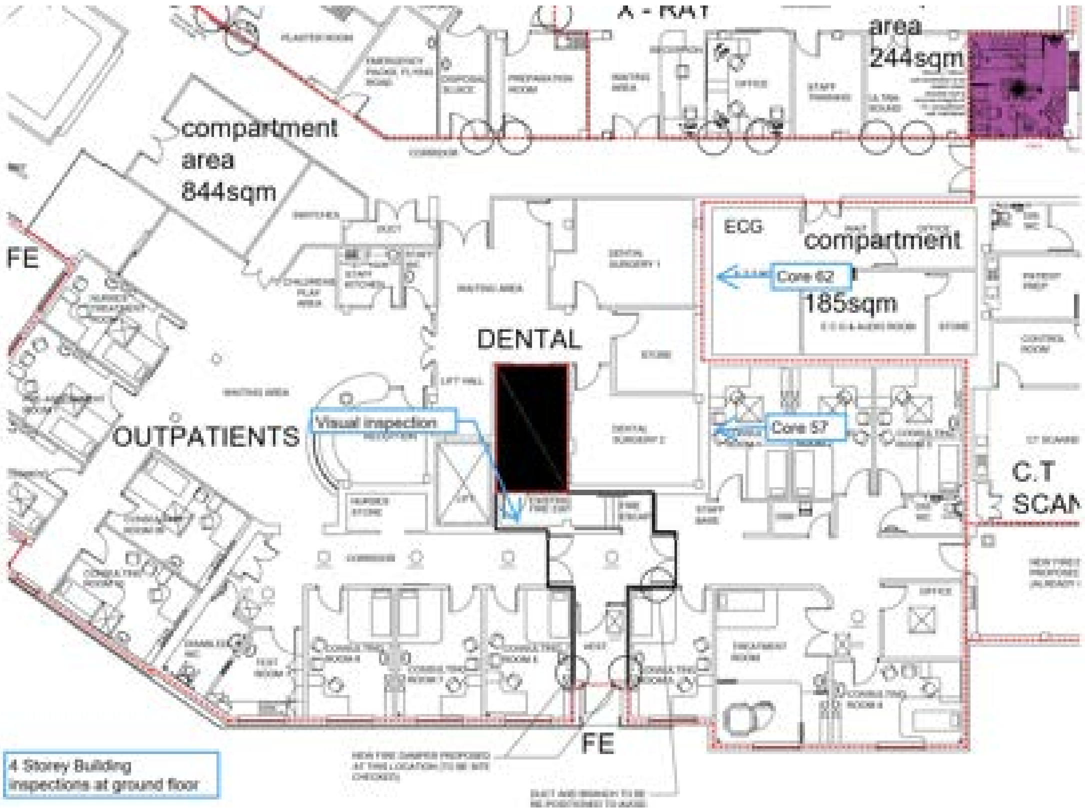

2024.10. 9 12:05

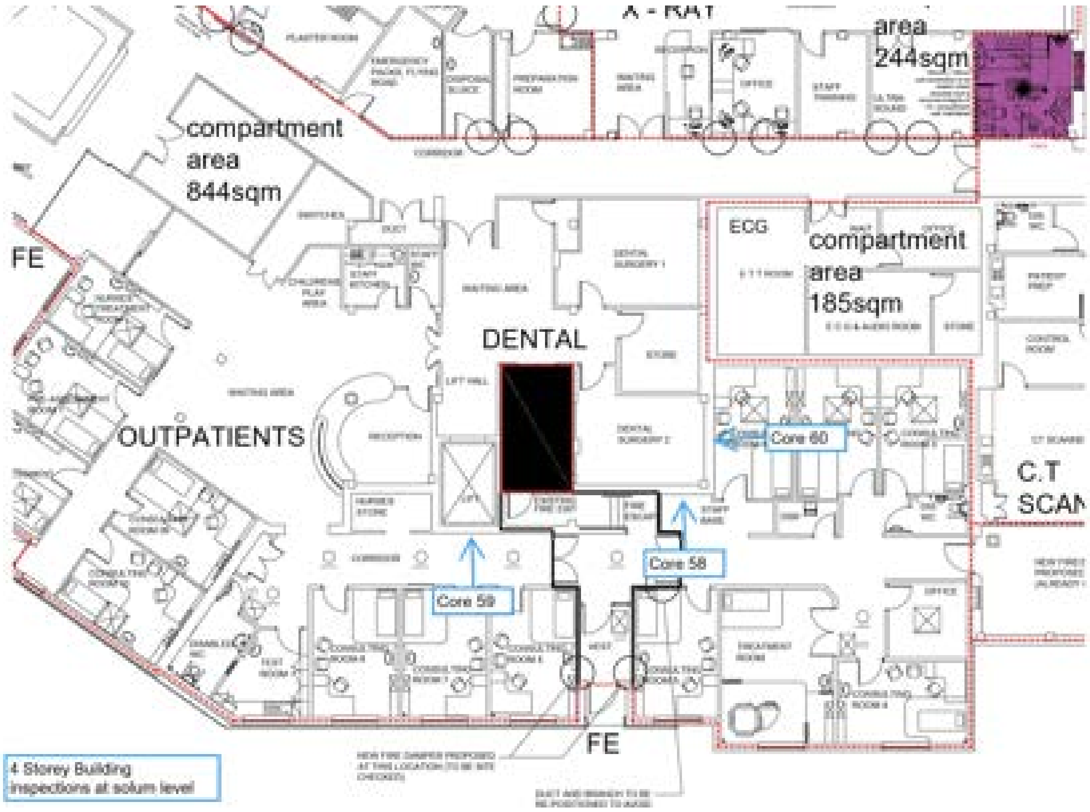
Core 52

Core 55

Core 56

J. Core locations at 4 Storey Building South and East Elevation Walls at Ground Floor and Solum Levels





Summary of Cores at 4 Storey Building South and East Elevation Walls at Ground Floor and Solum Levels

Core reference	Block condition	Mortar condition	No of Wall Ties found and condition	Comments
Visual inspection (south wall, ground storey)	100mm thick dense concrete outer leaf block in good condition. 200mm thick inner leaf of either dense concrete block or insitu concrete in good condition	Reasonable – mortar strength is adequate	2 no 450mm to right of service opening and 450mm to left of service opening/good. 1 no 450mm above service opening/covered with mortar.	65mm width cavity. No insulation noted at service opening for dry riser. Lot of mortar droppings in cavity.
Core 57 (east wall, ground storey)	100mm thick dense concrete in good condition	Reasonable – mortar strength is adequate	2 no 250mm to left upper of core and 700mm to right of core/covered with mortar	15mm cavity to 25mm insulation board. Lot of mortar droppings in cavity. Cavity width is 50mm overall. 150mm loadbearing stud wall construction in

				Outpatients Consulting Room 1 noted to east of Phase 1 construction
Core 58 (south wall, solum level)	100mm thick dense concrete in good condition. Inner leaf either of dense concrete block or insitu concrete in good condition	Reasonable – mortar strength is adequate	2 no 600mm to right upper of core and 600mm to left upper of core/good	60mm width cavity. No insulation noted. Lot of mortar droppings in cavity. Concrete solum with 1125mm high blockwork to wall plate.
Core 59 (south wall, solum level)	100mm thick dense concrete in good condition. Inner leaf of insitu concrete in good condition	Reasonable – mortar strength is adequate	2 no 600mm to left upper of core and 450mm to right of core/good	65mm width cavity. No insulation noted. Lot of mortar droppings in cavity. Concrete solum with 990mm high blockwork to wall plate.
Core 60 (east wall, solum level)	100mm thick dense concrete in good condition	Reasonable – mortar strength is adequate	1 no 700mm to right upper of core/good. 1 no 100mm to right of core/covered with mortar	55mm width cavity. No insulation noted. Lot of mortar droppings in cavity. 140mm loadbearing blockwork wall substructure in Outpatients Consulting Room 1 noted to east of Phase 1 construction
Core 62 (east wall, ground storey)	100mm thick dense concrete in good condition	Reasonable – mortar strength is adequate	2 no 600mm to left upper of core and 600mm to left lower of core/covered with mortar	20mm cavity to 25mm insulation board. Lot of mortar droppings in cavity. Cavity width is 55mm overall. 105mm non-loadbearing stud wall construction in ECG ETT room noted to east of Phase 1 construction

Visual inspection

Core 57


2024.10.11 10:08


2024.10.11 10:08

Core 58


2024.10.12 8:16

Core 60

Wall tie at Core 59

Core 62

K. Core Location at Entrance Area and block inspection at 3 Storey Building North Elevation Wall

Summary of Inspections at Entrance Area and 3 storey Building North Elevation

Core reference	Block condition	Mortar condition	No of Wall Ties found and condition	Comments
Core 61 (west wall, single storey)	100mm thick dense concrete in good condition.	Poor – weak and friable	2 no 200mm above and 900mm to right upper of core/good.	20mm cavity to 25mm insulation board. Lot of mortar droppings in cavity. Boss render has been removed previously due to proximity to main entrance.
Inner leaf block removed (3 Storey building stairwell north elevation wall)	140mm thick dense concrete inner leaf block in good condition	Poor to reasonable – low strength mortar in both inner and outer leafs	1 no at top of block/good. 1 no 600mm to left lower of block/covered with mortar	15mm gap to 25mm insulation board. Lot of mortar droppings in cavity. Cavity width is 60mm overall.

