REPORT 72418/F-K

EUSTON TOWER

TESTING OF CONCRETE CORES

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REPORT 72418/F-K

EUSTON TOWER

TESTING OF CONCRETE CORES

McGee Group (Holdings) Limited
Unit 8 Wharfside
Rosemont Road
Wembley
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This report comprises
2 pages of text
Table 1 of 21 sheets
Table 2 of 2 sheets
Appendix A of 2 sheets
Appendix B of 24 sheets

For the attention of Mr Diego Fenaroli

22 June 2022

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TESTING MATERIALS

REPORT 72418/F-K

EUSTON TOWER

TESTING OF CONCRETE CORES

Instruction: Email from Diego Fenaroli, dated 5/5/2022 and PO042901.

1. INTRODUCTION

A set of twenty eight concrete cores were received in our laboratory in two batches on 9 and 12 May 2022. A separate batch of fourteen cores were received in our laboratory on 30 May 2022. All samples were subjected to testing in accordance with your instructions.

2. SAMPLES RECEIVED

A copy of the two sample schedules provided, with corresponding Sandberg sample references added, is given in Appendix A.

3. TEST METHODS AND TEST RESULTS

3.1 Density and Compressive Strength of Concrete Cores

Forty two nominated concrete core samples were diamond sawn to give specimens with a length/diameter ratio in the range 1.95 to 2.05. Where this was not possible a correction factor was applied to specimens tested with a length/diameter ratio in the range 0.90 to 1.10. The ends of each specimen were ground flat and the prepared specimen was used to determine as-received density and compressive strength in accordance with BS EN 12390-7:2019, BS EN 12504-1:2019 and BS EN 12390-3:2019.

The results are given in Table 1.

3.2 Carbonation testing

Twelve nominated concrete core samples were tested to determine depth of carbonation accordance with Sandberg TP/F/10 (based on BRE IP 6/81) using phenolphthalein indicator solution.

The results are given in Table 2.

3.3 Chemical Analysis

Representative portions from forty two nominated core samples were tested for a suite of chemical analysis. The tests scheduled were:

- Determination of cement content, using a documented in-house method based on BS 1881-124:2015+A1:2021
- Determination of chloride content, using a documented in-house method based on BS 1881-124:2015+A1:2021
- Determination of presence of HAC, using a documented in-house method based on BS 1881-124:2015+A1:2021

As instructed on the sample schedule (Appendix A), 30 no tests were undertaken to determine cement content, 30 no tests were undertaken to determine chloride content and 6 no tests were undertaken to determine the presence of High Alumina Cement.

At the time of writing this report the testing is ongoing and will be provided separately.

3.4 Petrographic Examination

Sections from four nominated core samples were subjected to a petrographic microscopical examination including the preparation of a thin section following the procedures given in BS 1881-211: 2016.

The work was carried out by Geomaterials Research Services who are part of Sandberg LLP. Their report is reproduced in full as Appendix B.

4. REMARKS

The compressive test results provided in Table 1 are given as a 'core compressive strength' which provides a measure of the actual strength of the concrete as it presently exists in the structure and is the value that should be used for any assessment of insitu strength or quality in cases of doubt, in accordance with BS EN 13791:2019.

McGee Group (Holdings) Limited
Unit 8 Wharfside
Rosemont Road
Wembley
H40 4PE

For the attention of Diego Fenaroli

for Sandberg LLP

Conrad Newberry
Department Manager

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22 June 2022

TABLE 1
COMPRESSIVE STRENGTH AND DENSITY OF CORES
(21 SHEETS)

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Table/Sheet

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Date of Test

17/5/22

CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference		F23766	F23767
Site Mark/Client Reference		H1 - P1/02	H1 P1/07
Details: - Location Euston Tower		Position 1	Position 1
- Date of coring		N/A	N/A
- Date received		9/5/22 & 12/5/22	9/5/22 & 12/5/22
Presence of abnormalities		None	None
Reinforcement, as received (diameter/distance)[1]	mm	None	None
Reinforcement, prepared (diameter/distance)[1]	mm	None	None
Aggregate, maximum nominal size	mm	21	18
Condition on receipt		Exposed: Air	Exposed: Air
Storage conditions		As Received	As Received
Method of End preparation (Cap/Ground)		Ground	Ground
Actual Core Lengths			
- Core length, as received	mm	580-700	470-485
- Relation to length, as-received	mm	200-285	200-285
Mean Prepared Length	mm	85	84
Mean Core Diameter d_m	mm	84	84
Length/Diameter ratio of prepared specimen	λ	1.01	1.00
Density[2] - As received	kg/m³	2360	2350
Exposure time before Test	16-24h	N/A	N/A
Estimation of prepared core excess voidage	%	0.5	1.0
Maximum Load at Failure	kN	450	424
Compressive Strength[3]	MPa (N/mm²)	81.2	76.5
(Measured Core Strength)			
Mode of Failure[4]		Normal	Normal
Deviations from standard		See footnote 2	See footnote 2
Remarks:		2:1 Correction: 66.6 MPa	2:1 Correction: 62.7 MPa

[1] Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

[2] Volume by measurement/water displacement, densities given to nearest 10kg/m³. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

[3] Compressive strength values given to nearest 0.1 MPa (N/mm²).

[4] 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Table/Sheet

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Date of Test

17/5/22

CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference		F23768	F23769
Site Mark/Client Reference		H1 - P2/02	H1 - P2/06
Details: - Location Euston Tower		Position 2	Position 2
- Date of coring		N/A	N/A
- Date received		9/5/22 & 12/5/22	9/5/22 & 12/5/22
Presence of abnormalities		None	None
Reinforcement, as received (diameter/distance)[1]	mm	None	None
Reinforcement, prepared (diameter/distance)[1]	mm	None	None
Aggregate, maximum nominal size	mm	21	25
Condition on receipt		Exposed: Air	Exposed: Air
Storage conditions		As Received	As Received
Method of End preparation (Cap/Ground)		Ground	Ground
Actual Core Lengths			
- Core length, as received	mm	435-460	460-475
- Relation to length, as-received	mm	200-285	200-285
Mean Prepared Length	mm	88	85
Mean Core Diameter d_m	mm	83	84
Length/Diameter ratio of prepared specimen	λ	1.06	1.01
Density[2] - As received	kg/m³	2370	2340
Exposure time before Test	16-24h	N/A	N/A
Estimation of prepared core excess voidage	%	1.5	0.5
Maximum Load at Failure	kN	443	440
Compressive Strength[3] (Measured Core Strength)	MPa (N/mm²)	81.9	79.4
Mode of Failure[4]		Normal	Normal
Deviations from standard		See footnote 2	See footnote 2
Remarks:		2:1 Correction: 67.2	2:1 Correction: 65.1

1 Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

2 Volume by measurement/water displacement, densities given to nearest 10kg/m³. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

3 Compressive strength values given to nearest 0.1 MPa (N/mm²).

4 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Date of Test

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CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference	F23770	F23771
Site Mark/Client Reference	H1 - P3/01	H1 - P3/07
Details: - Location Euston Tower - Date of coring - Date received	Position 3 N/A 9/5/22 & 12/5/22	Position 3 N/A 9/5/22 & 12/5/22
Presence of abnormalities	None	None
Reinforcement, as received (diameter/distance)[1] mm Reinforcement, prepared (diameter/distance)[1] mm	None None	None None
Aggregate, maximum nominal size mm	17	20
Condition on receipt	Exposed to air: Dry	Exposed to air: Dry
Storage conditions	As Received	As Received
Method of End preparation (Cap/Ground)	Ground	Ground
Actual Core Lengths - Core length, as received mm - Relation to length, as-received mm	 1000-1010 170-340	 310-330 70-240
Mean Prepared Length mm	171	170
Mean Core Diameter d_m mm	84	83
Length/Diameter ratio of prepared specimen λ	2.04	2.05
Density[2] - As received kg/m^3	2360	2310
Exposure time before Test 16-24h	-	-
Estimation of prepared core excess voidage %	0.5	1.0
Maximum Load at Failure kN	307	266
Compressive Strength[3] MPa (N/mm^2) (Measured Core Strength)	55.4	49.2
Mode of Failure[4]	Normal	Normal
Deviations from standard Remarks:	See footnote 2	See footnote 2

1 Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

2 Volume by measurement/water displacement, densities given to nearest $10kg/m^3$. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

3 Compressive strength values given to nearest 0.1 MPa (N/mm^2).

4 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Date of Test **24/5/22**

CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference		F23773	F23774
Site Mark/Client Reference		H1 - P4/05	H1 - P5/02
Details: - Location Euston Tower		Position 4	Position 5
- Date of coring		N/A	N/A
- Date received		9/5/22 & 12/5/22	9/5/22 & 12/5/22
Presence of abnormalities		None	None
Reinforcement, as received (diameter/distance)[1]	mm	None	None
Reinforcement, prepared (diameter/distance)[1]	mm	None	None
Aggregate, maximum nominal size	mm	20	16
Condition on receipt		Exposed to air: Dry	Exposed to air: Dry
Storage conditions		As Received	As Received
Method of End preparation (Cap/Ground)		Ground	Ground
Actual Core Lengths			
- Core length, as received	mm	310-340	390-405
- Relation to length, as-received	mm	60-230	70-240
Mean Prepared Length	mm	171	173
Mean Core Diameter d_m	mm	84	85
Length/Diameter ratio of prepared specimen	λ	2.04	2.04
Density[2] - As received	kg/m³	2330	2340
Exposure time before Test	16-24h	-	-
Estimation of prepared core excess voidage	%	1.0	1.0
Maximum Load at Failure	kN	300	398
Compressive Strength[3] (Measured Core Strength)	MPa (N/mm²)	52.9	71.8
Mode of Failure[4]		Normal	Normal
Deviations from standard		See footnote 2	See footnote 2
Remarks:			

1 Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

2 Volume by measurement/water displacement, densities given to nearest 10kg/m³. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

3 Compressive strength values given to nearest 0.1 MPa (N/mm²).

4 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Date of Test

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CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference	F23775	F23776
Site Mark/Client Reference	H1 - P5/07	H1 - R2/01
Details: - Location Euston Tower	Position 5	Pile R2
- Date of coring	N/A	N/A
- Date received	9/5/22 & 12/5/22	9/5/22 & 12/5/22
Presence of abnormalities	None	None
Reinforcement, as received (diameter/distance)[1] mm	None	None
Reinforcement, prepared (diameter/distance)[1] mm	None	None
Aggregate, maximum nominal size mm	17	22
Condition on receipt	Exposed to air: Dry	Exposed to air: Dry
Storage conditions	As Received	As Received
Method of End preparation (Cap/Ground)	Ground	Ground
Actual Core Lengths		
- Core length, as received mm	455-470	400-450
- Relation to length, as-received mm	80-250	60-230
Mean Prepared Length mm	171	170
Mean Core Diameter d_m mm	84	84
Length/Diameter ratio of prepared specimen λ	2.04	2.02
Density[2] - As received kg/m^3	2310	2340
Exposure time before Test 16-24h	-	-
Estimation of prepared core excess voidage %	0.5	2.5
Maximum Load at Failure kN	266	250
Compressive Strength[3] MPa (N/mm^2) (Measured Core Strength)	48.0	45.1
Mode of Failure[4]	Normal	Normal
Deviations from standard Remarks:	See footnote 2	See footnote 2

[1] Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

[2] Volume by measurement/water displacement, densities given to nearest $10kg/m^3$. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

[3] Compressive strength values given to nearest 0.1 MPa (N/mm^2).