Core 61

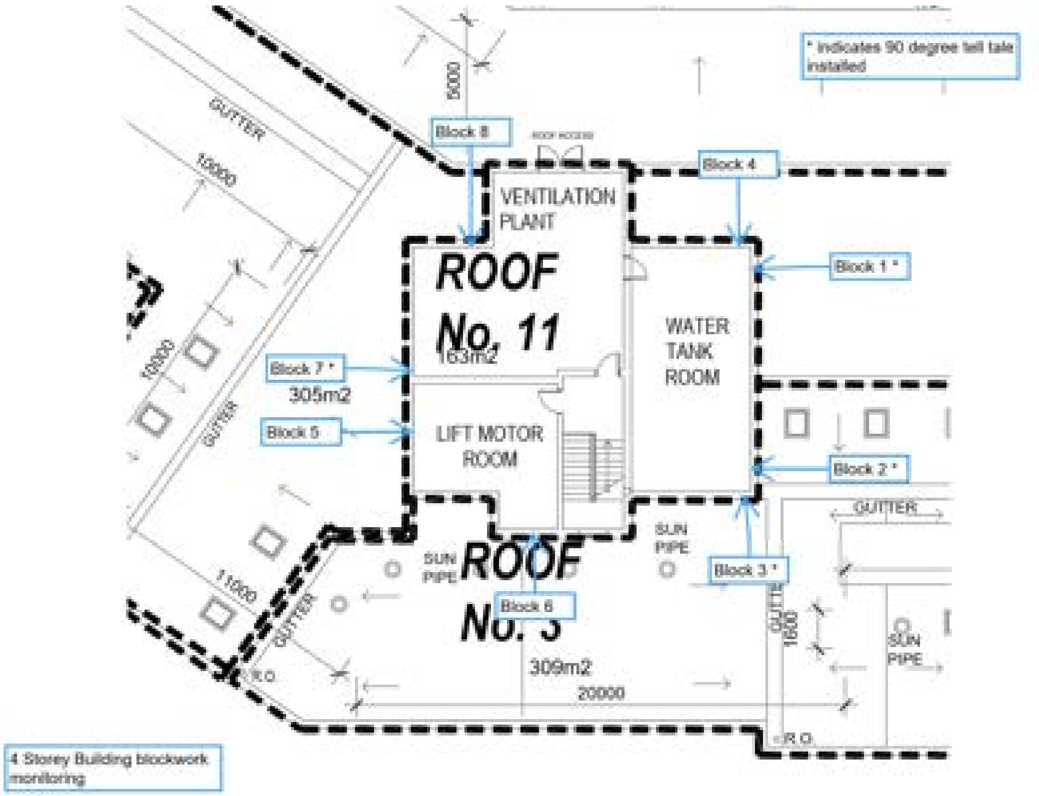

2024. 10. 14 8:46


2024. 10. 14 8:52

Inner leaf block


2024. 10. 14 11:18

L. Blockwork Movement Monitoring at Water Tank Room, Plant Room and Lift Motor Room



Summary of Blockwork Movement Monitoring at Water Tank Room, Plant Room and Lift Motor Room

Block reference	Cavity width (October 2024)	Tell tale reading on 18/10/24	Tell tale reading on 21/10/24	Comments
Block 1 (Water Tank Room east wall)	105mm	+0.45mm	+0.45mm	No difference in readings
Block 2 (Water Tank Room east wall)	90mm	+1.85mm	+1.7mm	0.15mm difference in readings is thought to be due to a slight variance in the position of the camera
Block 3 (Water Tank room south wall)	95mm	-2.9mm	-2.9mm	No difference in readings
Block 4 (Water Tank Room north wall)	75mm	N/A	N/A	N/A
Block 5 (Lift Motor Room west wall)	80mm	N/A	N/A	N/A
Block 6 (Lift Motor Room south wall)	80mm	N/A	N/A	N/A
Block 7 (Plant Room west wall)	90mm	-2.85mm	-2.85mm	No difference in readings
Block 8 (Plant Room north wall)	80mm	N/A	N/A	N/A

Block 1

Block 2

Block 3

Block 7

M. Sandberg Report

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Report - 78193/K

REPORT ON THE PETROGRAPHIC EXAMINATION AND MIX PROPORTION ANALYSIS OF SEVEN MORTAR SAMPLES
(Site – Gilbert Bain Hospital / Ref. Lerwick Project 100106891NH03)

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This report comprises
Cover page
5 pages of text
Appendix A – 1 page of petrographic descriptions
Appendix B – 7 pages of photographs illustrating the samples
Appendix C – 6 pages of photomicrographs of the thin sections
Appendix D – 8 pages of chemical test certificates
Appendix E – 6 pages of petrographic procedures and glossary
Back page

For the attention of Mr Neil Pearson

1 November 2024

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Report - 78193/K

REPORT ON THE PETROGRAPHIC EXAMINATION AND MIX PROPORTION ANALYSIS OF SEVEN MORTAR SAMPLES
(Site – Gilbert Bain Hospital / Ref. Lerwick Project 100106891NH03)

1 INTRODUCTION

Seven mortar samples were provided for analysis on 13 September 2024. We were advised that the samples were from a building that was approximately 35 years old and that there was concern that the mortar may have deteriorated or had a low cement content. It was requested that a sample from the Outer Leaf and another from the Inner Leaf be examined petrographically and that the remaining samples be tested for mix proportions. The table in Section 2 below lists testing carried out on each sample. Instructions to proceed with the analysis were submitted in a test schedule dated 11 September 2024.

2 SAMPLES

The following samples were provided for analysis:

Laboratory reference	Client / site reference	Sample mass	Testing carried out:
K19481/1	Outer leaf, Core 2	55.9 g	Mix proportions
K19481/2	Outer leaf, Core 11, 1 of 2	48.7 g	Petrographic examination
K19481/3	Outer leaf, Core 11, 2 of 2	39.7 g	Mix proportions
K19481/4	Outer leaf, Core 12	64.3 g	Mix proportions
K19481/5	Inner leaf, East Elvn (South)	20.8 g	Petrographic examination
K19481/6	Inner leaf, North Elevation	9.2 g	Mix proportions
K19481/7	Inner leaf, South Elevation	12.8 g	Mix proportions

3 TEST METHODS

The petrographic testing was carried out in accordance with BS 1881-211, 2016[1]. A summary of the procedures followed and a glossary of terms used in the description of the samples are given in Appendix E. In brief, the following work was carried out.

(i) The samples were examined as received and photographed.

(ii) A longitudinal fluorescent resin impregnated thin section was prepared from the most deteriorated inner ends of each core representing the cores between their inner surfaces and maximum depths of 67mm. Each thin section measured about 45x67mm.

(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 sections in fluorescent light using the petrological microscope.

(iv) The mortar mix proportions were determined in accordance with BS 4551:2005+A2:2013[2].

4 CHEMICAL TESTING FOR MIX PROPORTIONS

The full results of the mix proportions testing are given in Appendix D. The results are summarised in the table below.

Laboratory reference	Client / site reference	Binder type	Volume ratio PC: lime: aggregate	BS 4551 Mortar designation
K19481/1	Outer leaf, Core 2	Portland cement : lime : sand	1: 0.1: 8.7	iv (nearest)
K19481/3	Outer leaf, Core 11, 2 of 2	Portland cement : lime : sand	1: 0.9: 5.8	iii
K19481/4	Outer leaf, Core 12	Portland cement : lime : sand	1: 1.0: 7.1	iv
K19481/6	Inner leaf, North Elevation	Portland cement : lime : sand	1: 0.6: 7.6	iv (nearest)
K19481/7	Inner leaf, South Elevation	Portland cement : lime : sand	1: 0.6: 6.1	iii

The chemical testing showed that the sulfate contents of the following samples were higher than to be expected from the constituent materials:

- K19481/3 Outer leaf, Core 11, 2 of 2
- K19481/4 Outer leaf, Core 12

5 PETROGRAPHIC EXAMINATION RESULTS (OUTER LEAF AND INNER LEAF SAMPLES)

5.1 Petrographic description of the samples

Petrographic descriptions of the samples are given in Appendix A. The samples as received are illustrated in Appendix B and photomicrographs illustrating the thin sections are given in Appendix C.