[4] 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Date of Test

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CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference	F23778	F23779
Site Mark/Client Reference	H1 - L3/01	H1 - L3/02
Details: - Location Euston Tower	Pile L3	Pile L3
- Date of coring	N/A	N/A
- Date received	9/5/22 & 12/5/22	9/5/22 & 12/5/22
Presence of abnormalities	None	None
Reinforcement, as received (diameter/distance)[1] mm	None	None
Reinforcement, prepared (diameter/distance)[1] mm	None	None
Aggregate, maximum nominal size mm	24	23
Condition on receipt	Exposed to air: Dry	Exposed to air: Dry
Storage conditions	As Received	As Received
Method of End preparation (Cap/Ground)	Ground	Ground
Actual Core Lengths		
- Core length, as received mm	355-375	380-410
- Relation to length, as-received mm	60-230	70-240
Mean Prepared Length mm	172	170
Mean Core Diameter d_m mm	84	84
Length/Diameter ratio of prepared specimen λ	2.05	2.02
Density[2] - As received kg/m^3	2370	2370
Exposure time before Test 16-24h	-	-
Estimation of prepared core excess voidage %	2.5	1.5
Maximum Load at Failure kN	305	346
Compressive Strength[3] MPa (N/mm^2) (Measured Core Strength)	55.0	62.4
Mode of Failure[4]	Normal	Explosive
Deviations from standard Remarks:	See footnote 2	See footnote 2

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1 Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

2 Volume by measurement/water displacement, densities given to nearest 10kg/m^3. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

3 Compressive strength values given to nearest 0.1 MPa (N/mm^2).

4 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference		F23784	F23785
Site Mark/Client Reference		H2 - P1/01	H2 - P1/04
Details: - Location Euston Tower		Position 1	Position 1
- Date of coring		N/A	N/A
- Date received		9/5/22 & 12/5/22	9/5/22 & 12/5/22
Presence of abnormalities		None	None
Reinforcement, as received (diameter/distance)[1]	mm	None	None
Reinforcement, prepared (diameter/distance)[1]	mm	None	None
Aggregate, maximum nominal size	mm	19	17
Condition on receipt		Exposed to air: Dry	Exposed to air: Dry
Storage conditions		As Received	As Received
Method of End preparation (Cap/Ground)		Ground	Ground
Actual Core Lengths			
- Core length, as received	mm	670-680	540-570
- Relation to length, as-received	mm	60-230	60-230
Mean Prepared Length	mm	170	170
Mean Core Diameter d_m	mm	83	84
Length/Diameter ratio of prepared specimen	λ	2.05	2.02
Density[2] - As received	kg/m³	2360	2360
Exposure time before Test	16-24h	-	-
Estimation of prepared core excess voidage	%	1.0	1.0
Maximum Load at Failure	kN	409	352
Compressive Strength[3] (Measured Core Strength)	MPa (N/mm²)	75.6	63.5
Mode of Failure[4]		Explosive	Normal
Deviations from standard		See footnote 2	See footnote 2
Remarks:			

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[1] Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

[2] Volume by measurement/water displacement, densities given to nearest 10kg/m³. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

[3] Compressive strength values given to nearest 0.1 MPa (N/mm²).

[4] 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Date of Test

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CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference	F23786	F23787
Site Mark/Client Reference	H2 - P2/01	H2 - P2/02
Details: - Location Euston Tower	Position 2	Position 2
- Date of coring	N/A	N/A
- Date received	9/5/22 & 12/5/22	9/5/22 & 12/5/22
Presence of abnormalities	None	None
Reinforcement, as received (diameter/distance)[1] mm	None	None
Reinforcement, prepared (diameter/distance)[1] mm	None	None
Aggregate, maximum nominal size mm	15	21
Condition on receipt	Exposed to air: Dry	Exposed to air: Dry
Storage conditions	As Received	As Received
Method of End preparation (Cap/Ground)	Ground	Ground
Actual Core Lengths		
- Core length, as received mm	465-520	205-215
- Relation to length, as-received mm	80-250	20-200
Mean Prepared Length mm	170	171
Mean Core Diameter d_m mm	84	84
Length/Diameter ratio of prepared specimen λ	2.02	2.04
Density[2] - As received kg/m^3	2330	2340
Exposure time before Test 16-24h	-	-
Estimation of prepared core excess voidage %	1.5	1.0
Maximum Load at Failure kN	299	347
Compressive Strength[3] MPa (N/mm^2) (Measured Core Strength)	54.0	62.6
Mode of Failure[4]	Normal	Normal
Deviations from standard Remarks:	See footnote 2	See footnote 2

1 Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

2 Volume by measurement/water displacement, densities given to nearest 10kg/m^3. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

3 Compressive strength values given to nearest 0.1 MPa (N/mm^2).

4 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Date of Test
24/5/22

CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference		F23788	F23789
Site Mark/Client Reference		H2 - P3/02	H2 - P3/06
Details: - Location Euston Tower		Position 3	Position 3
- Date of coring		N/A	N/A
- Date received		9/5/22 & 12/5/22	9/5/22 & 12/5/22
Presence of abnormalities		None	None
Reinforcement, as received (diameter/distance)[1]	mm	None	None
Reinforcement, prepared (diameter/distance)[1]	mm	None	None
Aggregate, maximum nominal size	mm	18	17
Condition on receipt		Exposed to air: Dry	Exposed to air: Dry
Storage conditions		As Received	As Received
Method of End preparation (Cap/Ground)		Ground	Ground
Actual Core Lengths			
- Core length, as received	mm	535-570	285-340
- Relation to length, as-received	mm	80-250	60-230
Mean Prepared Length	mm	172	170
Mean Core Diameter d_m	mm	84	84
Length/Diameter ratio of prepared specimen	λ	2.04	2.02
Density[2] - As received	kg/m³	2360	2370
Exposure time before Test	16-24h	-	-
Estimation of prepared core excess voidage	%	1.0	0.5
Maximum Load at Failure	kN	390	380
Compressive Strength[3] (Measured Core Strength)	MPa (N/mm²)	70.4	68.6
Mode of Failure[4]		Normal	Explosive
Deviations from standard Remarks:		See footnote 2	See footnote 2

1 Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

2 Volume by measurement/water displacement, densities given to nearest 10kg/m³. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

3 Compressive strength values given to nearest 0.1 MPa (N/mm²).

4 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Date of Test

24/5/22

CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES
Position 4

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference		F23791	F23792
Site Mark/Client Reference		H2 - P4/07	H2 - P5/04
Details: - Location	Euston Tower	Position 4	Position 5
- Date of coring		N/A	N/A
- Date received		9/5/22 & 12/5/22	9/5/22 & 12/5/22
Presence of abnormalities		None	None
Reinforcement, as received (diameter/distance)[1]	mm	None	None
Reinforcement, prepared (diameter/distance)[1]	mm	None	None
Aggregate, maximum nominal size	mm	14	17
Condition on receipt		Exposed to air: Dry	Exposed to air: Dry
Storage conditions		As Received	As Received
Method of End preparation (Cap/Ground)		Ground	Ground
Actual Core Lengths			
- Core length, as received	mm	290-300	650-700
- Relation to length, as-received	mm	60-230	110-280
Mean Prepared Length	mm	171	172
Mean Core Diameter d_m	mm	84	88
Length/Diameter ratio of prepared specimen	λ	2.04	1.95
Density[2] - As received	kg/m^3	2380	2360
Exposure time before Test	16-24h	-	-
Estimation of prepared core excess voidage	%	0.5	0.5
Maximum Load at Failure	kN	445	465
Compressive Strength[3] (Measured Core Strength)	MPa (N/mm^2)	80.3	76.5
Mode of Failure[4]		Explosive	Explosive
Deviations from standard Remarks:		See footnote 2	See footnote 2

[1] Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

[2] Volume by measurement/water displacement, densities given to nearest 10kg/m^3. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

[3] Compressive strength values given to nearest 0.1 MPa (N/mm^2).

[4] 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Date of Test
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CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference	F23793	F23794
Site Mark/Client Reference	H2 - P5/07	H2 - L2/01
Details: - Location Euston Tower - Date of coring - Date received	Position 5 N/A 9/5/22 & 12/5/22	Pile R2 N/A 9/5/22 & 12/5/22
Presence of abnormalities	None	None
Reinforcement, as received (diameter/distance)[1] mm Reinforcement, prepared (diameter/distance)[1] mm	None None	None None
Aggregate, maximum nominal size mm	14	12
Condition on receipt	Exposed to air: Dry	Exposed to air: Dry
Storage conditions	As Received	As Received
Method of End preparation (Cap/Ground)	Ground	Ground
Actual Core Lengths - Core length, as received mm - Relation to length, as-received mm	 220-250 40-210	 120-165 55-140
Mean Prepared Length mm	172	87
Mean Core Diameter d_m mm	88	84
Length/Diameter ratio of prepared specimen λ	1.95	1.04
Density[2] - As received kg/m³	2360	2370
Exposure time before Test 16-24h	-	-
Estimation of prepared core excess voidage %	0.5	2.5
Maximum Load at Failure kN	474	487
Compressive Strength[3] MPa (N/mm^2) (Measured Core Strength)	77.9	87.9
Mode of Failure[4]	Explosive	Explosive
Deviations from standard Remarks:	See footnote 2	See footnote 2 2:1 Correction: 72.1 MPa

1 Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

2 Volume by measurement/water displacement, densities given to nearest 10kg/m³. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

3 Compressive strength values given to nearest 0.1 MPa (N/mm²).

4 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Date of Test
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CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference	F23796	F23797
Site Mark/Client Reference	H2-R1/01	H2 - R1/02
Details: - Location Euston Tower - Date of coring - Date received	Pile L3 N/A 9/5/22 & 12/5/22	Pile L3 N/A 9/5/22 & 12/5/22
Presence of abnormalities	None	None
Reinforcement, as received (diameter/distance)[1] mm Reinforcement, prepared (diameter/distance)[1] mm	None None	None None
Aggregate, maximum nominal size mm	22	16
Condition on receipt	Exposed to air: Dry	Exposed to air: Dry
Storage conditions	As Received	As Received
Method of End preparation (Cap/Ground)	Ground	Ground
Actual Core Lengths - Core length, as received mm - Relation to length, as-received mm	 270-320 70-240	 265-230 50-220
Mean Prepared Length mm	170	172
Mean Core Diameter d_m mm	84	84
Length/Diameter ratio of prepared specimen λ	2.02	2.05
Density[2] - As received kg/m^3	2360	2370
Exposure time before Test 16-24h	-	-
Estimation of prepared core excess voidage %	0.5	1.0
Maximum Load at Failure kN	362	481
Compressive Strength[3] MPa (N/mm^2) (Measured Core Strength)	65.3	86.8
Mode of Failure[4]	Explosive	Explosive
Deviations from standard Remarks:	See footnote 2	See footnote 2

[1] Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

[2] Volume by measurement/water displacement, densities given to nearest 10kg/m^3. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

[3] Compressive strength values given to nearest 0.1 MPa (N/mm^2).

[4] 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Date of Test

27/5/22

CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference	F23772	F237777
Site Mark/Client Reference	H1-P4/02	H1-R2/02
Details: - Location Euston Tower - Date of coring - Date received	Position 4 N/A 9/5/22-12/5/22	Pile R2 N/A 9/5/22-12/5/22
Presence of abnormalities	None	None
Reinforcement, as received (diameter/distance)[1] mm Reinforcement, prepared (diameter/distance)[1] mm	None None	None None
Aggregate, maximum nominal size mm	18	19
Condition on receipt	Exposed to air: Dry	Exposed to air: Dry
Storage conditions	As Received	As Received
Method of End preparation (Cap/Ground)	Ground	Ground
Actual Core Lengths - Core length, as received mm - Relation to length, as-received mm	 420-430 0-170	 240-260 0-85
Mean Prepared Length mm	171	87
Mean Core Diameter d_m mm	84	83
Length/Diameter ratio of prepared specimen λ	2.04	1.05
Density[2] - As received kg/m³	2380	2360
Exposure time before Test 16-24h	-	-
Estimation of prepared core excess voidage %	1.0	1.0
Maximum Load at Failure kN	270	348
Compressive Strength[3] MPa (N/mm²) (Measured Core Strength)	48.7	64.3
Mode of Failure[4]	Normal	Normal
Deviations from standard Remarks:	See footnote 2	See footnote 2 2:1 Correction: 52.7 MPa

1 Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

2 Volume by measurement/water displacement, densities given to nearest 10kg/m³. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

3 Compressive strength values given to nearest 0.1 MPa (N/mm²).

4 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

Date of Test

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CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference		F23790	F23795
Site Mark/Client Reference		H2-P4/02	H2-L2/02
Details: - Location Euston Tower		Position 4	Pile R2
- Date of coring		N/A	N/A
- Date received		9/5/22-12/5/22	9/5/22-12/5/22
Presence of abnormalities		None	None
Reinforcement, as received (diameter/distance)[1]	mm	None	None
Reinforcement, prepared (diameter/distance)[1]	mm	None	None
Aggregate, maximum nominal size	mm	20	20
Condition on receipt		Exposed to air: Dry	Exposed to air: Dry
Storage conditions		As Received	As Received
Method of End preparation (Cap/Ground)		Ground	Ground
Actual Core Lengths			
- Core length, as received	mm	510-525	340-365
- Relation to length, as-received	mm	0-170	0-170
Mean Prepared Length	mm	172	170
Mean Core Diameter d_m	mm	84	83
Length/Diameter ratio of prepared specimen	λ	2.05	2.05
Density[2] - As received	kg/m³	2370	2370
Exposure time before Test	16-24h	-	-
Estimation of prepared core excess voidage	%	1.0	1.5
Maximum Load at Failure	kN	378	414
Compressive Strength[3] (Measured Core Strength)	MPa (N/mm²)	68.2	76.5
Mode of Failure[4]		Normal	Explosive
Deviations from standard Remarks:		See footnote 2	See footnote 2

1 Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

2 Volume by measurement/water displacement, densities given to nearest 10kg/m³. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

3 Compressive strength values given to nearest 0.1 MPa (N/mm²).

4 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference		F23908	F23909
Site Mark/Client Reference		H3 - P1/01	H3 - P2/01
Details: - Location Euston Tower		Position 1	Position 2
- Date of coring		N/D	N/D
- Date received		30/5/22	30/5/22
Presence of abnormalities		None	None
Reinforcement, as received (diameter/distance)[1]	mm	Sliver/65 (⌀30)	None
Reinforcement, prepared (diameter/distance)[1]	mm	None	None
Aggregate, maximum nominal size	mm	16	20
Condition on receipt		Dry	Dry
Storage conditions		Ambient Air	Ambient Air
Method of End preparation (Cap/Ground)		Ground	Ground
Actual Core Lengths			
- Core length, as received	mm	345-360	505-510
- Relation to length, as-received	mm	85-260	25-200
Mean Prepared Length	mm	170	170
Mean Core Diameter d_m	mm	84	83
Length/Diameter ratio of prepared specimen	λ	2.02	2.05
Density[2] - As received	kg/m^3	2380	2360
Exposure time before Test	16-24h	×	×
Estimation of prepared core excess voidage	%	1.5	2.0
Maximum Load at Failure	kN	444	422
Compressive Strength[3] (Measured Core Strength)	MPa (N/mm^2)	80.1	78.0
Mode of Failure[4]		Explosive	Explosive
Deviations from standard		See footnote 2	See footnote 2
Remarks:			

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1 Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

2 Volume by measurement/water displacement, densities given to nearest 10kg/m^3. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

3 Compressive strength values given to nearest 0.1 MPa (N/mm^2).

4 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference	F23910	F23911
Site Mark/Client Reference	H3 - P3/01	H3 - C2/01
Details: - Location Euston Tower	Position 3	Pile C2
- Date of coring	N/D	N/D
- Date received	30/5/22	30/5/22
Presence of abnormalities	None	None
Reinforcement, as received (diameter/distance)[1] mm	None	None
Reinforcement, prepared (diameter/distance)[1] mm	None	None
Aggregate, maximum nominal size mm	20	20
Condition on receipt	Dry	Dry
Storage conditions	Ambient Air	Ambient Air
Method of End preparation (Cap/Ground)	Ground	Ground
Actual Core Lengths		
- Core length, as received mm	415-445	275-295
- Relation to length, as-received mm	70-245	70-245
Mean Prepared Length mm	163	165
Mean Core Diameter d_m mm	81	82
Length/Diameter ratio of prepared specimen λ	2.01	2.01
Density[2] - As received kg/m^3	2320	2300
Exposure time before Test 16-24h	×	×
Estimation of prepared core excess voidage %	1.5	1.5
Maximum Load at Failure kN	308	264
Compressive Strength[3] MPa (N/mm^2) (Measured Core Strength)	59.8	50.0
Mode of Failure[4]	Normal	Normal
Deviations from standard Remarks:	See footnote 2	See footnote 2

[1] Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

[2] Volume by measurement/water displacement, densities given to nearest 10kg/m^3. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

[3] Compressive strength values given to nearest 0.1 MPa (N/mm^2).

[4] 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference	F23912	F23913
Site Mark/Client Reference	H3 - C2/02	H3 - R2/01
Details: - Location Euston Tower	Pile C2	Pile R2
- Date of coring	N/D	N/D
- Date received	30/5/22	30/5/22
Presence of abnormalities	None	None
Reinforcement, as received (diameter/distance)[1] mm	None	7/130
Reinforcement, prepared (diameter/distance)[1] mm	None	None
Aggregate, maximum nominal size mm	22	20
Condition on receipt	Dry	Dry
Storage conditions	Ambient Air	Ambient Air
Method of End preparation (Cap/Ground)	Ground	Ground
Actual Core Lengths		
- Core length, as received mm	425-430	500-530
- Relation to length, as-received mm	100-275	200-375
Mean Prepared Length mm	168	168
Mean Core Diameter d_m mm	83	83
Length/Diameter ratio of prepared specimen λ	2.02	2.02
Density[2] - As received kg/m^3	2290	2380
Exposure time before Test 16-24h	×	×
Estimation of prepared core excess voidage %	2.0	3.0
Maximum Load at Failure kN	261	381
Compressive Strength[3] MPa (N/mm^2)	48.2	70.4
(Measured Core Strength)		
Mode of Failure[4]	Normal	Normal
Deviations from standard	See footnote 2	See footnote 2
Remarks:		

[1] Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

[2] Volume by measurement/water displacement, densities given to nearest $10kg/m^3$. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

[3] Compressive strength values given to nearest 0.1 MPa (N/mm^2).

[4] 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference		F23914	F23915
Site Mark/Client Reference		H3 - R2/02	H3 - LC1/03
Details: - Location Euston Tower		Pile R2	Location 1
- Date of coring		N/D	N/D
- Date received		30/5/22	30/5/22
Presence of abnormalities		None	None
Reinforcement, as received (diameter/distance)[1]	mm	None	None
Reinforcement, prepared (diameter/distance)[1]	mm	None	None
Aggregate, maximum nominal size	mm	18	20
Condition on receipt		Dry	Dry
Storage conditions		Ambient Air	Ambient Air
Method of End preparation (Cap/Ground)		Ground	Ground
Actual Core Lengths			
- Core length, as received	mm	215-225	940-950
- Relation to length, as-received	mm	70-160	100-275
Mean Prepared Length	mm	86	170
Mean Core Diameter d_m	mm	83	83
Length/Diameter ratio of prepared specimen	λ	1.04	2.05
Density[2] - As received	kg/m^3	2370	2340
Exposure time before Test	16-24h	×	×
Estimation of prepared core excess voidage	%	1.0	2.0
Maximum Load at Failure	kN	554	290
Compressive Strength[3] (Measured Core Strength)	MPa (N/mm^2)	102.4 (84.0)*	53.6
Mode of Failure[4]		Explosive	Normal
Deviations from standard		See footnote 2	See footnote 2
Remarks:		*Corrected 2:1 Ratio	

[1] Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

[2] Volume by measurement/water displacement, densities given to nearest $10kg/m^3$. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

[3] Compressive strength values given to nearest 0.1 MPa (N/mm^2).