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

[2] BS 4551:2005+A2:2013 Mortar – Methods of test for mortar and screed – Chemical analysis and physical testing.

6 SUMMARY AND DISCUSSION

6.1 Cement contents

Three samples from the Outer leaf and two from the Inner leaf were tested for mix proportions. The chemical testing indicates a Portland cement / lime binder. It should however be noted that the small amounts of shell in the sand may inflate the lime content determined petrographically. The mix proportions testing indicates BS 4551 Mix Designations in the range of iii to iv.

The chemical testing showed that the sulfate contents of the following samples were higher than to be expected from the constituent materials:

- K19481/3 Outer leaf, Core 11, 2 of 2
- K19481/4 Outer leaf, Core 12

It should however be noted that none of the samples showed evidence of sulfate attack of the mortar in the thin sections.

6.2 Petrographic observations (Samples K19481/2 and 5)

(i) Aggregate type

The aggregate is finely graded in both samples with the majority of the particles likely to pass a 600µm sieve. The fine aggregate is a sand rather than a crushed rock fine aggregate and the presence of shell in the sand indicates that the sand is likely to be of marine origin.

The sand is of nearly identical composition in both samples consisting of abundant schist particles with much smaller amounts of quartzite and phyllite.

(ii) Potential aggregate properties

The majority of the aggregate particles in all samples would be expected to have a moderately high compressive strength and low water absorption.

The free mica and dust content of the sand is low.

(iii) Aggregate deterioration

No evidence has been found to suggest deterioration of the sand. The complete carbonation of the mortar matrix means that alkali -aggregate will not occur even though the aggregate includes some rock types possibly reactive with alkalis in cement paste.

(iv) Binder type

The binder in both samples is Portland cement based. The possible presence of small amounts of well-dispersed lime cannot however be ruled out. In the Inner leaf sample (K19481/5) the occasional patches of microcrystalline calcite in the matrix suggest the possible presence of small amounts of lime. The chemical testing confirms the presence of lime, although the quantities of lime detected by the chemical analysis may be overestimates due to the shell in the sand.

The matrix of the mortar in both samples contains the carbonated outlines of hydrated Portland cement grains that broadly resemble ordinary Portland cement and BS EN 197-1[3] CEM I cement. No fly ash or GGBS are present.

(v) Moisture movement

No evidence is seen to suggest weakening of the mortar since its placement.

No evidence of moisture movement is seen. The lack of void infillings with secondary minerals such as ettringite, gypsum or calcite indicates that little alteration of the mortar has occurred.

6.3 Comments on the strength characteristics of the mortar (Samples K19481/2 and 5)

Both samples are subjectively weaker and more friable than would be typical for Portland cement based mortars. The microscopic analysis shows that high void content is likely to be a factor in this. The chemical testing also shows the binder content to be low, especially in the case of the Outer Leaf Cores 2 and 12 and the Inner Leaf north elevation sample and this again would be a factor in the apparently weak and friable nature of the mortar.

6.4 General magnitude of deterioration

With respect to the Levels of Deterioration table given in Appendix E the levels of deterioration of the tow mortar samples examined petrographically are considered to be as follows:

Laboratory reference	**Client sample reference**	**Level of deterioration** (1 = Low / 10 = High)
K19481/2	Outer leaf, Core 11, 1 of 2	Level 1
K19481/5	Inner leaf, East Elevation (South)	Level 1

[3] BS EN 197-1:2011 Cement. Composition, specifications and conformity criteria for common cements (Incorporating corrigenda November 2011, October 2015 and February 2019)

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7 CONCLUSIONS

7.1 Both samples examined petrographically are of the same type of mortar with a Portland cement based binder and containing fine siliceous sand that is likely to be of marine origin.

7.2 No evidence is seen to suggest *in-situ* weakening of the mortar due to processes of deterioration such as sulfate attack or leaching.

7.3 High void contents and low binder contents are both factors that would be expected adversely affect the strength and durability of the mortar.

7.4 Samples K19481/3 (Outer leaf, Core 11, 2 of 2) and K19481/4 (Outer leaf, Core 12) had elevated sulfate levels but the petrographic examination of these samples showed no evidence of sulfate attack.

8 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 the attention of Mr Neil Pearson

for GEOMATERIALS RESEARCH SERVICES
(part of Sandberg LLP)

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Senior Associate

1 November 2024

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 OUTER AND INNER LEAF SAMPLES (K19481, 2 AND 5)

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
BS 1881-211, 2016

TABLE A1 OF 1: PETROGRAPHIC AL DESCRIPTION OF THE SAMPLES

Sandberg Ref.	**K19481/2**	**K19481/5**
Site / Client Ref.	**Outer leaf, Core 11, 1 of 2**	**Inner leaf, East Elevation (South)**
Overall colour of mortar	Medium brownish grey with patches of light brownish grey mortar visible on the surfaces.	Mostly light brownish grey
Surface observations	The bed surfaces are smooth with no visible traces of substrate	Most surfaces are rough
Brick / substrate materials	None seen	None seen
Mortar Type	Portland cement / siliceous sand	Portland cement / siliceous sand
Mixing of aggregates and binder	Throughout the majority of the sample the aggregates and matrix are uniformly distributed. The patches of light brownish grey mortar are of similar composition to the majority of the mortar but have a very porous matrix.	The aggregates and matrix are uniformly distributed
Estimated void content	20%	15%
Size and shape of voids	Mostly irregular voids, typically measuring <0.5mm. The smaller voids tend to be more spherical in shape.	Mostly irregular voids, typically measuring <0.5mm. The smaller voids tend to be more spherical in shape.
Aggregate		
Estimated BS EN 13139 sand grading classification	Fine 0/0.6	Fine 0/0.6
Particle shape	Subrounded	Subrounded
Sand grain coatings	Traces of micaceous dust	Traces of micaceous dust
Major rock types (>20% of aggregate)	Schist	Schist
Minor rock types (5-20% of aggregate)	Quartzite, Phyllite	Quartzite, Phyllite
Trace rock types (<5% of aggregate)	Epidiorite, Feldspar, Shell	Epidiorite, Feldspar, Shell, Limestone
Matrix		
Binder type	Portland cement	Portland cement
Occurrence of lime	None seen	Uncertain
Undispersed lime / lime lumps	No undispersed lime patches seen	Possible traces of poorly dispersed lime patches
Portland cement and calcium silicates	There are common outlines of carbonated cement grains	There are common outlines of carbonated cement grains
Carbonation	Fully carbonated with a fine-textured carbonation	Fully carbonated with a fine-textured carbonation
Microporosity	Moderately high	High
Cracking	None seen	None seen
Void and crack fillings	None seen	None seen
Alteration of matrix	None seen other than carbonation	None seen other than carbonation

APPENDIX B – PHOTOGRAPHS ILLUSTRATING THE SAMPLES AS RECEIVED

Figure B1

Sample K19481/1 (Outer leaf, Core 2)

Close-up view of the sample

Side 1

Side 2

Scale: The scale is given by the graph paper that is divided into millimetres and centimetres

Figure B2

Sample K19481/2 (Outer leaf, Core 11, 1 of 2)

Close-up view of the sample where

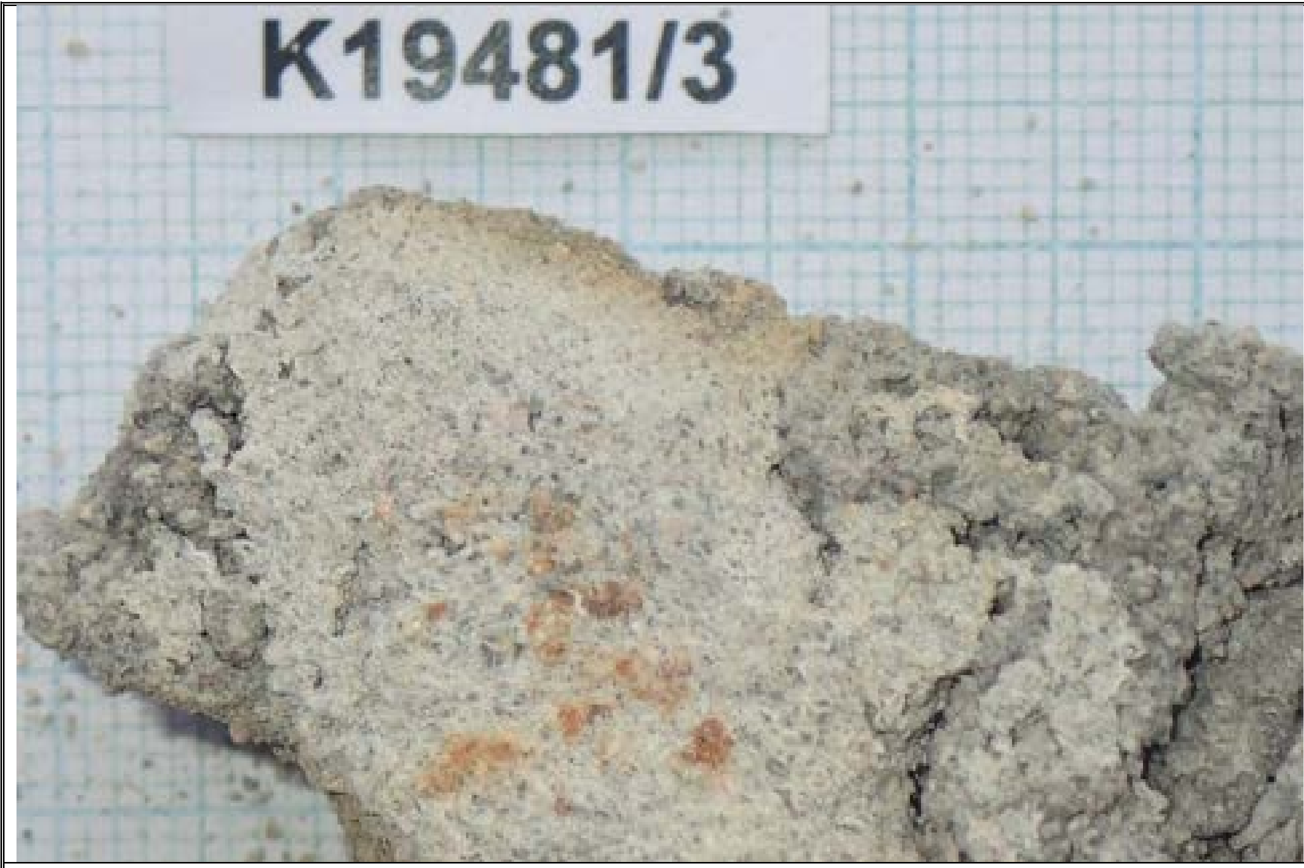
Side 1

Side 2

Scale: The scale is given by the graph paper that is divided into millimetres and centimetres

Figure 3

Sample K19481/3 (Outer leaf, Core 11, 2 of 2)



Close-up view of the sample where

Side 1

Side 2

Scale: The scale is given by the graph paper that is divided into millimetres and centimetres

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Figure B4

Sample K19481/4 (Outer leaf, Core 12)

Close-up view of the sample where

Side 1

Side 2

Scale: The scale is given by the graph paper that is divided into millimetres and centimetres

Figure B5

Sample K19481/5 (Inner leaf, East Elvn (South))

Close-up view of the sample where

	
Side 1	Side 2

Scale: The scale is given by the graph paper that is divided into millimetres and centimetres

Figure B6

Sample K19481/6 (Inner leaf, North Elevation)

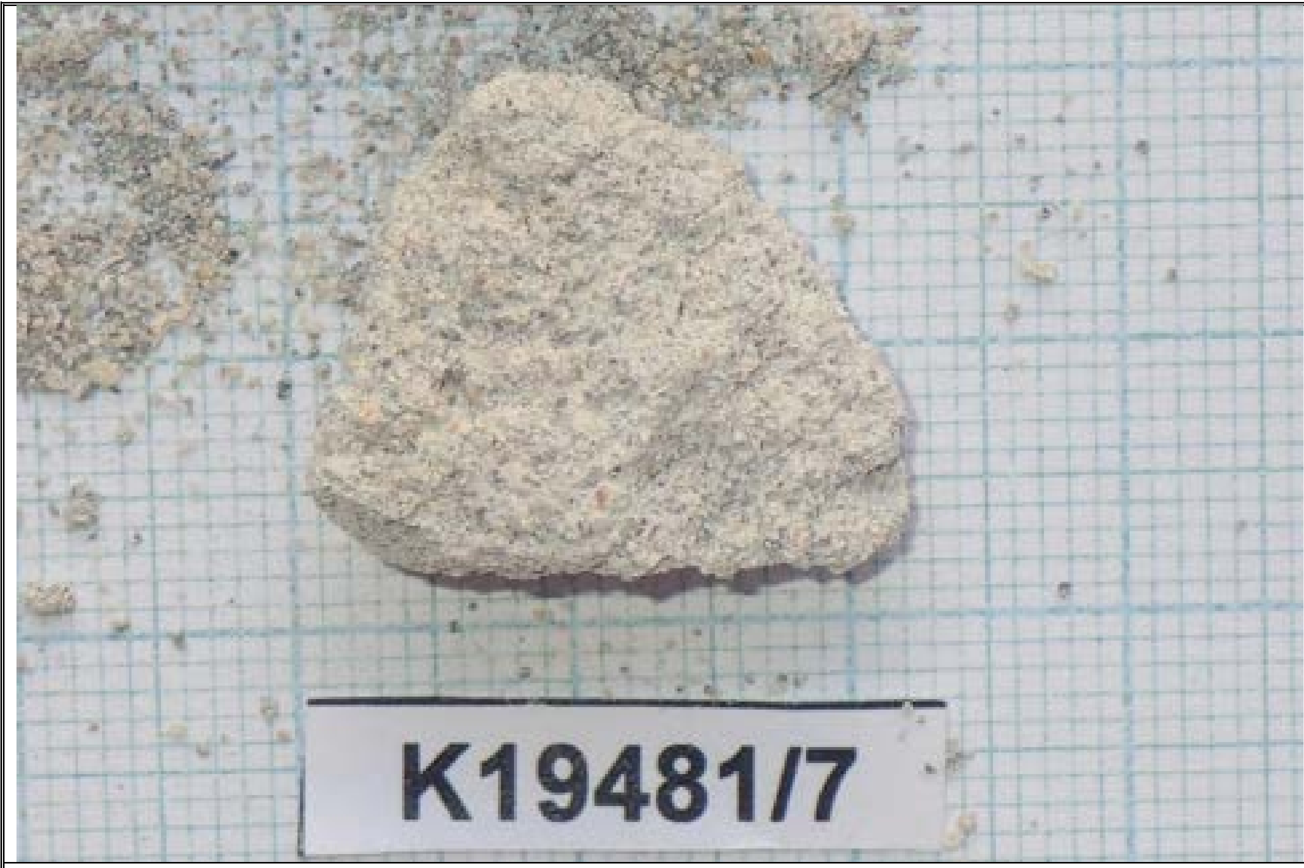
Close-up view of the sample where

Side 1	Side 2

Scale: The scale is given by the graph paper that is divided into millimetres and centimetres

Figure B7

Sample K19481/7 (Inner Leaf, South Elevation)



Close-up view of the sample where

Side 1

Side 2

Scale: The scale is given by the graph paper that is divided into millimetres and centimetres

APPENDIX C – PHOTOMICROGRAPHS ILLUSTRATING THE THIN SECTIONS

Figure C1

Sample K19481/2 (Outer leaf, Core11, 1 of 2)

Thin section, oblique polars: Low magnification view of the thin section showing abundant schist sand particles, visible for example in B6 and F2 that are surrounded by a carbonated matrix containing Portland cement. There are abundant voids throughout the field of view that have taken in the green fluorescent resin used during sample preparation.