[4] 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Date of Test

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CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference		F23916	F23917
Site Mark/Client Reference		H3 - LC1/06	H3 - LC2/02
Details: - Location Euston Tower		Location 1	Location 2
- Date of coring		N/D	N/D
- Date received		30/5/22	30/5/22
Presence of abnormalities		None	None
Reinforcement, as received (diameter/distance)[1]	mm	None	None
Reinforcement, prepared (diameter/distance)[1]	mm	None	None
Aggregate, maximum nominal size	mm	16	18
Condition on receipt		Dry	Dry
Storage conditions		Ambient Air	Ambient Air
Method of End preparation (Cap/Ground)		Ground	Ground
Actual Core Lengths			
- Core length, as received	mm	525-530	350-365
- Relation to length, as-received	mm	100-275	100-275
Mean Prepared Length	mm	169	169
Mean Core Diameter d_m	mm	83	84
Length/Diameter ratio of prepared specimen	λ	2.04	2.01
Density[2] - As received	kg/m³	2340	2360
Exposure time before Test	16-24h	×	×
Estimation of prepared core excess voidage	%	0.5	0.5
Maximum Load at Failure	kN	368	299
Compressive Strength[3] (Measured Core Strength)	MPa (N/mm²)	68.0	54.0
Mode of Failure[4]		Normal	Normal
Deviations from standard Remarks:		See footnote 2	See footnote 2

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1 Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

2 Volume by measurement/water displacement, densities given to nearest 10kg/m³. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

3 Compressive strength values given to nearest 0.1 MPa (N/mm²).

4 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Date of Test 14/6/22

CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference		F23918	F23919
Site Mark/Client Reference		H3 - LC2/07	H3 - LC3
Details: - Location Euston Tower		Location 2	Location 3
- Date of coring		N/D	N/D
- Date received		30/5/22	30/5/22
Presence of abnormalities		None	Crack 0 - 70 mm
Reinforcement, as received (diameter/distance)[1]	mm	None	Sliver (⌀30)/155
Reinforcement, prepared (diameter/distance)[1]	mm	None	Sliver (⌀30)/38
Aggregate, maximum nominal size	mm	18	18
Condition on receipt		Dry	Dry
Storage conditions		Ambient Air	Ambient Air
Method of End preparation (Cap/Ground)		Ground	Ground
Actual Core Lengths			
- Core length, as received	mm	690-700	200-210
- Relation to length, as-received	mm	100-275	100-190
Mean Prepared Length	mm	171	86
Mean Core Diameter d_m	mm	84	82
Length/Diameter ratio of prepared specimen	λ	2.04	1.05
Density[2] - As received	kg/m³	2350	2370
Exposure time before Test	16-24h	×	×
Estimation of prepared core excess voidage	%	2.0	0.5
Maximum Load at Failure	kN	367	362
Compressive Strength[3] (Measured Core Strength)	MPa (N/mm²)	66.2	68.5 (56.2)*
Mode of Failure[4]		Explosive	Normal
Deviations from standard		See footnote 2	See footnote 2
Remarks:			*Corrected 2:1 Ratio

1 Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

2 Volume by measurement/water displacement, densities given to nearest 10kg/m³. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

3 Compressive strength values given to nearest 0.1 MPa (N/mm²).

4 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

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Date of Test

14/6/22

CONCRETE TEST RESULTS
COMPRESSIVE STRENGTH AND DENSITY OF CORES

BS EN 12504-1:2019, BS EN 12390-3:2019 and BS EN 12390-7:2019

Sandberg Reference		F23920	F23921
Site Mark/Client Reference		H3 - LC4	H3 - LC5
Details: - Location Euston Tower - Date of coring - Date received		Location 4 N/D 30/5/22	Location 5 N/D 30/5/22
Presence of abnormalities		Shear Crack 225 - 320 mm	None
Reinforcement, as received (diameter/distance)[1] Reinforcement, prepared (diameter/distance)[1]	mm mm	None None	None None
Aggregate, maximum nominal size	mm	20	20
Condition on receipt		Dry	Dry
Storage conditions		Ambient Air	Ambient Air
Method of End preparation (Cap/Ground)		Ground	Ground
Actual Core Lengths - Core length, as received - Relation to length, as-received	 mm mm	 380-415 170-345	 485-500 100-275
Mean Prepared Length	mm	167	170
Mean Core Diameter d_m	mm	82	83
Length/Diameter ratio of prepared specimen	λ	2.04	2.05
Density[2] - As received	kg/m³	2300	2360
Exposure time before Test	16-24h	×	×
Estimation of prepared core excess voidage	%	2.0	1.5
Maximum Load at Failure	kN	202	278
Compressive Strength[3] (Measured Core Strength)	MPa (N/mm²)	38.3	51.4
Mode of Failure[4]		Shear	Normal
Deviations from standard Remarks:		See footnote 2	See footnote 2

1 Centre of bar to core end, before and after end preparation (eg. 20/100/40 = 20mm diameter bar, 100mm from the core end as-received and 40mm

2 Volume by measurement/water displacement, densities given to nearest 10kg/m³. Balance used complies to BSEN 12504-1:2009. (This will not reduce confidence in the test result.)

3 Compressive strength values given to nearest 0.1 MPa (N/mm²).

4 'Normal' (symmetrical failure) or otherwise as described.

ND = Not determined. NA = Not applicable.

TABLE 2
DEPTH OF CARBONATION
(2 SHEETS)

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Date of Test

23/5/22

CONCRETE TEST RESULTS
DEPTH OF CARBONATION
TP/F/10

Sandberg Sample Reference	Client Reference	Depth of Carbonation, mm	Sandberg Sample Reference	Client Reference	Depth of Carbonation, mm
F23780		< 1			
F23781		< 1			
F23782		< 1			
F23783		< 1			
F23798		< 1			
F23799		< 1			
F23800		< 1			
F23801		< 1			

Note: Top surfaces of all samples seem to be broken.

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CONCRETE TEST RESULTS
DEPTH OF CARBONATION
TP/F/10

Date of Test

10/6/22

Sandberg Sample Reference	Client Reference	Depth of Carbonation, mm	Sandberg Sample Reference	Client Reference	Depth of Carbonation, mm
F23922	CL3.1	1			
F23923	CL3.2	1			
F23924	CL3.3	1			
F23925	CL3.4	1			

APPENDIX A

CONCRETE SAMPLES - SCHEDULE OF TESTS

(2 SHEETS)

EUSTON TOWER- SAMPLE SCHEDULES RECEIVED

72418 /k

ETF149 - EUSTON TOWER FOUNDATION INVESTIGATION WORKS
CONCRETE SAMPLES - SCHEDULE OF TESTS

McGEE

Revision -
Issued 27/04/2022
Prepared by Diego Fenaroli
Checked by

rec 9/5/22
and 12/5/22

Actually H1-P2/06

Sample Reference	Heading	Location	Sandberg ref	Compressive Strength	Cement Content	Chloride Content	Alumina Content	Petrographic Test	Carbonation Test
				Tests Required					
H1-P1/02	1	Position 1	F23766	x	x	x			
H1-P1/07	1	Position 1	67	x		x			
H1-P2/02	1	Position 2	68	x	x		x		
H1-P2/07	1	Position 2	69	x			x		
H1-P3/01	1	Position 3	F23770	x	x	x			
H1-P3/07	1	Position 3	71	x	x	x			
H1 P4/02	1	Position 4	72	x	x	x		x	
H1-P4/05	1	Position 4	73	x	x				
H1-P5/02	1	Position 5	74	x	x	x			
H1-P5/07	1	Position 5	75	x	x				
H1-R2/01	1	Pile R2	76	x	x	x			
H1-R2/02	1	Pile R2	77	x		x		x	
H1- L3/01	1	Pile L3	78	x		x			
H1-L3/02	1	Pile L3	79	x	x	x			
CL1.1	1	Not Specified	F23780						x <1 (Both Surface)
Cl1 2	1	Not Specified	81						x
CL1.3	1	Not Specified	82						x
CL1 4	1	Not Specified	83						x
			↓						
H2-P1/01	2	Position 1	F23784	x	x	x			
H2-P1/04	2	Position 1	85	x		x			
H2-P2/01	2	Position 2	86	x	x		x		
H2-P2/02	2	Position 2	87	x			x		
H2-P3/02	2	Position 3	88	x	x	x			
H2-P3/06	2	Position 3	89	x	x	x			
H2-P4/02	2	Position 4	F23790	x	x	x		x	
H2-P4/07	2	Position 4	91	x	x				
H2-P5/04	2	Position 5	92	x	x	x			
H2-P5/07	2	Position 5	93	x	x				
H2-L2/01	2	Pile R2	94	x	x	x			
H2-L2/02	2	Pile R2	95	x		x		x	
H2-R1/01	2	Pile L3	96	x		x			
H2-R1/02	2	Pile L3	97	x	x	x			
CL2.1	2	Not Specified	98						x
CL2.2	2	Not Specified	99						x
CL2.3	2	Not Specified	F23800						x
CL2.4	2	Not Specified	01						x