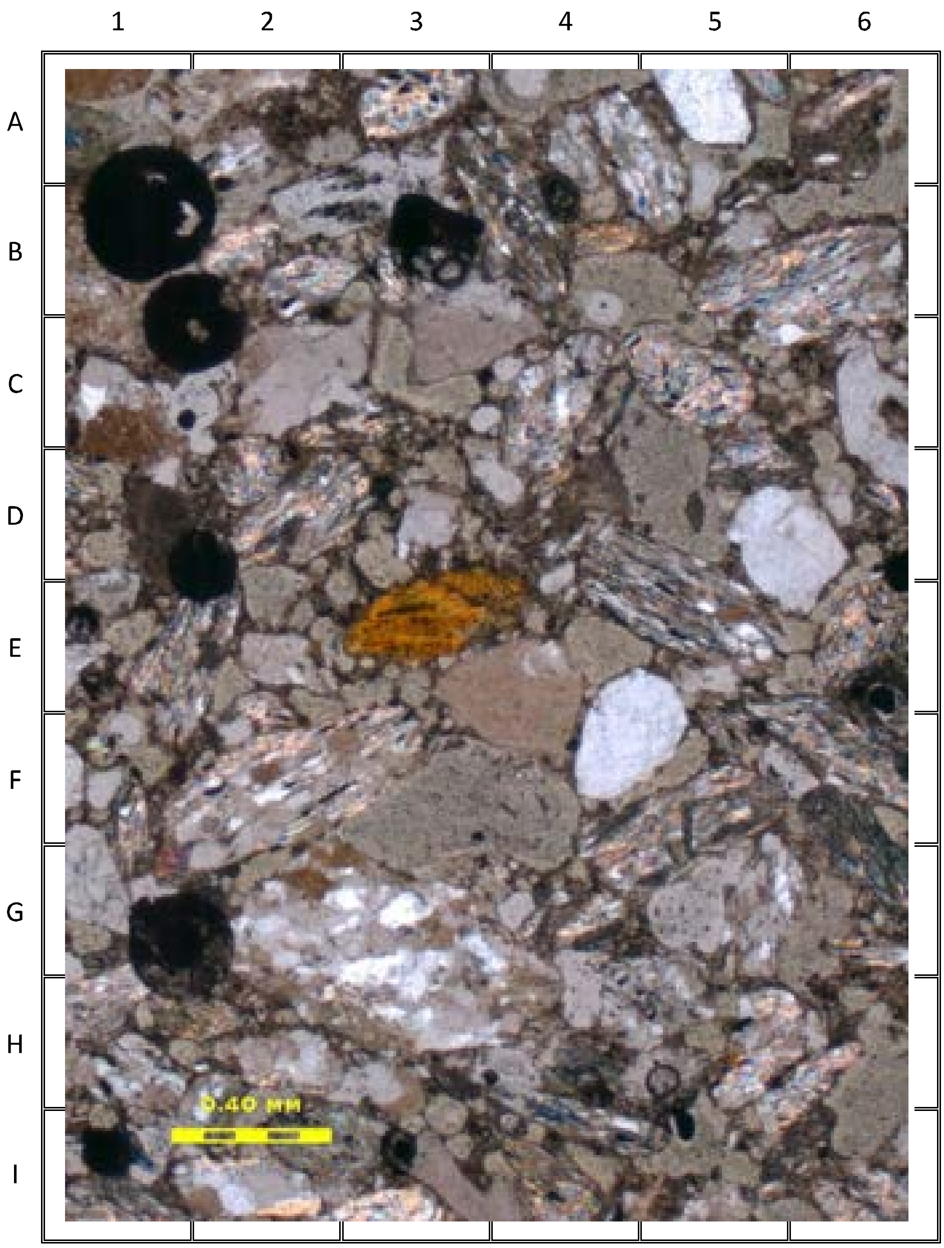


Figure C2

Sample K19481/2 (Outer leaf, Core11, 1 of 2)

<u>Thin section, oblique polars:</u> View showing the typical appearance of the mortar matrix with the outlines of carbonated and hydrated Portland cement grains visible for example in F1/2. Schist particles can be seen in B/C1 and A6. A quartz particle occurs in H1 and an empty void can be seen in I6.

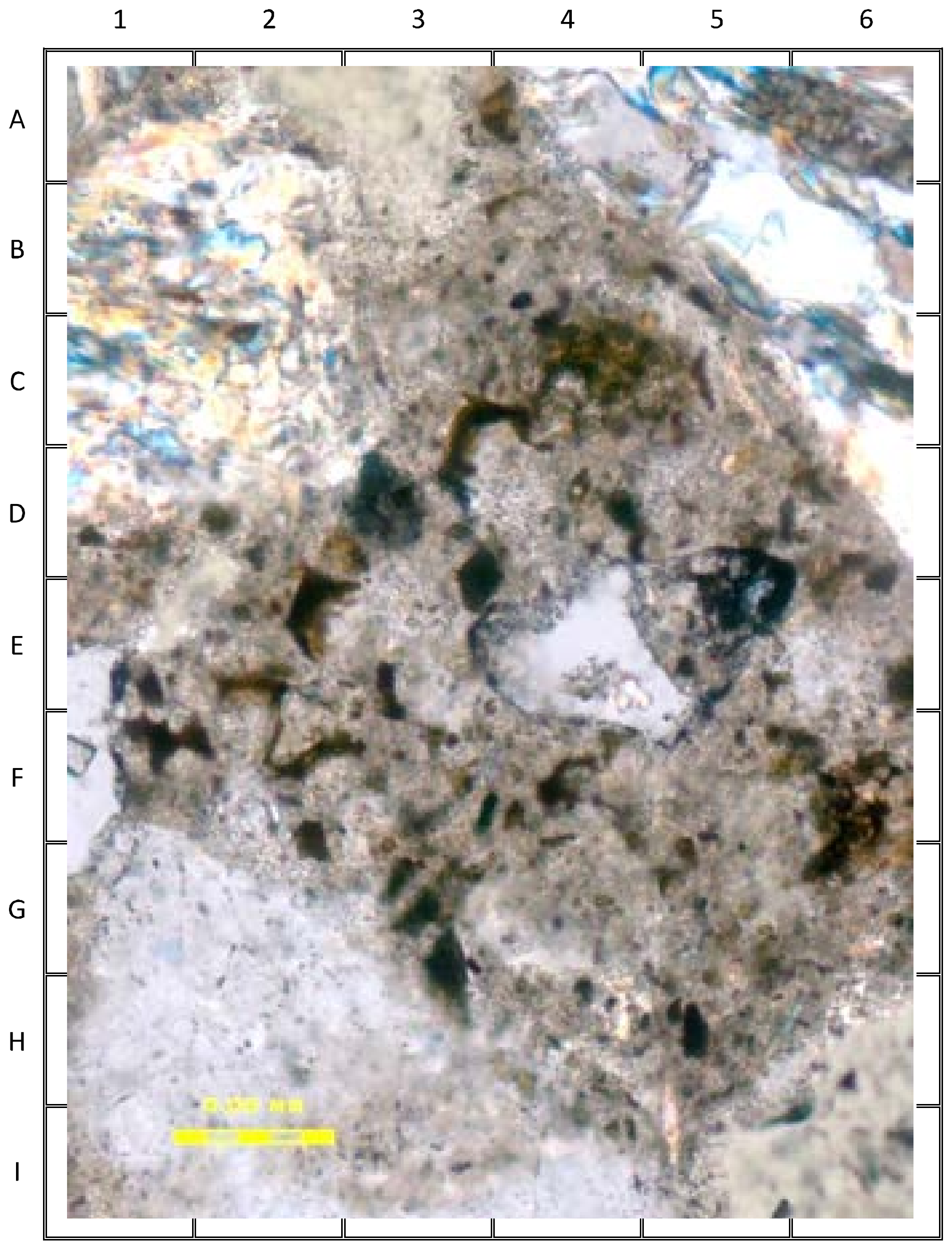


Figure C3

Sample K19481/2 (Outer leaf, Core11, 1 of 2)

<u>Thin section, crossed polars:</u> Areas of carbonated matrix containing the outlines of carbonated Portland cement grains can be seen for example in E1. Schist particles occur in H2/3 and G5/6. Empty voids can be seen for example in G1 and D6.

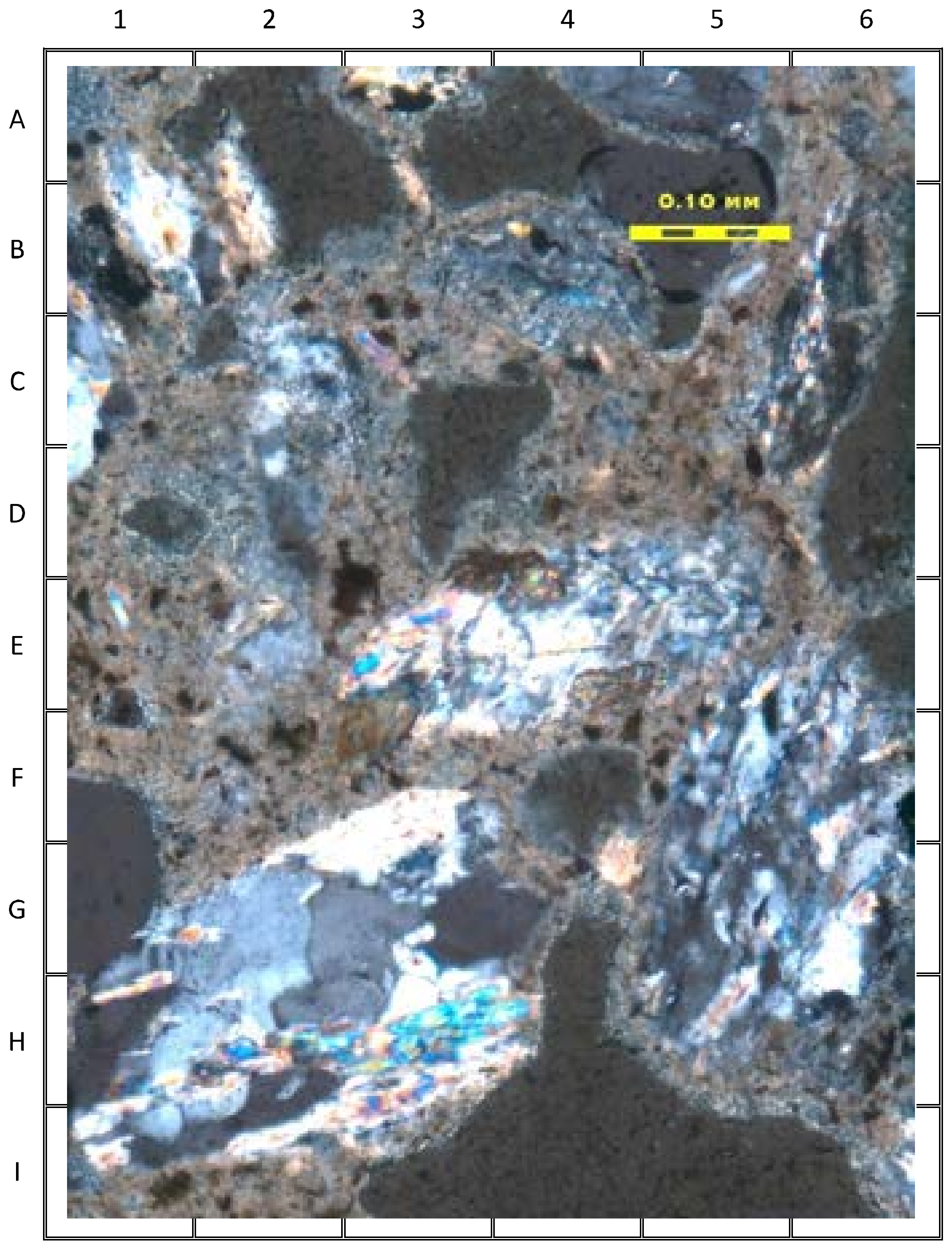


Figure C4

Sample K19481/5 (Inner leaf, East Elevation (South)

<u>Thin section, oblique polars:</u> Low magnification view of the thin section showing abundant schist sand particles, visible for example in E1 and F1 that are surrounded by a carbonated matrix containing Portland cement. Quartz particles can be seen in C4 and G2. There are abundant voids throughout the field of view that have taken in the green fluorescent resin used during sample preparation.

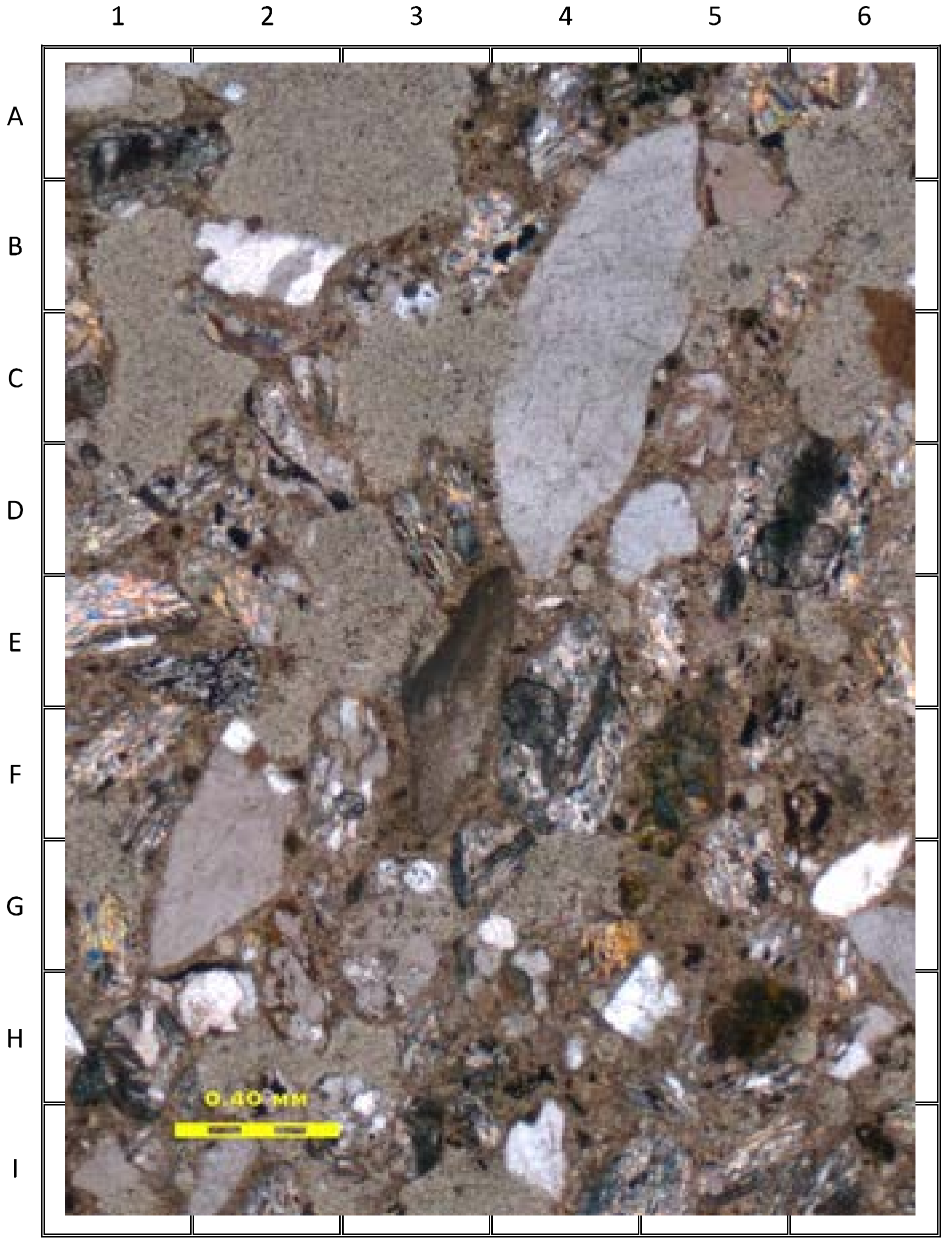


Figure C5

Sample K19481/5 (Inner leaf, East Elevation (South)

Thin section, oblique polars: View showing the typical appearance of the mortar matrix with the outlines of carbonated and hydrated Portland cement grains visible for example in E3. Schist particles can be seen in D1 and H1. Quartz particles occur in B3 and H/I3.