EUSTON TOWER- SAMPLE SCHEDULES RECEIVED

72418/k

ETF149 - EUSTON TOWER FOUNDATION INVESTIGATION WORKS

CONCRETE SAMPLES - SCHEDULE OF TESTS - Page 2 of 2

Revision A
Issued 20/05/2022
Prepared by Diego Panarali
Checked by

McGEE

Sample Reference	Heading	Location	Comments	Tests Required					
				Compressive Strength	Cement Content	Chloride Content	Alumina Content	Petrographic Test	Carbonation Test
H3-P1/01	3	Position 1	F23908	x	x	x			
H3-P2/01	3	Position 2	9	x		x			
H3-P3/01	3	Position 3	F23910	x	x		x		
H3-C2/01	3	Pile C2	1	x			x		
H3-C2/02	3	Pile C2	2	x	x	x			
H3-R2/01	3	Pile R2	3	x	x	x			
H3-R2/02	3	Pile R2	4	x	x	x		x	
H3-LC1/03	3	Location 1	5	x	x				
H3-LC1/06	3	Location 1	6	x	x	x			
H3-LC2/02	3	Location 2	7	x	x				
H3-LC2/07	3	Location 2	8	x	x	x			
H3-LC3	3	Location 3	9	x		x		x	
H3-LC4	3	Location 4	F23920	x		x			
H3-LC5	3	Location 5	1	x	x	x			
CL3.1	3	Not Specified	2						x
CL3.2	3	Not Specified	3						x
CL3.3	3	Not Specified	4						x
CL3.4	3	Not Specified	F23925						x

APPENDIX B

PETROGRAPHIC REPORT

(24 SHEETS)

SANDBERG
CONSULTING ENGINEERS
INVESTIGATION INSPECTION
MATERIALS TESTING

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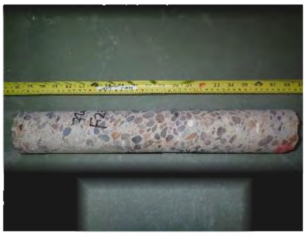
Report - 72418/K

REPORT ON THE PETROGRAPHIC EXAMINATION OF FOUR CONCRETE CORES

(Client Ref: ETF149 – Euston Tower Foundation Investigation Works)






McGee Group (Holdings) Limited
Unit 8 Wharfside
Rosemount Road
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This report comprises
6 pages of text
Appendix A – Petrographic description - 2 pages
Appendix B – Photographs - 4 page
Appendix C – Photomicrographs - 4 page
Appendix D – Glossary - 6 pages

For the attention of Diego Fenaroli

16 June 2022

Sandberg established in 1860 is a member firm of the Association for Consultancy and Engineering

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Report - 72418/K

REPORT ON THE PETROGRAPHIC EXAMINATION OF FOUR CONCRETE CORES
(Client Ref: ETF149 – Euston Tower Foundation Investigation Works)

1 INTRODUCTION

Four core samples for petrographic examination were received on 09 May 2022. As per the Client's instructions (PO reference M-ETF149/0056 dated 13 May 2022), it was requested that the cores were subject to petrographic examination. No information was provided on the age of the structure from which the core was obtained.

2 SAMPLES

The following samples were provided for petrographic examination:

Laboratory reference	Client reference	Location	Core diameter, mm	Core length, mm
K17404/1	H1-P4/02	Position 4	82	414-426
K17404/2	H1-R2/02	Pile R2	82	236-255
K17404/3	H2-P4/02	Position 4	82	507-528
K17404/4	H2-L2/02	Pile R2	82	335-365

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 D. In brief, the following work was carried out.

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

(ii) Fluorescent resin impregnated thin section were prepared from the locations highlighted in red illustrated below. The thin-section represented approximately 67 x 45 mm of concrete.

H1-P4/02	H1-R2/02
	
H2-P4/02	H2-L2/02
	

(iii) The thin section was 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.

---

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

4 PETROGRAPHIC EXAMINATION RESULTS

4.1 Visual description of the samples

The visual descriptions of the samples as received is given in Table A1 in Appendix A and photographs illustrating the samples as received are given in Appendix B.

4.2 Petrographic description of the aggregate

A petrographic description of the aggregate in the samples is given in Table A2 in Appendix A.

4.3 Petrographic description of the paste

A petrographic description of the paste in the samples is given in Table A3 in Appendix A. Photomicrographs illustrating the typical appearance of the paste in the thin section are given in Appendix C.

5 DISCUSSION

5.1 Aggregate characteristics

(i) Coarse aggregate type

The coarse aggregate in all cores comprised natural flint gravel.

(ii) Fine aggregate type

The fine aggregate in all cores was dominated by quartz, with minor proportions of quartzite and flint, with variable trace proportions of ironstone, glauconite, sandstone and shell.

(iii) Potential aggregate properties

The dominant coarse aggregate constituent (flint) is a dense and robust rock type that would be expected to have a high compressive strength. The fine aggregate is dominated by quartz, which would be expected to have a combined normal water absorption value.

(iv) Alkali-aggregate reaction (AAR) and aggregate deterioration

The combination of coarse and fine aggregate is typically classified as being of potentially normal reactivity[2] with alkalis in cement paste. No evidence of alkali-silica reaction (ASR) was observed within any of the samples.

5.2 General paste characteristics in the samples at depth

(i) Binder type

The binder type for the samples examined was similar comprising ordinary Portland cement (OPC / CEM I[3]). No evidence of replacement materials, such as fly ash or ground granulated blastfurnace slab (GGBS) was observed.

(ii) Moisture ingress and paste alteration

No evidence of moisture ingress or paste alteration was observed in any of the cores.

(iii) Microporosity and apparent water/binder ratio

The current level of microporosity of the paste has been used in conjunction with laboratory control concretes to make a petrographic assessment of the water/binder ratio for these samples and the results are as follows:

Laboratory reference	Client reference	Apparent water / binder ratio	Apparent degree of leaching
K17404/1	H1-P4/02	0.40-0.50, typically 0.45	None
K17404/2	H1-R2/02	0.40-0.50, typically 0.45	None
K17404/3	H2-P4/02	0.45-0.55, typically 0.50	None
K17404/4	H2-L2/02	0.45-0.55, typically 0.50	None

---

[2] Concrete Society Technical Report No. 30, Alkali-silica reaction: minimizing the risk of damage to concrete, Guidance notes and model clauses for specifications, Report of a Concrete Society Working Party, 1999 (3rd edition)

[3] BS EN 197-1: 2011, Cement, Part 1: Composition, specifications and conformity criteria for common cements

5.3 Characteristics of the surface concrete

Other than carbonation, there was no change in the cement matrix at the surfaces of any of the samples.

5.4 Magnitude of deterioration

With respect to the Grades of Deterioration table given in Appendix D the grades of deterioration of these samples are considered to be as follows:

Laboratory reference	Client reference	Evidence of moisture ingress	Grade of Deterioration (1 = Low, 10 = high)
K17404/1	H1-P4/02	None	1
K17404/2	H1-R2/02	None	1
K17404/3	H2-P4/02	None	1
K17404/4	H2-L2/02	None	1

6 CONCLUSIONS

6.1 The samples comprised flint gravel coarse aggregate and natural quartzitic sand fine aggregate.

6.2 The sample exhibited a Portland-type binder (OPC/CEM I), which did not exhibit any cement replacement materials, such as fly ash or GGBS.

6.3 The samples exhibited a range of apparent water/cement ratios between 0.45 and 0.50.

6.4 The samples did not exhibit any evidence of distress or deterioration.

6.6 The combination of coarse aggregate and fine aggregate would be considered normal reactivity in respect of alkali-silica reaction. No evidence of ASR was observed in any of the samples.

7 REMARKS

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

McGee Group (Holdings) Limited
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H40 4PE

For the attention of Diego Fenaroli

for GEOMATERIALS RESEARCH SERVICES
(part of Sandberg LLP)

Paul Bennett-Hughes, MGeol, FGS., C.Geol. EurGeol
Senior Associate

16 June 2022

APPENDIX A – PETROGRAPHIC DESCRIPTION OF THE SAMPLES – PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE – ASTM C856-20

TABLE A1 OF 3: VISUAL DESCRIPTION OF THE SAMPLE

Lab Ref.	**K17404/1**	**K17404/2**	**K17404/3**	**K17404/4**
Client Ref	**H1-P4/02**	**H1-R2/02**	**H2-P4/02**	**H2-L2/02**
Core Dia. / length, mm	82 / 414-426	82 / 236-255	82 / 507-528	82 / 333-365
Description of outer end	Broken end	Broken end	Broken end	Broken end
Description of inner end	Broken end	Broken end	Broken end	Broken end
Paste colour	Light brown	Light brown	Light brown	Light brown
Macroscopic cracking	None	None	None	None
Carbonation at outer end:				
General depth (mm)	1.1	0.8	0 / 0.2	0
Maximum depth (mm)	1.4	2.0	1.6	0
Reinforcement:				
Diameter / Min depth of cover	-	-	-	An imprint of a bar was observed on the inner end surface.
Corrosion	-	-	-	None seen on the impression surface
Comment	-	-	-	-
Voids:				
Maximum size (mm)	7	13	14	21
Typical size (mm)	1	1	1	1
Estimated excess void content (%)	2	1	1	2
Deposits:	None	None	None	None

TABLE A2 OF 3: PETROGRAPHIC DESCRIPTION OF THE AGGREGATE

Lab Ref.	**K17404/1**	**K17404/2**	**K17404/3**	**K17404/4**
Client Ref	**H1-P4/02**	**H1-R2/02**	**H2-P4/02**	**H2-L2/02**
Coarse aggregate:				
Maximum size (mm)	19	20	21	19
Typical shape	Sub-rounded	Sub-rounded	Sub-rounded	Sub-rounded
Major rock types	Flint gravel	Flint gravel	Flint gravel	Flint gravel
Minor rock types	-	-	-	-
Trace rock types	-	-	-	-
Aggregate type	Natural gravel	Natural gravel	Natural gravel	Natural gravel
Additional comments	-	-	-	-
Fine aggregate:				
Grading	Fine (0/2)	Fine (0/2)	Fine (0/2)	Fine (0/2)
Typical shape	Sub-rounded to sub-angular	Sub-rounded to sub-angular	Sub-rounded to sub-angular	Sub-rounded to sub-angular
Major rock types	Quartz	Quartz	Quartz	Quartz
Minor rock types	Quartzite, Flint	Quartzite, Flint	Quartzite, Flint	Quartzite, Flint
Trace rock types	Ironstone, Shell	Ironstone, Shell	Ironstone, Glauconite, Sandstone	Ironstone, Glauconite, Sandstone, Shell
Aggregate type	Natural sand	Natural sand	Natural sand	Natural sand
Additional comments	None	None	None	None
Alkali-aggregate reaction:				
Gel on surfaces of sample as received	None	None	None	None
Gel in voids	None	None	None	None
Gel in cracks	None	None	None	None

APPENDIX A – PETROGRAPHIC DESCRIPTION OF THE SAMPLES – PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE – ASTM C856-20

TABLE A3 OF 3: PETROGRAPHIC DESCRIPTION OF THE PASTE

GMRS Ref.	**K17404/1**	**K17404/2**	**K17404/3**	**K17404/4**
Client Ref.	**H1-P4/02**	**H1-R2/02**	**H2-P4/02**	**H2-L2/02**
Binder type	OPC / CEM I	OPC / CEM I	OPC / CEM I	OPC / CEM I
Cement replacement/additions	None	None	None	None
Portlandite (estimated. vol.% of paste)	6	5	6	5
Portlandite - typical crystal size, mm	0.03	0.03	0.025	0.03
Unhydrated cement (estimated. vol.% of paste)	3	2	3	6
Apparent water/cement ratio	0.40-0.50, typically 0.45	0.40-0.50, typically 0.45	0.45-0.55, typically 0.50	0.45-0.55, typically 0.5
Porosity:				
General level	Very low to moderate	Very low to moderate	Moderate	Moderate
Porosity distribution	Typically even	Typically even	Typically even	Typically even
Microcracking level	Low Microcracks observed rarely running between fine aggregate particles	Low Microcracks observed rarely running between fine aggregate particles	Low Microcracks observed rarely running between fine aggregate particles	Low Microcracks observed rarely running between fine aggregate particles
Crack fillings	None	None	None	None
Void fillings	None	None	None	None
Leaching	None	None	None	None

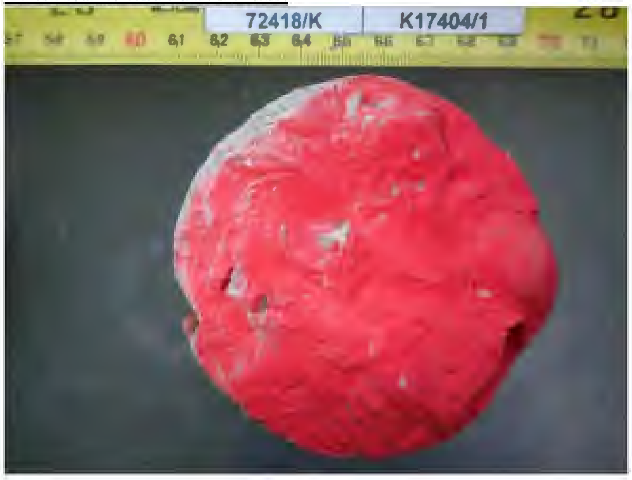
APPENDIX B – PHOTOGRAPHS ILLUSTRATING THE SAMPLE AS RECEIVED