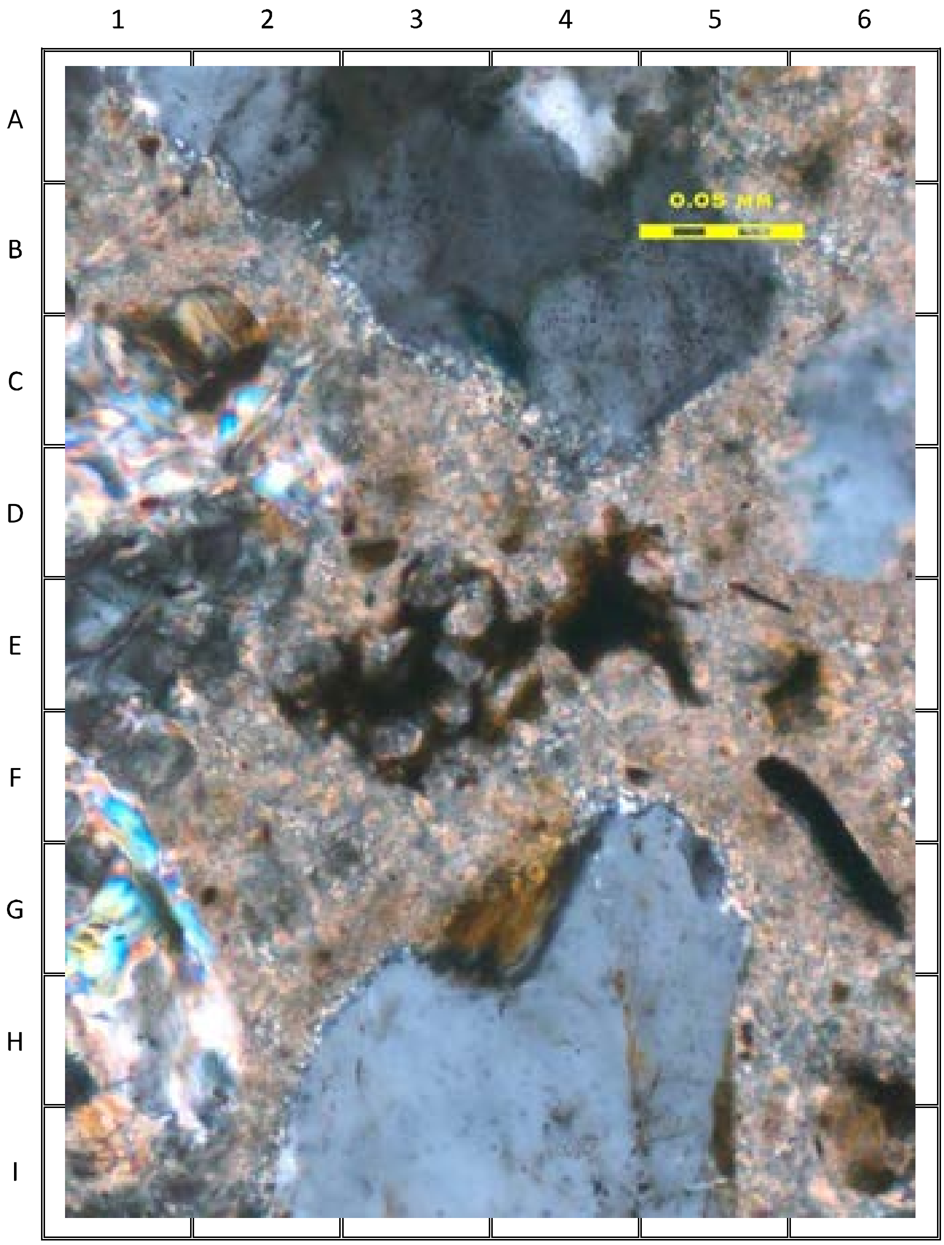
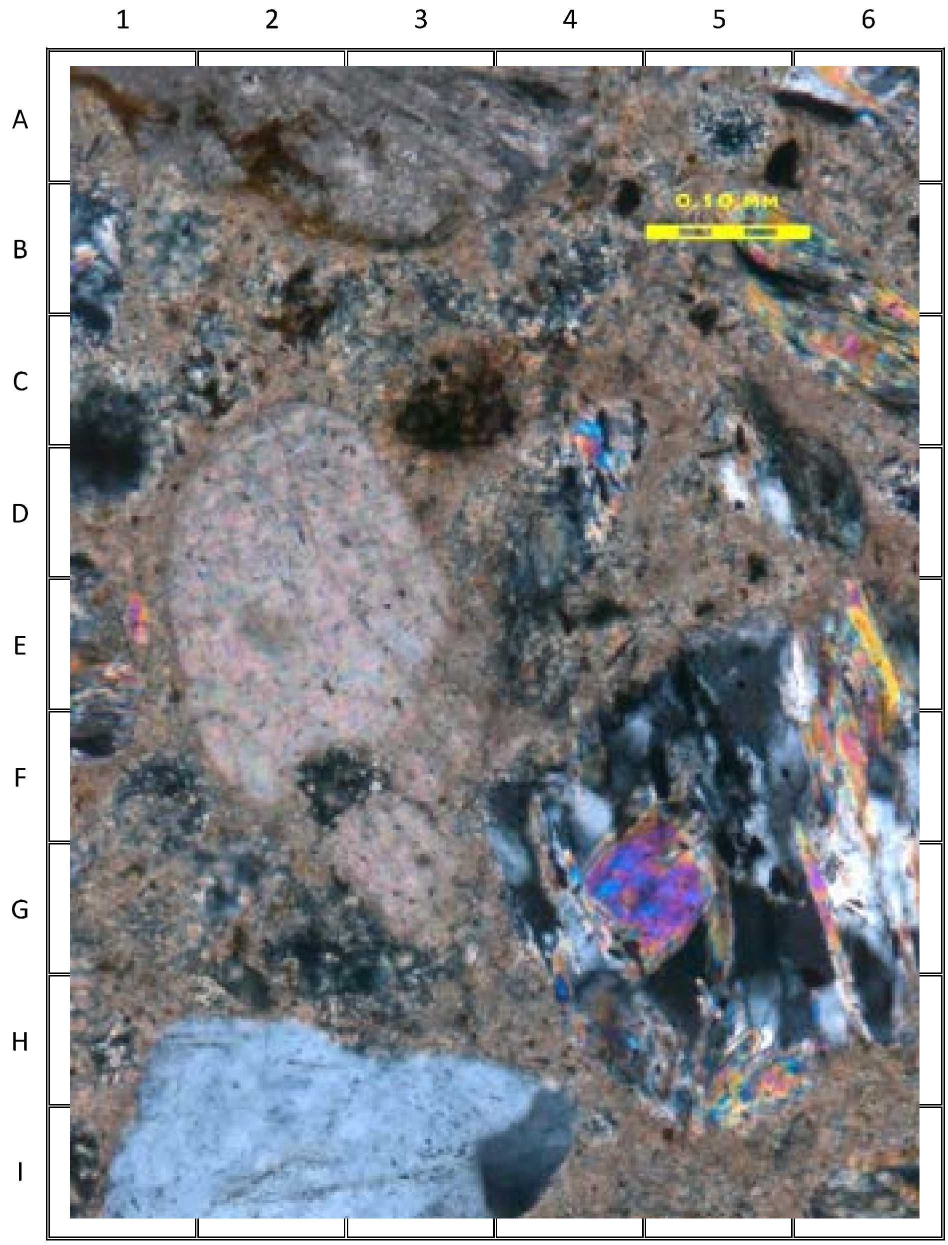


Figure C6

Sample K19481/5 (Inner leaf, East Elevation (South)

<u>Thin section, crossed polars:</u> A shell particle occurs in E2. Schist particles can be seen in G5/6 and A2/3. A quartz particle occurs in I2. The aggregate particles are surrounded by carbonated matrix with a fine-grained texture that can be seen for example in I5 and G1.



APPENDIX D – CHEMICAL TEST CERTIFICATES

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REPORT 78193/K-C

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REPORT 78193/K-C

LERWICK PROJECT

ANALYSIS OF MORTAR SAMPLES

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For the attention of Mr Neil Pearson	**14** October 2024

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ANALYSIS OF MORTAR SAMPLES

References: Internal instruction dated 20 September 2024.

1. INTRODUCTION

Five mortar samples, taken by yourselves from the above project, were received in our laboratories on 13 September 2024.

We were instructed to carry out analysis to determine the mix composition and proportions of the samples.

2. SAMPLE DETAILS

Sandberg reference	Sample reference	Sample details	Mass of sample received, g
K19481/1	Outer leaf core 2	Light brownish grey mortar piece	56
K19481/3	Outer leaf core 11, 2 of 2	Darker brownish grey mortar piece	40
K19481/4	Outer leaf core 12	Darker brownish grey mortar piece	64
K19481/6	Inner leaf north elevation	Light brownish grey mortar pieces and powder	9
K19481/7	Inner leaf south elevation	Light brownish grey mortar pieces and powder	13

3. **ANALYSIS METHODS AND RESULTS**

The samples were prepared and analysed using documented in-house methods based on BS 4551:2005 + A2:2013 "Methods of test for mortar".

Examination of the analysis data did not allow a clear distinction to be made as to whether the mixes consisted of Portland cement and sand or of Portland cement, lime and sand. Alternative mix proportions to include these possibilities were therefore calculated following the directions given in Table 3 of BS 4551.

The cement contents were calculated from the soluble silica contents, making the assumptions shown in the analysis table. Traditional volume proportions were found by reference to Table 7 of BS 4551.

The values assumed by us in the calculations are those that appear to be the most likely after full consideration of the chemical composition and other properties of the samples examined. If further information about any of the constituents of the samples becomes available, calculations of mix proportions could be repeated to take this into consideration.