Figure B1

Laboratory Ref: K17404/1
Client Ref: H1-P4/02

Profile view of the sample

View of the outer surface

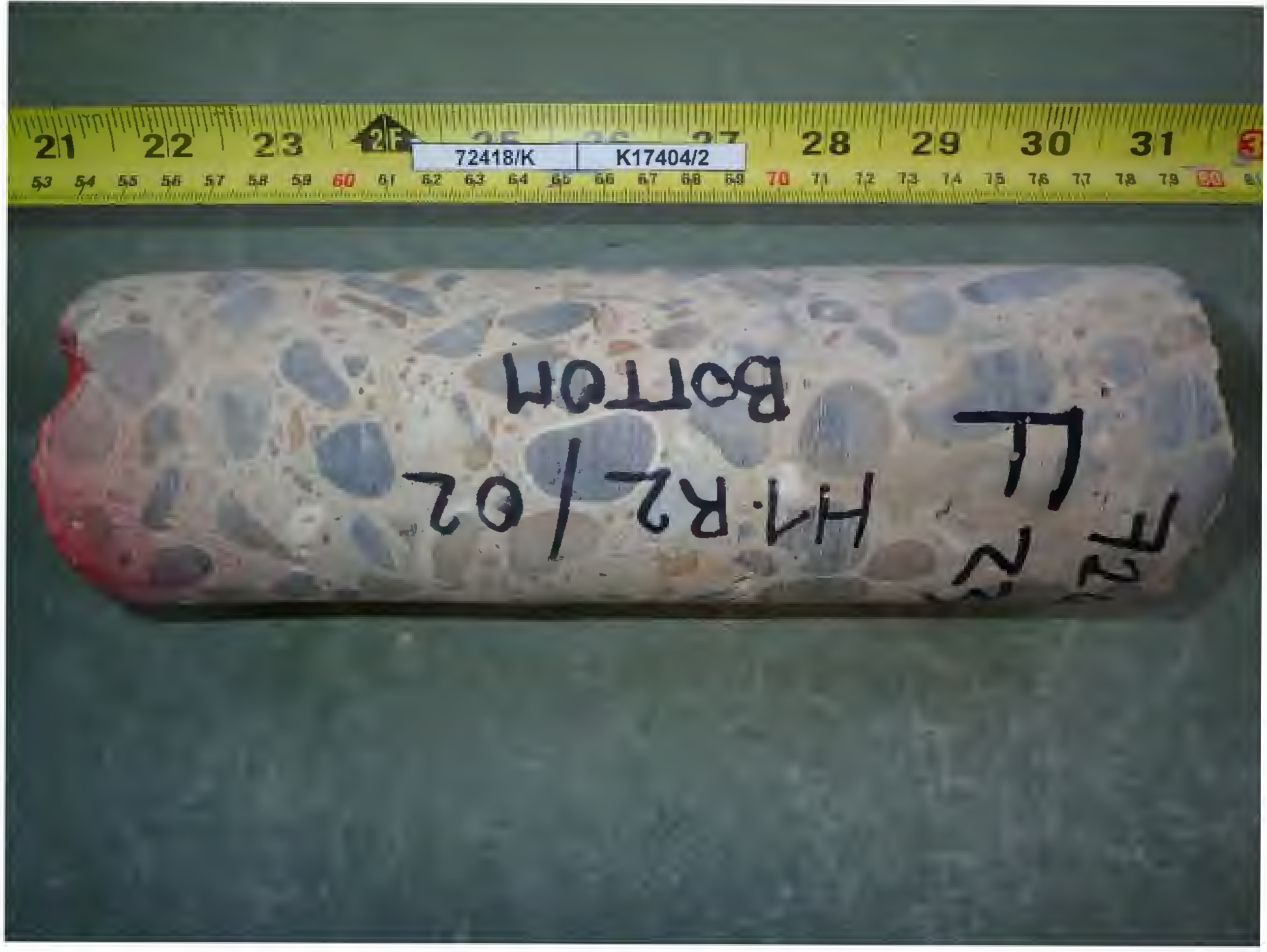


View of the inner surface

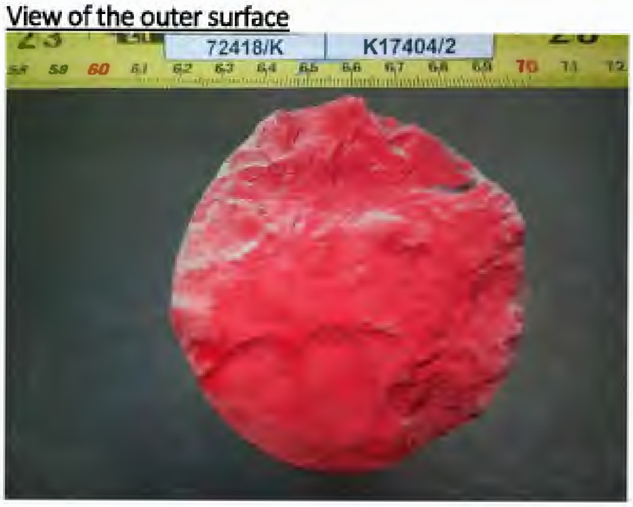
Figure B2

Laboratory Ref: K17404/2
Client Ref: **H1-R2/02**

Profile view of the sample



View of the outer surface



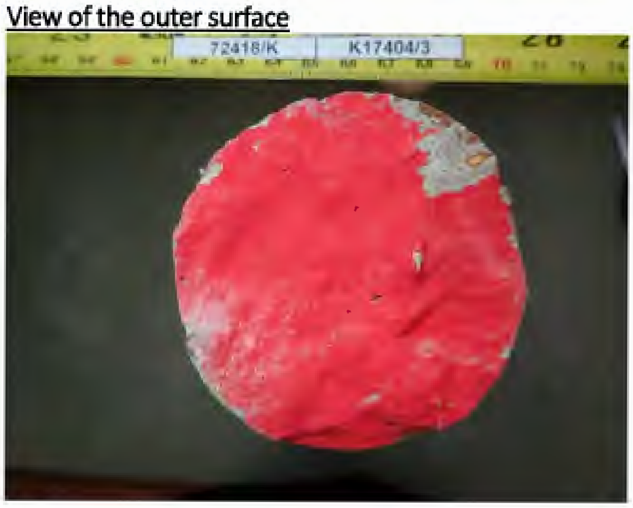
View of the inner surface

Figure B3

Laboratory Ref: K17404/3
Client Ref: **H2-P4/02**

Profile view of the sample

View of the outer surface

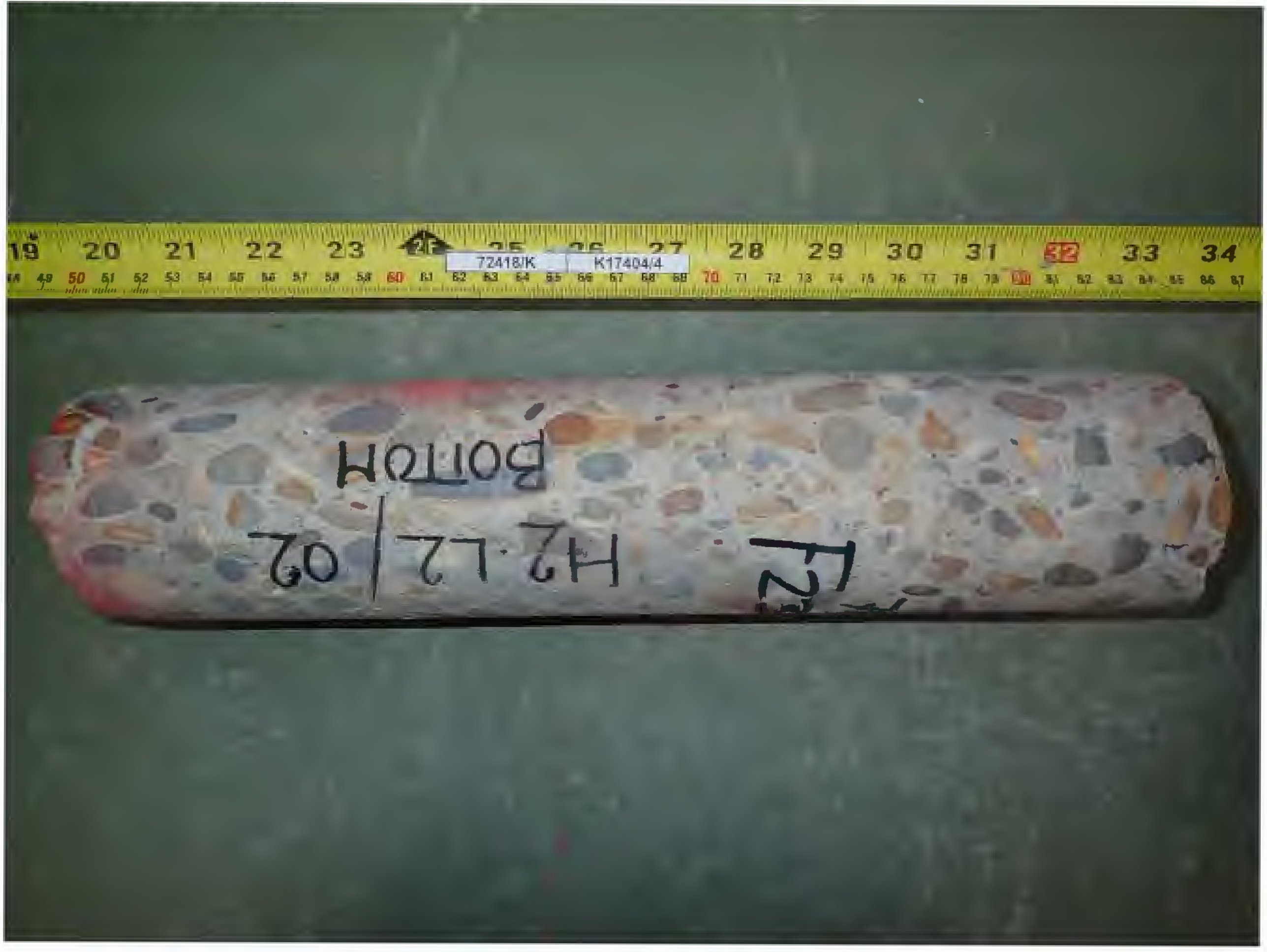


View of the inner surface

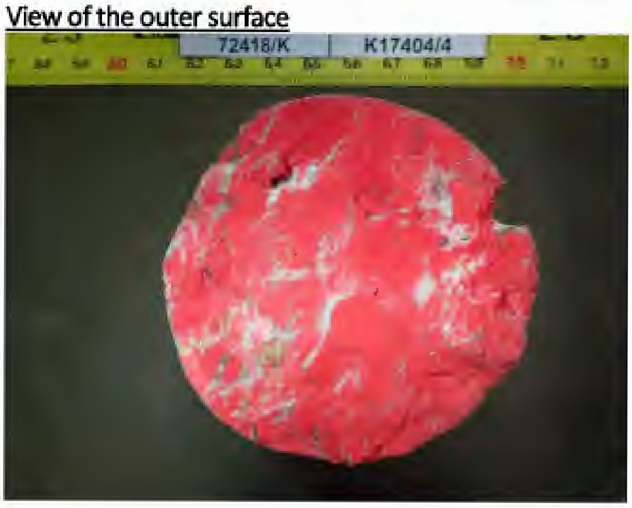
Figure B4

Laboratory Ref: K17404/4
Client Ref: **H2-L2/02**

Profile view of the sample



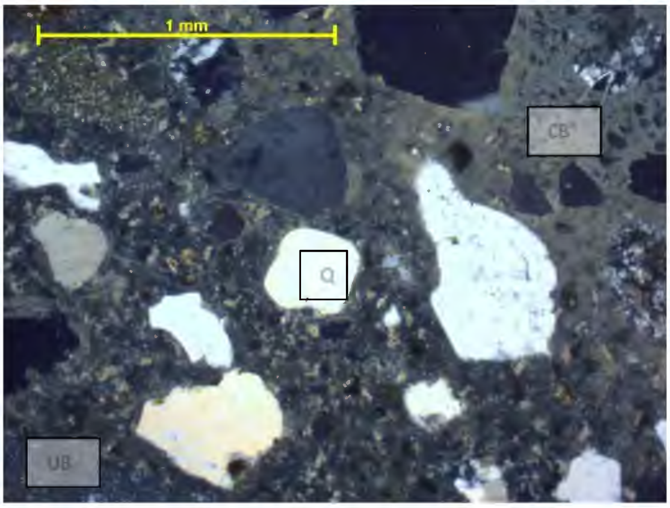
View of the outer surface



View of the inner surface

APPENDIX C – PHOTOMICROGRAPHS ILLUSTRATING THE THIN SECTIONS

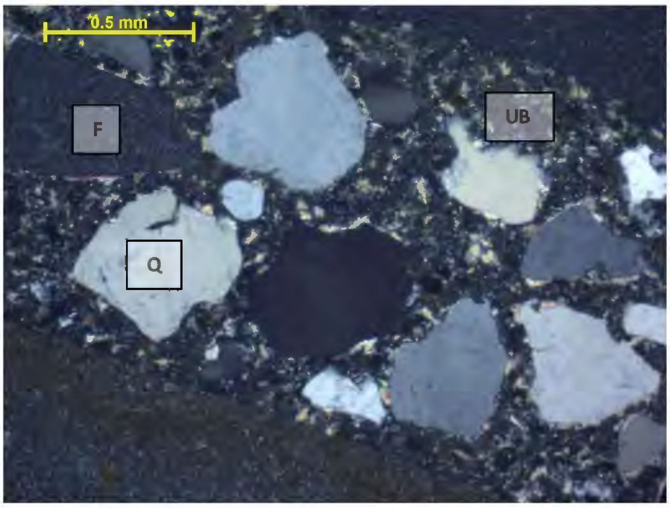
Figure C1 - **H1-P4/02**



Photomicrograph A:

View of the outer surface of the concrete, showing quartz (Q) aggregate particles, bound by carbonated (CB) and uncarbonated (UB) Portland-type cement matrix.

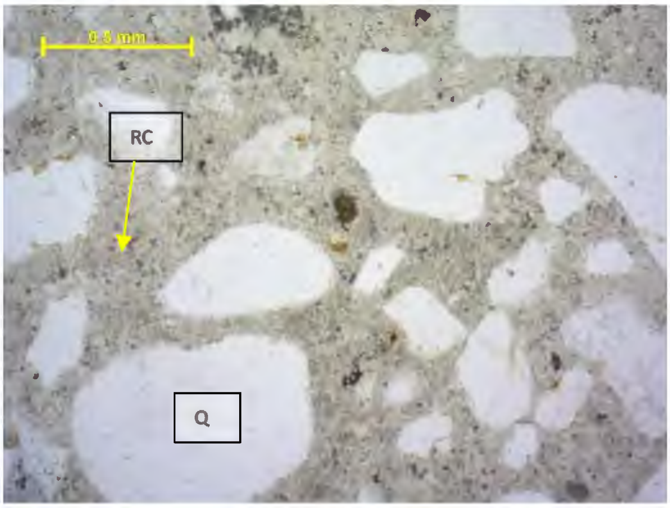
x50, Cross-polarised light



Photomicrograph B:

View of the concrete, showing flint (F) and quartz (Q) fine aggregate particles, bound by uncarbonated Portland-type cement matrix (UB), which includes portlandite crystallites.

x50, Cross-polarised light

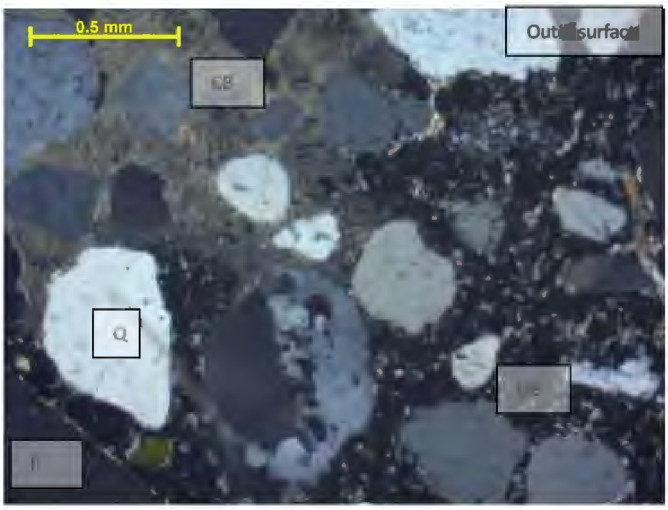


Photomicrograph C:

View of the concrete, showing quartz (Q) fine aggregate particles, bound by uncarbonated Portland-type cement matrix, which includes relict unhydrated cement grains (RC).

x50, Plane-polarised light

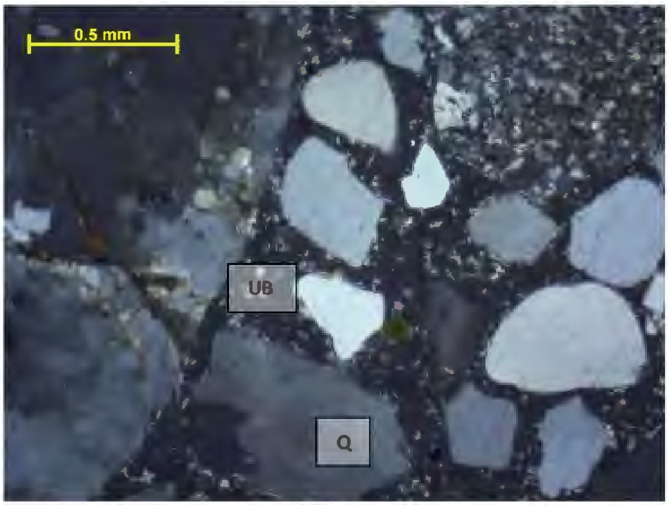
Figure C2 - **H1-R2/02**



Photomicrograph A:

View of the outer surface of the concrete, showing flint (F) and quartz (Q) aggregate particles, bound by carbonated (CB) and uncarbonated (UB) Portland-type cement matrix (CB).

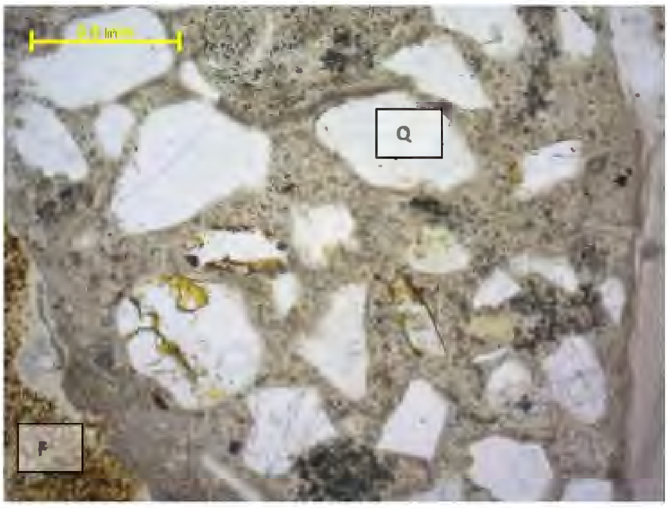
x50, Cross-polarised light



Photomicrograph B:

View of the concrete, showing quartz (Q) fine aggregate particles, bound by uncarbonated Portland-type cement matrix (UB), which includes portlandite crystallites.

x50, Cross-polarised light

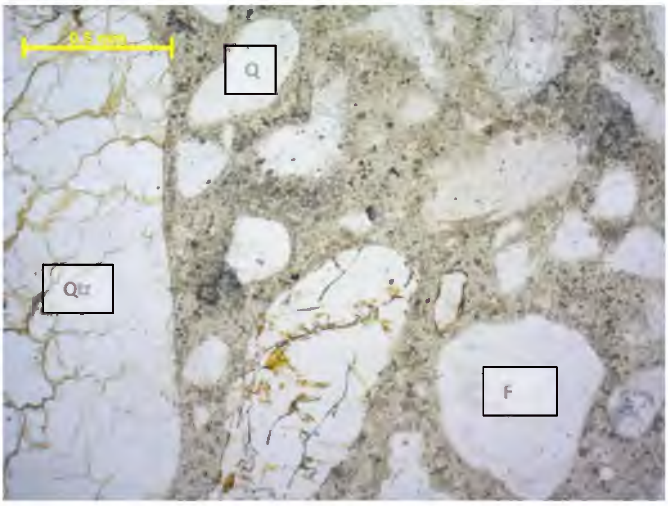


Photomicrograph C:

View of the concrete, showing quartz (Q) and flint (F) fine aggregate particles, bound by uncarbonated Portland-type cement matrix.

x50, Plane-polarised light

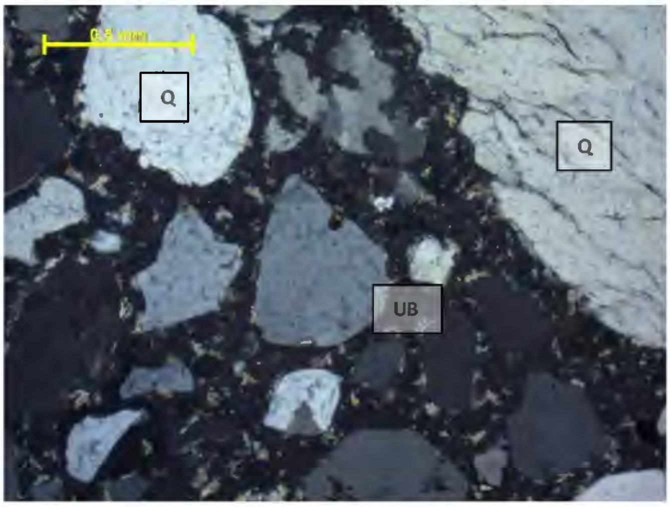
Figure C3 - **H2-P4/02**



Photomicrograph A:

View of the outer surface zone of the concrete, showing flint (F), quartz (Q) and quartzite (Qtz) aggregate particles, bound by uncarbonated Portland-type cement matrix (CB).

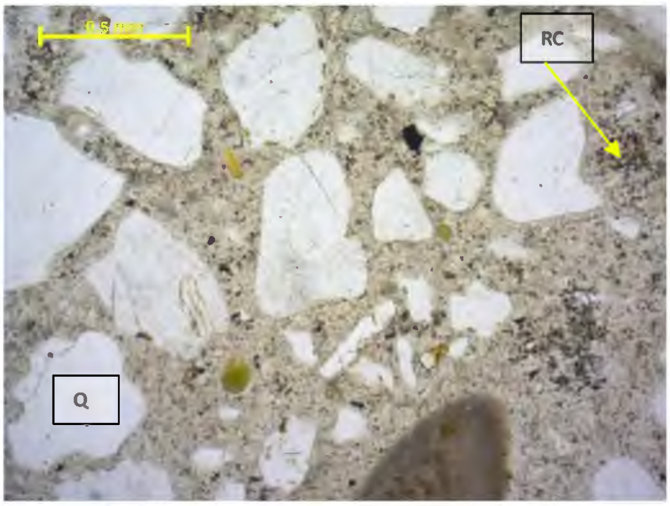
x50, Plane-polarised light



Photomicrograph B:

View of the concrete, showing quartz (Q) fine aggregate particles, bound by uncarbonated Portland-type cement matrix (UB), which includes portlandite crystallites.

x50, Cross-polarised light

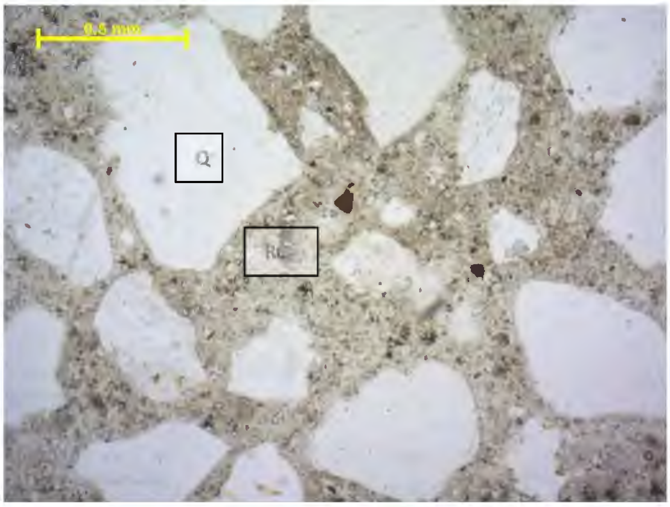


Photomicrograph C:

View of the concrete, showing quartz (Q) fine aggregate particles, bound by uncarbonated Portland-type cement matrix, which includes relict unhydrated cement grains (RC).

x50, Plane-polarised light

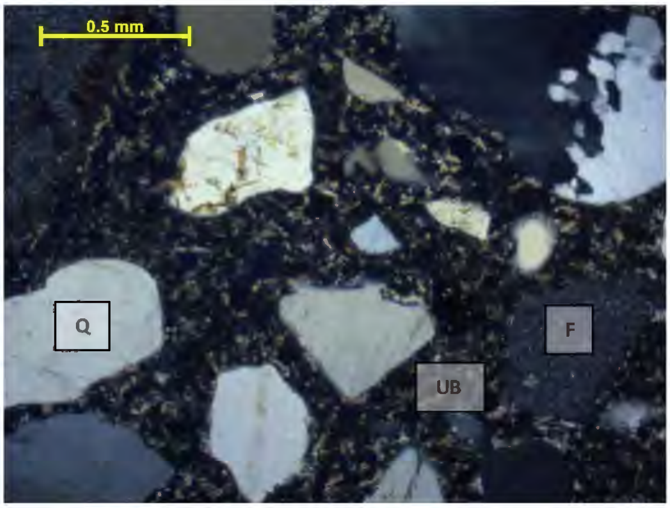
Figure C4 - **H2-L2/02**



Photomicrograph A:

View of the concrete, showing quartz (Q) aggregate particles, bound by uncarbonated Portland-type cement matrix, which includes relict cement grains (RC).

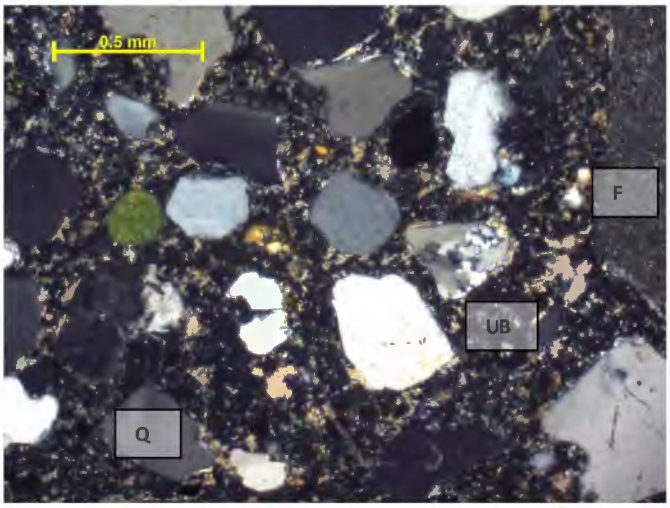
x50, Plane-polarised light



Photomicrograph B:

View of the concrete, showing flint (F) and quartz (Q) fine aggregate particles, bound by uncarbonated Portland-type cement matrix, which includes portlandite crystallites.

x50, Cross-polarised light



Photomicrograph C:

View of the concrete, showing quartz (Q) and flint (F) fine aggregate particles, bound by uncarbonated Portland-type cement matrix, which includes portlandite crystallites.

x50, Cross-polarised light

APPENDIX D – PETROGRAPHIC PROCEDURES AND GLOSSARY

GRADES 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.

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.

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[4] From APG SR-2

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

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

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: 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.

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

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

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

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

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

Thaumasite: This is a carbonate-sulfate calcium hydrate mineral with a complex composition. It is a common reaction product in concrete exposed to moisture containing both carbonate and sulfate ions. Thaumasite is most commonly encountered in concrete exposed to temperatures of <4°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.

End of report

End of report.