Details of the analyses are given in Table 1 of this report, including details of the assumptions made in the calculations. The mix proportions are summarized below:

Sandberg reference	Client reference	Mix type	Mix proportions by volume	Designation from BS 4551:2005 + A2:2013
K19481/1	Outer leaf core 2	Portland cement : lime : sand	1 : 0.1 : 8.7	iv (nearest)
K19481/3	Outer leaf core 11, 2 of 2	Portland cement : lime : sand	1 : 0.9 : 5.8	iii
K19481/4	Outer leaf core 12	Portland cement : lime : sand	1 : 1.0 : 7.1	iv
K19481/6	Inner leaf north elevation	Portland cement : lime : sand	1 : 0.6 : 7.6	iv (nearest)
K19481/7	Inner leaf south elevation	Portland cement : lime : sand	1 : 0.6 : 6.1	iii

4. REMARKS

It is not always possible by chemical analysis alone to distinguish with certainty between Portland cement and lime binders or between hydraulic and non-hydraulic limes.

Microscopical examination can usually ascertain the presence or otherwise of Portland cement in the mortar and of calcareous material in the aggregate. In the absence of such confirmatory work, interpretation of the analytical results is made on the basis of consideration of the analysis in conjunction with the appearance and any available background information for the mortar.

The samples were found to comprise Portland cement, lime and sand mixes and would fall within or nearest to Designations iv or iii as given in BS 4551:2005 + A2:2013.

The majority of the sulphate contents of the samples were found to be at normal levels. The sulphate content of the samples K19481/3 (Outer leaf core 11, 2 of 2) and K19481/4 (Outer leaf core 12) were found to be higher than would be expected from the constituent materials indicating the possibility of sulphate leaching from the surrounding building materials.

The sample sizes were small and therefore the results obtained should be treated with a degree of caution. Any decisions based on the results should be undertaken taking this into account.

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For the attention of Mr Neil Pearson

for Sandberg LLP

G S Mayers

G S Mayers
Department Manager
14 October 2024

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UKAS TESTING 0262

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MORTAR - CHEMICAL ANALYSIS
DETERMINATION OF MIX PROPORTIONS
Documented In-house Methods 34.1(*) and BS 4551:2005+A2:2013

Sandberg reference	K19481/1	K19481/3	K19481/4	
Client reference	Outer leaf core 2	Outer leaf core 11, 2 of 2	Outer leaf core 12	
Details	Mortar	Mortar	Mortar	
CHEMICAL ANALYSIS	% by mass			
Insoluble residue	83.11	73.35	77.01	
Soluble silica, SiO_2*	1.87	2.49	2.17	
Acid soluble alumina, Al_2O_3*	0.35	0.70	0.45	
Acid soluble iron, Fe_2O_3*	0.32	0.48	0.39	
Acid soluble calcium, CaO	5.76	10.15	8.81	
Acid soluble magnesium, MgO	0.25	0.45	0.49	
Acid soluble sulphate, SO_3	0.29	0.63	0.45	
Loss on ignition	7.15	11.46	9.60	
Total	99.13	99.71	99.37	

Calculated Mix Proportions				
Composition to nearest 0.5%	% by mass of dry mass			
Portland cement : lime : sand				
Portland cement	9.0	12.5	10.5	
Lime, dry $Ca(OH)_2$	0.5	4.5	4.0	
Sand	90.5	83.0	85.5	
Calculated volume	1 : 0.1 : 8.7	1 : 0.9 : 5.8	1 : 1.0 : 7.1	
Mortar Designation From Table 7, BS4551 :2005	iv (nearest)	iii	iv	
Possible alternative mix	PC : Sand 1 : 8.8	PC : Sand 1 : 6.1	PC : Sand 1 : 7.4	

Assumptions used in calculations	SiO_2 %	CaO %	Bulk density kg/m³	Material type
Sand	0.2	0.0	1675	Siliceous
Portland cement	20.5	64.5	1450	OPC
Lime, hydrated	0.6	72.7	575	

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MORTAR - CHEMICAL ANALYSIS
DETERMINATION OF MIX PROPORTIONS

Documented In-house Methods 34.1(*) and BS 4551:2005+A2:2013

Sandberg reference	K19481/6	K19481/7		
Client reference	Inner leaf north elevation	Inner leaf south elevation		
Details	Mortar	Mortar		
CHEMICAL ANALYSIS	% by mass			
Insoluble residue	79.45	76.00		
Soluble silica, SiO_2*	2.09	2.45		
Acid soluble alumina, Al_2O_3*	0.52	0.60		
Acid soluble iron, Fe_2O_3*	0.44	0.50		
Acid soluble calcium, CaO	7.56	9.13		
Acid soluble magnesium, MgO	0.26	0.32		
Acid soluble sulphate, SO_3	0.29	0.41		
Loss on ignition	9.09	9.98		
Total	99.72	99.39		

Calculated Mix Proportions				
Composition to nearest 0.5%	% by mass of dry mass			
Portland cement : lime : sand				
Portland cement	10.0	12.0		
Lime, dry $Ca(OH)_2$	2.5	3.0		
Sand	87.5	85.0		
Calculated volume	1 : 0.6 : 7.6	1 : 0.6 : 6.1		
Mortar Designation From Table 7, BS4551 : 2005	iv (nearest)	iii		
Possible alternative mix	PC : Sand 1 : 7.8	PC : Sand 1 : 6.4		

Assumptions used in calculations	SiO_2 %	CaO %	Bulk density kg/m³	Material type
Sand	0.2	0.0	1675	Siliceous
Portland cement	20.5	64.5	1450	OPC
Lime, hydrated	0.6	72.7	575	

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Materials, samples and test specimens are retained for a period of 2 months from the issue of the final report.

Tests reported on sheets not bearing the UKAS mark in this report/certificate are not included in the UKAS accredited schedule for this laboratory.

Opinions and interpretations expressed herein are outside the scope for UKAS accreditation.

End of report.

APPENDIX E – PETROGRAPHIC PROCEDURES AND GLOSSARY

LEVELS OF DETERIORATION

COHERENT CONCRETE WITH NO MACROSCOPIC EVIDENCE OF DETERIORATION

1. Normal homogeneous concrete with few microcracks. Void content in keeping with the amount of paste. Paste structure in keeping with water/cement ratio. Portlandite abundance in keeping with water/cement ratio.

2. Slight deterioration, possibly through slightly excess voidage, excess microcracking, uneven paste composition, low levels of alkali-aggregate reaction, drying shrinkage, low temperature curing, possibly slightly lean mixture.

3. Moderately low deterioration, possibly with enhanced voidage, microcracking frequency fairly high, excessive paste porosity, evidence of leaching or other forms of secondary alteration, possible lean mixture.

COHERENT CONCRETE WITH MACROSCOPIC EVIDENCE OF DETERIORATION

4. Moderate deterioration, possibly with evident macrocracking or fine cracking, enhanced voidage, high frequencies of microcracking or fine cracks, evidence of significant leaching or other forms of secondary alteration, evidence of ettringite in cracks and voids, evidence of significant alkali-aggregate reaction with gel in cracks.

5. Moderate deterioration, possibly with much fine cracking and some macrocracking, high frequency of microcracks, very high excess voidage, evidence of paste recrystallization, excessive porosity, carbonation highly penetrative, evidence of significant alkali-aggregate in some abundance.

6. As for 5, but with enhanced level of deterioration but with concrete remaining intact.

CONCRETE LACKS COHERENCE AND IS FRIABLE OR READILY DECOMPOSED

7. Concrete shows deterioration and may be partly decomposed or friable. May be difficult to cut and to polish.

8. As 7, but enhanced friability and tending to break into fragments. Loose aggregate particles, honeycombed.

9. As 8, but enhanced deterioration. Much cracking and fragmentation.

10. All cementitious value, coherence and strength lost.

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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 >100cm^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 concrete [4].

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 alkalies 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 alkalies 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-sulphate mineral. It occurs in most concretes where moisture ingress has occurred. Ettringite formation may be deleterious in the case of DEF or sulphate 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 area 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 sulphate-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.

Sulphate attack: This is a general term encompassing both conventional sulphate attack resulting in gypsum and ettringite formation, but also includes sulphate attack associated with thaumasite formation. Sulphate 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-sulphate calcium hydrate mineral with a complex composition. It is a common reaction product in concrete exposed to moisture containing both carbonate and sulphate ions. Thaumasite is most commonly encountered in concrete exposed to temperatures of <4°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 <1mm 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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